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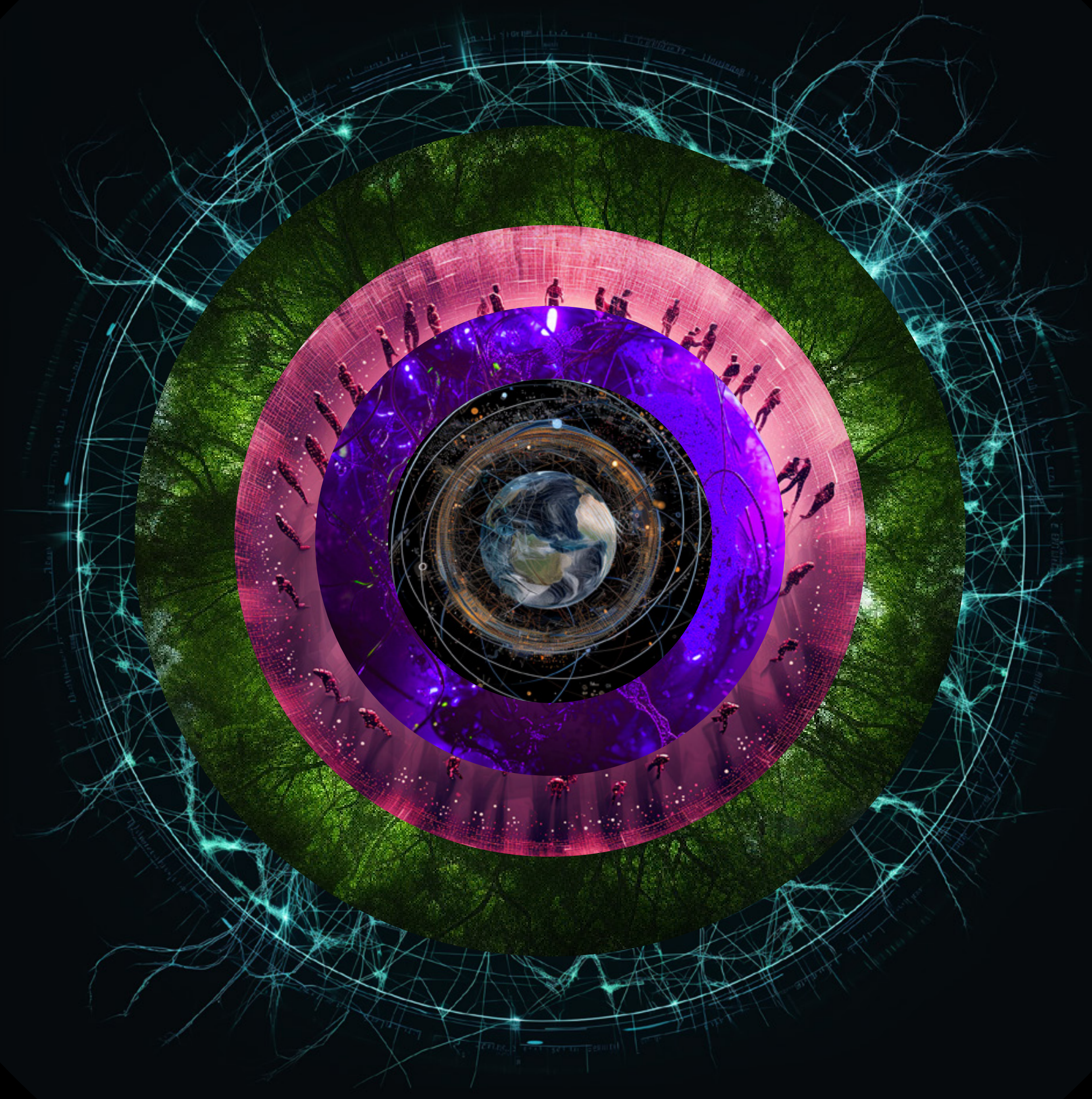

FUTURE OPPORTUNITIES REPORT

THE GLOBAL 50

2024

REVIVING HOPE FOR TOMORROW

Mohammad Abdullah Al Gergawi
Vice Chairman of the Board of Trustees and Managing Director of Dubai Future Foundation

The wheel of progress and future design is spinning faster than we, or our ancestors, could have imagined. Innovations and transformations initiated millennia ago have profoundly influenced humanity's evolution, surpassing all initial forecasts. In today's world, the wide-ranging diversity of our planet has shrunk to a global village, where civilisations, cultures, ideas, knowledge, and scientific advancements converge seamlessly – a future that could not have been fully envisioned.

Throughout history, civilisations have understood the importance of planning for the future. We have learned that ancient societies such as the Egyptians, Babylonians, and Sumerians monitored celestial bodies to navigate, schedule their agricultural efforts, observe religious celebrations, organise trade expeditions, and even strategize for wars. Since the beginning of human history, our intellectual capacity has broken through the constraints of time, leading to innovative breakthroughs that have propelled us into the current age of scientific discovery and enlightenment.

In contrast to the simple tools of the past, today we face the need to develop real-time predictive technologies. This effort is set against the backdrop of groundbreaking developments, such as quantum computing, which is poised to achieve speeds up to 158 million times faster than current supercomputers, and advanced, continual machine learning that is on the brink of vastly outperforming today's artificial intelligence capabilities.

Given the exponential technological and informational growth we are witnessing, it is projected that the data universe will increase tenfold by 2030. This growth underscores the crucial need for institutions and governments to skilfully manage, analyse, and leverage this data for decision-making, policy creation, and attracting talented individuals who can effectively utilise this data. As the saying goes, those who own data, own the future.

Indeed, as policymakers and futurists, our responsibility is to meticulously analyse global trends, uncover future opportunities, assess risks, and devise strategic plans for diverse scenarios. This approach enables us to effectively tackle challenges, swiftly address urgent matters, and proactively handle crises.

On this journey, we unite around a shared vision and ambition for growth, prosperity, and equal opportunities for all communities. Together, we adapt to future trends and create adaptable strategies and work models to improve economic, social, environmental, health, and technological frameworks.

'The Global 50' report, in its third edition, seeks to explore and capitalise on future opportunities to refine work methodologies and lifestyles, offering insights and best practices to governments, businesses, and civil society worldwide. The report also identifies significant challenges that may impede global advancement, preparing us to face them effectively. Additionally, the report outlines the 10 megatrends shaping current and future transformations and their impact on worldwide development.

As we advance into the future with optimism, we are guided by the belief that well-prepared nations embrace change rather than fear it. They confidently and efficiently navigate transformations, capitalising on the opportunities that await. It is this mindset that truly enriches a nation’s readiness for the future.

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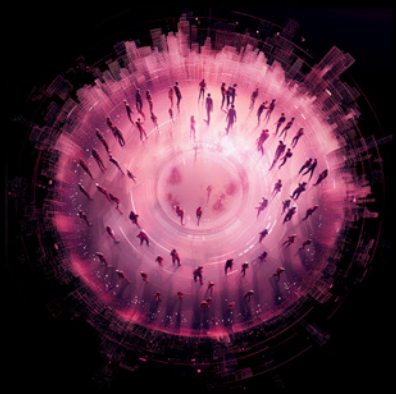

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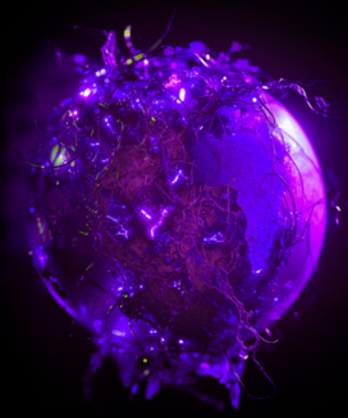
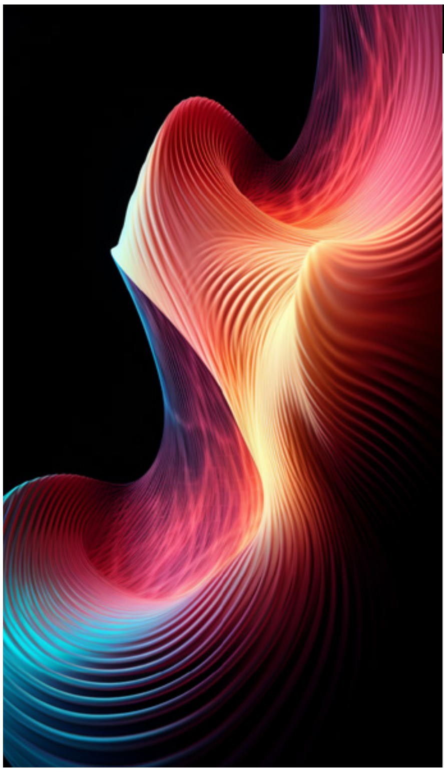


INTRODUCTION

'The Global 50' focuses on the future through the lens of growth, prosperity, and well-being – and for good reason. Economic progress alone has historically been the primary measure of success; however, **people's evolving needs demand a more inclusive view of progress, reflecting environmental and societal considerations.**

Humans have always sought economic growth as a means to a better life and it has delivered that for many. However, as the world changes, people will see their needs evolve and desire greater prosperity and well-being: growth alone will not be enough. People will face very different futures depending on where they are and the challenges that are relevant to their countries and communities. It will be necessary to understand and monitor their needs, with a focus on managing uncertainties and the challenges that result. People will look for places that meet their basic needs or otherwise they may not be able to engage positively with their community, and this risks increases in psychological and social disorders. **Introduced back in 2022, welcome to the era of quantum shifts.**[1]



BOX 1

THE ERA OF QUANTUM SHIFTS

The term 'quantum' originates in quantum theory, where it denotes an abrupt transition from one energy state to another through atomic and subatomic particles. It also includes the concept of 'entanglement'[2] where the behaviour of objects can be correlated even when they are far away from each other.

'The Global 50' uses the concept of 'quantum' to describe the rapid, disruptive, and dramatic changes that may occur in technology, business, government, medicine, culture, and other areas. We also use it to acknowledge the intertwined, complex relationships and interconnections that determine how the future may play out. Some forces can drive societies in opposite directions, and some innovations may either enable societies to move forward or prevent them from doing so.

When such changes occur swiftly, we describe them as 'shifts'. This is the era we live in.

In our engagements with local and global stakeholders, we explain that **'The Global 50' is like a blueprint for the future:** through the **uncertainties**, we can form a plan to explore our strengths and weaknesses and the opportunities and threats that we may encounter, in any of the extremes that might materialise over the next 50 years. Through the **assumptions**, we can monitor the key things that we take for granted or assume to be true, which is important because the whole basis of a future opportunity might otherwise shift. We also use the 10 **megatrends**, which are valid over a decade or so, to identify areas of future opportunity, with the aim of positively influencing future growth, prosperity, and well-being.

Reserving capacity for breakthrough ideas – those that may at times emerge unexpectedly, **the key across these concepts is agility: agility to monitor, agility to respond, and agility to shift when needed.**

In this year's edition of 'The Global 50', we provide greater detail on signals to look for when monitoring uncertainties. We also provide commentary on some signals related to the assumptions. We reintroduce the 10 megatrends, one of which has evolved, and share areas of future opportunity relating to the megatrends that can guide our collective thought processes. We then end by sharing 50 specific (non-exhaustive) opportunities that are the result of brainstorming, ideation, expert interviews, research translation and blue-sky thinking. Together with the 50 opportunities in each of the 2022 and 2023 editions of 'The Global 50', readers now have 150 opportunities to consider for the future resulting in potentially over 700 ideas and initiatives either in preparing for, enabling, capturing, or mitigating the risk of, a future opportunity.

This year, **we see once more that the potential for human creativity is unlimited.** With this comes hope – hope that inspires greater accomplishments and innovations that, in today's interconnected world, can impact on both local and global communities **under shared definitions of growth, prosperity, and well-being that will continue to evolve** (see Box 2).

BOX 2

DEFINITIONS OF GROWTH, PROSPERITY, AND WELL-BEING[A]

TODAY	TOMORROW
Growth Increases in the total output of goods and services in an economy over time.	**Growth** 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 The ability to live with dignity and stability, free from the threat of poverty or harm, including from the environment. It includes access to suitable employment opportunities, sufficient food, and basic services such as water, energy, education, and healthcare.	**Prosperity** The definition may evolve to include access to personalised and self-managed or self-sustainable services. Beyond employment, it may include varied streams or opportunities for income generation to enable people to earn a living. It may encompass broader life choices and a more supportive – and self-sufficient – environment in which to make them.
Well-being A multifaceted dimension defined by 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.	**Well-being** 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 entire removal of (or greater ability to overcome) mental and physical health issues.

[A] Evolved definition from 'The Global 50' (2022 and 2023).

This year's report, like in the past, splits opportunities into five categories. What is different is that the category 'Systems Optimised' from the 2022 edition is brought back into this year's edition and 'Collaboration Advanced' introduced in 2023 is embedded into each of the opportunities because without collaboration many of the opportunities or their associated benefits may not be realised. What is also new in this edition is that we used generative artificial intelligence (GenAI) where appropriate to improve both the quality of research and the quality of design. We include a short commentary that transparently covers how we used GenAI within the methodology section of the report.

As has been the case throughout history, the next 50 years are set to bring both opportunities and challenges for all generations. Some of us will live long enough to benefit from some opportunities more than others. However, **by working together, we can better manage uncertainties, navigate shifts and take advantage of opportunities** for ourselves and future generations.

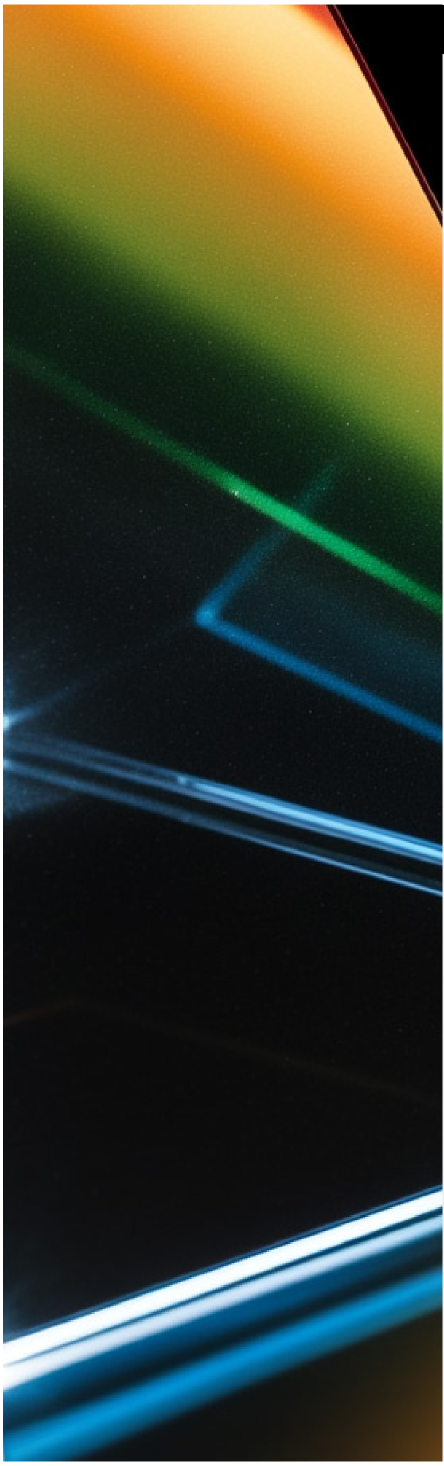
OUR VIEW OF THE FUTURE

Our view of the future in **'The Global 50' is a framework that can guide thinking and decision-making as the future unfolds.**

With a focus on growth, prosperity, and well-being, whose definitions will evolve over time,[3] **our view of the future is built upon three aspects: uncertainties, assumptions, and megatrends.** By helping the world to take advantage of opportunities, anticipate challenges, and manage risks through innovation, our view of the future acts as a conceptual model for those interested in navigating the era of quantum shifts. It can help us find new means to meet basic human needs and motivations for self-realisation in the diverse coexisting and constantly changing realities that the world faces.[4]

While the uncertainties and assumptions are relevant over multiple decades and will remain stable over time, the megatrends are relevant over a shorter period of time and are likely to change within a decade or so.[5] Each of these has featured in previous editions of 'The Global 50'.

Thinking about and planning for the future is not straightforward.[6] While the pillars of our view of the future are presented as silos, they are in fact interrelated. The job of the foresight professional (see Box 3) is – with curiosity – to manage these aspects in an agile, entrepreneurial, and creative way that enables action.



BOX 3

THE FORESIGHT PROFESSIONAL

The foresight professional has a multidisciplinary perspective, with or without a clear area of specialisation, and works with global experts who have a future orientation in their own areas of expertise or vertical. The foresight professional is entrepreneurial in their approach to carrying out activities related to foresight. Their role includes futures-related communications, engagement, and outreach with a focus on supporting strategic goals, competitiveness, and have an impact on wider local and global communities.

A decade ago, the ‘foresight professional’ was not a well-defined role.[7] Using the keywords ‘foresight’, ‘future studies’, and ‘scenario planning’,[B] we randomly selected 30 job adverts posted on LinkedIn around the world[C] and looked at both stated titles and underlying job descriptions to see how the foresight professional is portrayed today. While our review offers a preliminary glimpse, a more in-depth analysis might reveal more insights based on geographical context, sector, and seniority.

While there were roles that included the word 'foresight', such as ‘Officer or Manager Futures and Foresight’, ‘Foresight Lead’, and ‘Future Studies and Foresight Expert’, more than half did not include either ‘foresight’ or ‘future studies’ in their titles and fell under strategy, planning, and/or development functions.

SAMPLE JOB TITLES

- **Chief Strategy Officer**
- **Engagement Leader**
- **Head Of Corporate Affairs and Engagement**
- **Strategic Planner**
- **Future Foresight Researcher**
- **Strategic Development Consultant**
- **Director Of Strategy and Corporate Development**
- **Head Of Strategy and Operations**
- **Strategy Consultant**
- **Manager Strategy**
- **Director Planning and Analysis**
- **Senior Director, Corporate Strategy, Market Intelligence**

[B] In conducting this short exercise, we included ‘scenario planning’ as a keyword, recognising it as a tool prominently noted in approaches to foresight. Additionally, scenario planners are often sought by industries as practitioners of foresight.

[C] Carried out on 15 November 2023.

The job descriptions took two primary perspectives. On the one hand, some roles referenced **planning and capacity-building**, covering the development of tools and resources for foresight, design, and delivery of training on foresight, establishment of global expert networks, and crafting of foresight policies and strategies. In contrast, other roles had an **operational** remit, involving more actively **identifying, anticipating, and responding to emerging trends, challenges, opportunities, risks, and technologies from diverse sources.**

In both perspectives, job descriptions also referred to leveraging foresight for one or more of the following: product and service development, influencing strategy, creating case studies and modelling capacities, developing multiple future scenarios and aligning them to strategies, testing models against the market and competitors' actions, and/or using quantitative and qualitative methods for insights.

In addition, there were also some aspects related to **knowledge- and content-sharing**. The descriptions referred to content creation for media and digital marketing; communicating possible future scenarios that incorporate knowledges from various domains; translating findings into engaging narratives, visualisations, and presentations; sharing reports with policymakers; aligning scenarios with the strategic goals of the organisation and its stakeholders; and producing content that reviews risks and opportunities on an annual or semi-annual basis.

While the foresight professional is not typically an expert in one subject, they may further evolve into specialised areas of the natural sciences, social sciences, technology, climate, and sustainability.[8] The foresight professional focuses on pragmatic research,[9] contributes to other fields of expertise,[10] and uses relevant foresight tools and emerging technologies, including AI,[11] when exploring futures.[12]

The Dubai Future Foundation's view of the future across the 2022, 2023, and now 2024 editions of 'The Global 50' provides a starting point and a framework for government, business, and civil society to guide thinking. For those with future initiatives already in development or in place, it serves as a unique form of peer collaboration. While there is no single right or perfect framework for foresight, lacking a guide means relinquishing control over 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 on our future growth, prosperity, and well-being either positively or negatively.** On a broad spectrum, where a global community – city, country, or region – falls along the spectrum varies in terms of both location and time – there is no one general view or assessment.[13]

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 will manifest in new challenges within ever-evolving realities over the next five decades. **Meeting the global populations' expectations will require a nuanced understanding of the multifaceted and dynamic landscapes shaping our shared future.**

The 2022 edition of 'The Global 50' described five key uncertainties, and the 2023 edition outlined their implications for future growth, prosperity, and well-being. In this 2024 edition, we update the uncertainties by outlining their two extremes. For each extreme, we suggest some signals to watch out for in order to assess whether you are already well equipped to face the uncertainty on your path towards your vision of the future or whether you might require new solutions or capacities.[14]

UNCERTAINTY 1

COLLABORATION

Question for the future of growth, prosperity, and well-being

To what extent will governance and International Collaboration advance at the global level?[15]

Multilateralism

Global communities collaborate and reach agreement on global challenges and approaches to resolving them.

Signals:

- Increased number of treaties and agreements in more than one domain
- Increased trade and commerce between countries and/or regions
- Higher number of global conferences with engagement from an increasing number of countries around the globe
- Higher level of internet traffic, communication, and travel

Multipolarity

The world is multipolar, failing to reach agreement on global challenges or the steps to take to advance human progress.

Signals:

- Lack of policymaking and programmatic progress via multilateral institutions
- Increased numbers of unresolved issues and disputes
- Negative sentiments and/or lack of trust between different communities
- Stagnating or decreasing membership of international organisations

UNCERTAINTY 2

VALUES

Question for the future of growth, prosperity, and well-being

To what extent will global communities converge on shared values or become divided by differences?[16]

Universality

Values are highly aligned around the world and nearly universal.

Uniqueness

Values diverge immensely between different countries and cities.

Signals:

- Improvements in social cohesion
- Increases in diversity and expanding expatriate communities at country levels
- Alignment of laws, regulations, and policies on emerging global challenges
- Decreases in global conflict

Signals:

- Low levels of social stability
- High levels of debate and criticism between different communities
- Strong political polarisation
- Differing policy priorities on global challenges

UNCERTAINTY 3

TECHNOLOGY[D]

Question for the future of growth, prosperity, and well-being

To what extent will technology dictate our lives or serve as a multiplier for productivity and a better quality of life?[17]

Technology as Multiplier

Technology improves quality of life and access to services, enabling and multiplying efforts to work towards the common good.

Signals:

- Greater resource efficiency and reductions in raw material use
- Increases in energy efficiency and reductions in energy use
- Fewer incidences of data breaches
- Increased productivity and potentially new industries and opportunities for income generation

Technology as Master

Technology controls processes and livelihoods, making it difficult for individuals to reach their full potential.

Signals:

- Increases in job displacement
- Increased income and skill disparities
- Public contempt of and/or increasing feelings of insecurity of technology
- Pace of technology governance lags behind technological advances

[D] Technology is both an uncertainty and an assumption. See the assumptions to understand the difference.

UNCERTAINTY 4

NATURE[E]

Question for the future of growth, prosperity, and well-being

To what extent will our innovative technologies and governance efforts help nature to restore itself?[18]

Renewal

New developments and opportunities reduce land degradation and pollution, support cleaner energy use, allow biodiversity to flourish, and otherwise support nature's well-being.

Signals:

- Increased food and water security
- Increased ecosystem and biodiversity health
- Reductions in greenhouse gas emissions
- Rising investment in environmental sustainability (e.g. nature-based solutions, renewable energy, and agroecology)

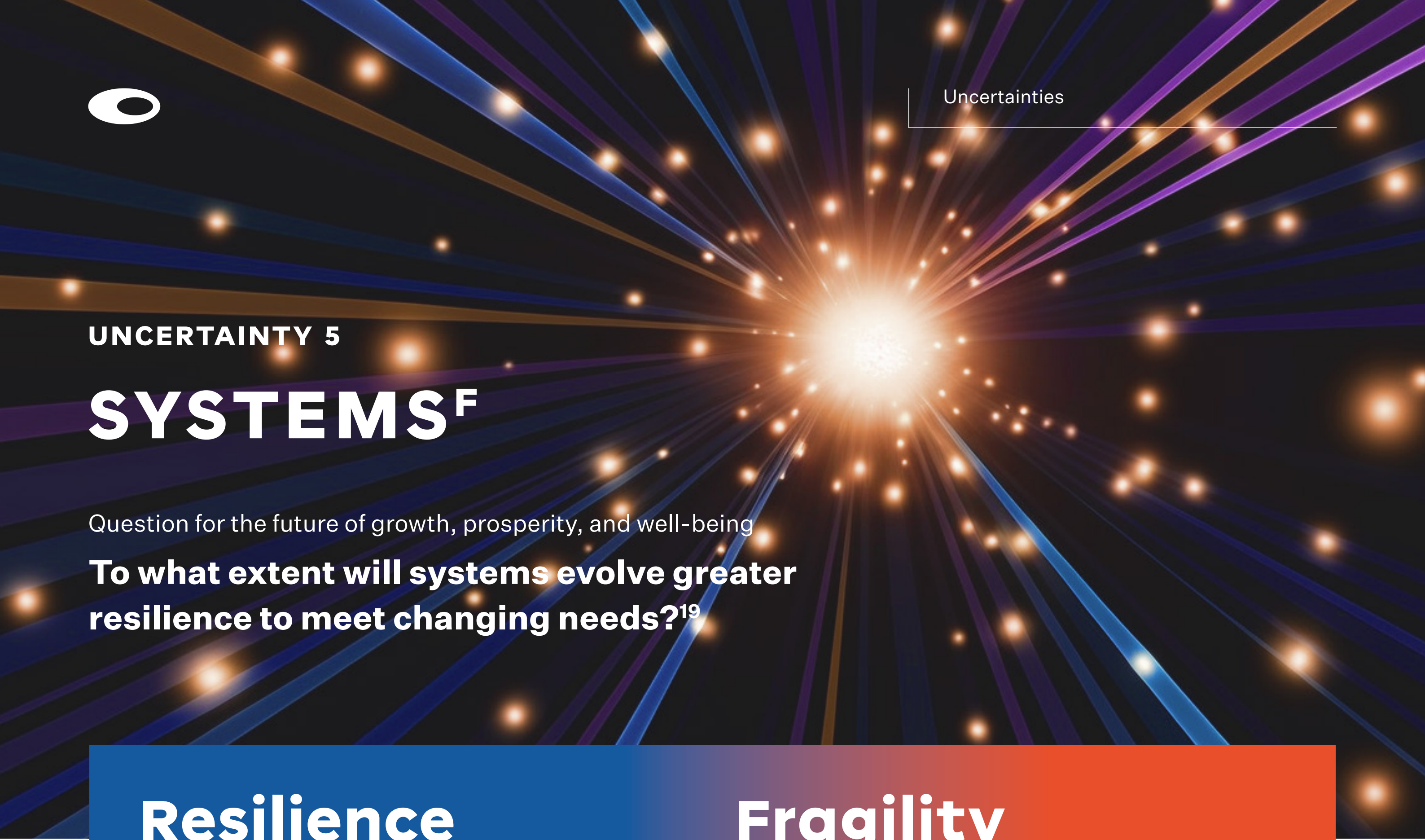
Degradation

Increasing pressures on nature, the climate, and natural resources negatively impact on food chains and natural processes, including extreme weather events becoming more common.

Signals:

- Continued increases in the global temperature and a rising sea level
- Increases in incidences of zoonotic diseases
- Ongoing rise in species extinctions
- Continued degradation of the soil and ecosystem health

[E] Nature is both an uncertainty and an assumption. See the assumptions to understand the difference.



UNCERTAINTY 5

SYSTEMS[F]

Question for the future of growth, prosperity, and well-being

To what extent will systems evolve greater resilience to meet changing needs?[19]

Resilience

Health, education, financial, legal, communication, and social systems adapt to changes and become more resilient in the face of new challenges and opportunities.

Signals:

- Technology-powered legal systems and processes (e.g. using AI, blockchain)
- Introduction of new trade mechanics (e.g. blockchain and the metaverse)
- Technological and procedural interoperability within and between government and business
- Increased public–private cooperation and innovation in social problem-solving

Fragility

Systems become more vulnerable as they adopt new technologies and processes, leading to unforeseen challenges and instability.

Signals:

- Decreasing public satisfaction with public and private services and systems
- Increases in unmitigated cyberattacks and other technological vulnerabilities
- Lack of interoperability between and within different government agencies, sectors, and businesses

[F] Systems as an uncertainty refers to the processes and mechanisms that are used to operationalise global policies, laws, regulations, and cross-border transactions.

ASSUMPTIONS

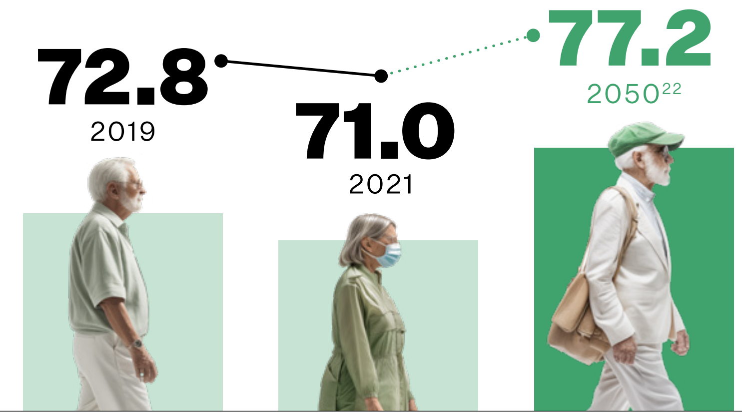
Assumptions in 'The Global 50' play a crucial role, just as they do in scenario planning. **While they may change over time, assumptions generally remain stable over several decades.**[20] Any shifts in these assumptions could substantially change future scenarios that are built on them (and on the uncertainties). Similarly, shifts in the assumptions could affect how the megatrends impact on growth, prosperity, and well-being and our ability to realise future opportunities. In this section, we share data or outlooks (non-exhaustive) on some signals that put assumptions into context. While we take the long view on assumptions, we recognise that figures may change in the short term due to unforeseen events and may have a lasting impact.

ASSUMPTION 1

LIVES WILL BE LONGER AND HEALTHIER

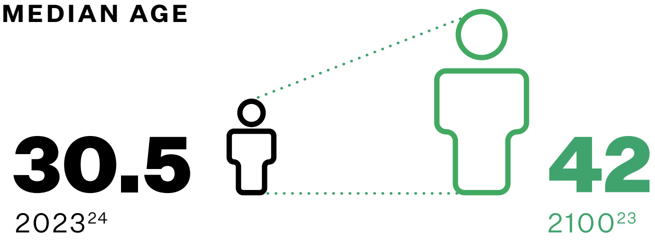
1 **While it dropped marginally during the Covid19- pandemic, global life expectancy continues to rise.[21]**

AVERAGE LIFE EXPECTANCY



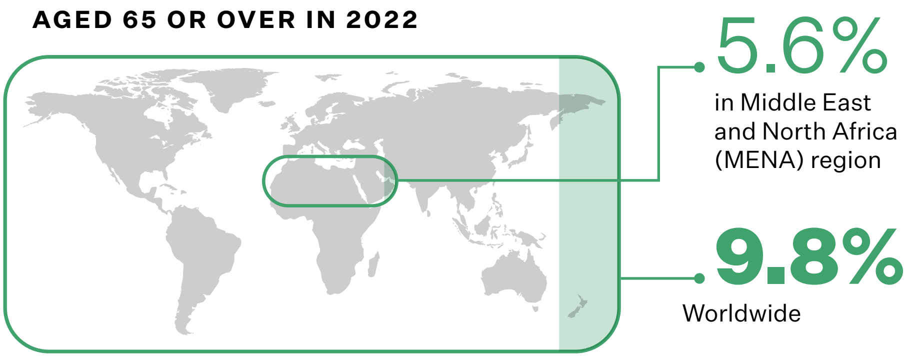
2 **The population distribution will shift from younger to older.**

WORLD'S MEDIAN AGE



3 **The proportion of MENA's population made up of the elderly, while increasing, remains below the global average.[25]**

PERCENTAGE OF PEOPLE AGED 65 OR OVER IN 2022

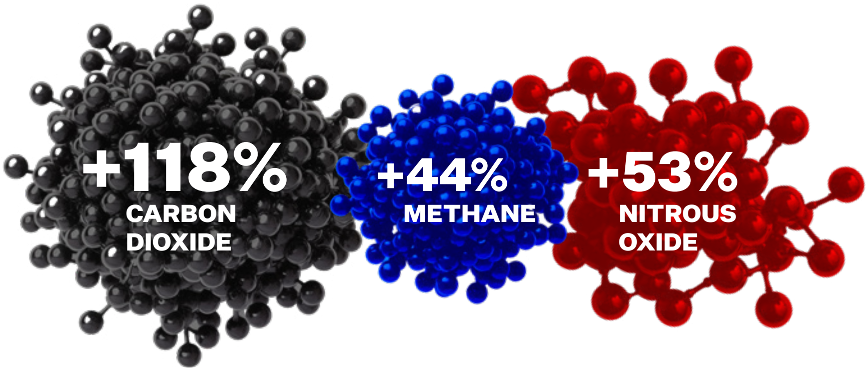


ASSUMPTION 2

CLIMATE CHANGE WILL PERSIST

1 **While the rate of greenhouse gas (GHG) emissions seems to be slowing,[26] GHGs remain high on a decade to decade basis.[27]**

1970–1979 TO **2012–2021**



2 **Climate-caused poverty and displacement, continue to be a concern, especially in already impoverished countries.[28]**

PEOPLE INTERNALLY DISPLACED BY CLIMATE-RELATED HAZARDS

21.6M

Each year between 2012 and 2021[29]

113M–216 M

by 2050[30]

3 **The MENA region will continue to face critical water stress.**

MENA REGION POPULATION EXPOSED TO WATER STRESS[31]

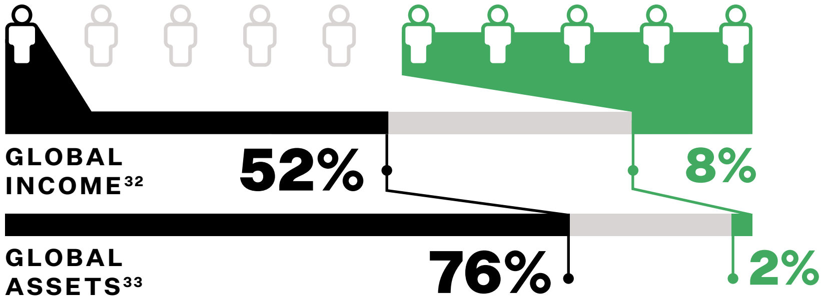
ASSUMPTION 3

INEQUALITIES WILL CONTINUE

1 Global wealth distribution varies widely.

The richest 10% of the global population

The bottom 50% of the global population

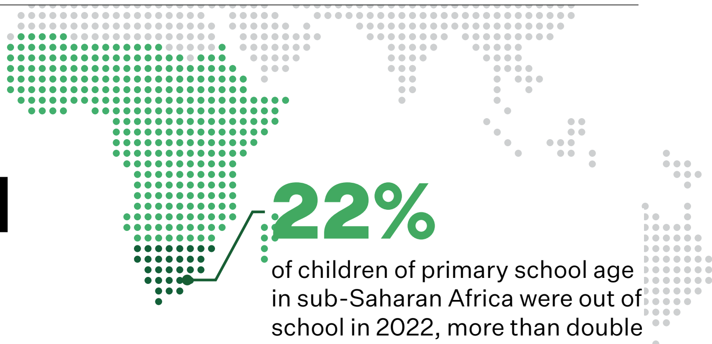


2 Some children still do not go to school.

Globally,

250M

children were not participating in full-time education in 2022.[34]



22%

of children of primary school age in sub-Saharan Africa were out of school in 2022, more than double the next highest rate of out-of-school children (in South Asia).[35]

3 Global gaps in internet access persist.

ACCESS TO THE INTERNET[36]

9 OUT OF 10

school-aged children in high-income countries

1 IN 5

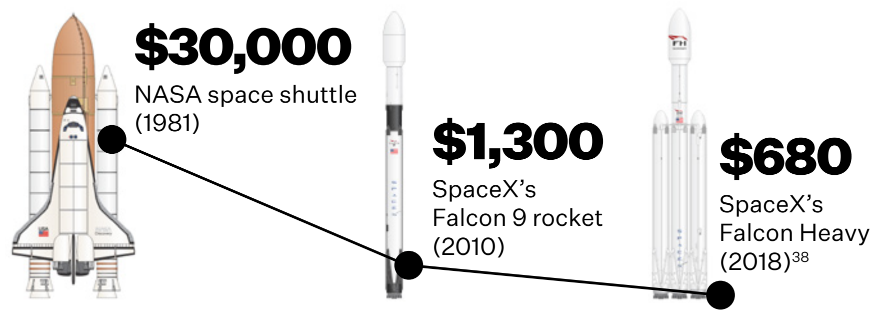
school-aged children in low-income countries

ASSUMPTION 4

TECHNOLOGY WILL CONTINUE TO ADVANCE

1 Technology's impact continues to be transformational.

COST OF LAUNCHES PER POUND OF PAYLOAD BY DATE OF FIRST ORBIT LAUNCH (2022)[37]



2 The IT sector will continue to rapidly expand with quantum computing holding great potential.

Market size for quantum computing may reach

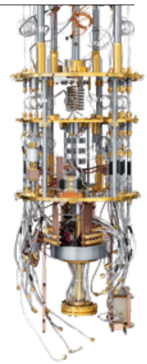
$1.27 TRILLION

by maturity in 2035 across four industries (chemicals, life sciences, finance, and automotive)[39]

Quantum computing is projected to generate net profits of

+13%

across various industries by maturity in 2035[40]



3 The MENA region has a rising influence on technology.[41]

Some of the future initiatives announced in the region and key milestone years:

- 2026 — Egypt's space city[42]
- 2028 — Dubai International Financial Centre's Dubai AI & Web 3.0 Campus[43]
- 2030 — Saudi Arabia's space strategy through Vision 2030[44]
- 2033 — Dubai Future Foundation's Dubai Program for Gaming[45]
- 2117 — UAE's Mars 2117 project[46]

MEGATRENDS

In contrast to uncertainties and assumptions, megatrends – as defined by the DFF in 'The Global 50' [47] – are applicable over a shorter period of time. In our approach, these research-led thematic paths are expected to significantly impact on global economies and societies. They are likely to influence growth, prosperity, and well-being, either positively or negatively, over a decade or more.[48] **Megatrends, characterised by their complexity and interrelatedness, provide decision-makers and foresight professionals with inspiration to think further about and ideate potential opportunities for future growth, prosperity, and well-being in their respective sectors or future strategic objectives.**

The nature of megatrends is that they are dynamic and may evolve, especially when they intersect with uncertainties. For this year, Megatrend 2 (previously called 'Devaluation of Raw Data') has evolved into 'Boundless Multidimensional Data'.[G] This evolution reflects a broader shift in data capture and analytical capabilities.

While the megatrends are presented individually, it should be kept in mind that their interrelated nature means that they overlap with each other. Additionally, it should be noted that any drivers, trends, and signals are not exhaustive. For each megatrend, we offer a mix of current facts and future forecasts. Additionally, we identify three potential areas of opportunity within each megatrend, which may be of interest to decision-makers and individuals alike.

[G] Diverse, seamless, constant, processed, data flows, complex, multidimensional, never-ending data landscape

MEGATREND 1
MATERIALS REVOLUTION

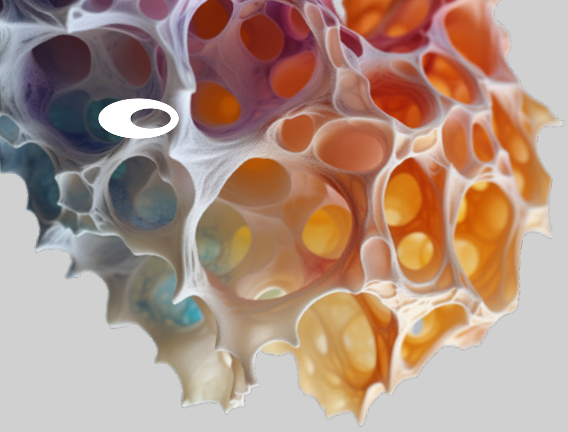
Materials are fundamental to everything we use and consume on a daily basis. Advances in materials science are being driven by machine intelligence and nanotechnology, as well as increased research activity amid recognition of the massive potential in improving what things are made of — and how they are made. Sectors spanning industry, technology, and consumer goods will experience a material transformation.

KEY SECTORS THAT MAY BE IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Consumer Goods, Services & Retail
Healthcare
Infrastructure & Construction

KEYWORDS

Alternative Fuels
Graphene
Green Carbon Materials
Metallic Foam
Nanotechnology
Polymers
Responsive/Smart Materials
Self-Repairing Materials
Semiconductors
Synthetic Biology



Current tissue-engineering applications are estimated to mature within

3 to 10 years

TISSUE ENGINEERING

The future of tissue engineering is highly promising, with significant breakthroughs anticipated in tissue regeneration and repair. This field is expected to see rapid growth, with the global market projected to reach nearly $43 billion by 2030, expanding at a CAGR of 14% from 2023 to 2030.[49]

The synergy between materials science and tissue engineering is pivotal, especially in developing biocompatible scaffolds critical for successful tissue growth and reconstruction.[50]

Current tissue-engineering applications under development are estimated to mature within 3 to 10 years, underscoring the rapid evolution of this sector.[51]

The market for tissue engineering in the Middle East and North Africa (MENA) region, similarly to the global market, is set to grow from nearly $494 million in 2022 to $955 million by 2028 at a CAGR of nearly 10%.[52]

MATERIALS FOR ENGINEERING PARTS

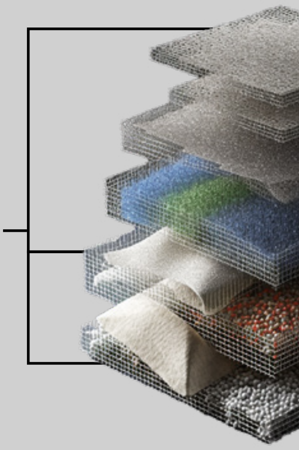
Advances in 3D printing and materials science are driving significant enhancements to engineering components – advances that are poised to transform the construction industry. Besides common construction materials such as concrete, steel, and wood, essential components such as gaskets, wires, pipes, ducts, and fasteners are undergoing transformative changes.

The global use of raw materials is set to nearly double by 2060[53] and innovation to re-engineer parts for quality, sustainability, and performance through materials reduces both the need for new raw materials and the built environment's[H] carbon emissions, which currently make up at least 37% of global energy-related carbon emissions.[54] Examples include sustainable metals and alloys, synthetic biology for sealants, and the use of agrowaste in concrete.[55]

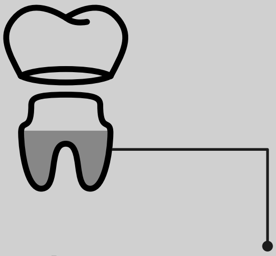
The global use of raw materials is set to nearly

double

by 2060



NANOBIOMATERIALS FOR DENTAL APPLICATIONS



In the UK,

over a third

of Generation Z are inclined towards DIY dentistry compared to 12% of those aged over 55

Advances in biocompatible nanomaterials are expected to transform dental prevention, treatments, and monitoring.

The human mouth is home to over 700 microbial species that form complex protective biofilms,[56] and traditional antibacterial solutions are inadequate as they disrupt this balance.[57] Nanomaterials with enhanced antibacterial properties have the potential to replace traditional antibacterial solutions; however, challenges remain in clinical application and design for specific oral needs, including non-toxicity and cost-effectiveness.[58]

Another area for nanomaterials is DIY dentistry. Demand for DIY dentistry is in part a response to the partial or complete shutdown of dental clinics during the COVID-19 pandemic.[59]

In the United Kingdom, for example, lack of access to dental care is the result of up to 98% of NHS dental clinics not accepting new adult patients.[60] This has resulted in over a third of Generation Z (those born between mid-to-late 1990s and the early 2010s) being inclined towards DIY dentistry compared with only 12% of those aged over 55.[61] The future of biocompatible nanomaterials and dental healthcare is poised to facilitate DIY applications at home, going beyond teeth whitening.

The global dental biomaterials market, valued at $8.5 billion in 2022, is projected to reach $15.9 billion by 2032, growing at a CAGR of 6.6%.[62]

[H] Includes ongoing residential and non-residential building operations.

MEGATREND 2
BOUNDLESS MULTIDIMENSIONAL DATA[1]

An evolution of the Megatrend ‘Devaluation of Raw Data’ in 2022 and 2023, the rise of quantum computing, blockchains, the IoT, edge computing, automation, and digital realities are all contributing to a data environment that is both constant and multi-dimensional. There is unprecedented volume and speed when it comes to the data available today. Enhanced by 5G, 6G, and advanced connectivity through multiple networks, and with an expected increase in the number of multilateral agreements focused on information interoperability, raw data will continue to increase in both quantity and variety. Under the right conditions, widespread access to immediate insights and real-time analysis will become commonplace.

KEY SECTORS THAT MAY BE IMPACTED

Communication Technologies & Systems
Data Science, AI & Machine Learning
Government Services
Healthcare
Financial Services & Investment

KEYWORDS

Artificial Intelligence
Automation
Big Data
Cellular (5G, 6G) and Broadband Networks
Data Analytics
Data Trust
Digital Trade
Internet of Things (IoT)
Open Data
Quantum Computing

[1] Evolved from the 2023 Global 50 report

BIOINFORMATICS

Bioinformatics, although not a new discipline, is poised for significant growth as a result of advanced machine intelligence.

Combining biology, computer science, and statistics, bioinformatics analyses and interprets biological data and is expected to open new frontiers in genomics to impact on the food and the agricultural sector.

The global bioinformatics market is projected to reach $38 billion by 2029 from nearly $11 billion in 2022, expanding at a CAGR of 13.4% between 2023 and 2029.[63] Specifically in the Middle East and Africa, the bioinformatics market is estimated to grow from $668 million in 2022 to $1.4 billion by 2028, with a CAGR of nearly 14%.[64]

The global bioinformatics market is projected to reach

$38 billion

by 2029

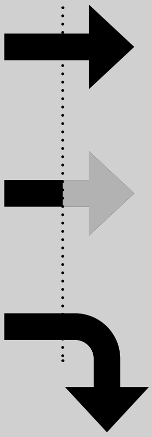
a growth rate of 13.4%

DATA FOR CLIMATE ACCOUNTABILITY

15%
are on track

37%
have not shown any progress

48%
have deviated negatively from targets



138 out of 160 SDG that can be evaluated using data and analysis

Effective climate actions require accountability and fair incentive distribution driven by data quantity, quality, and analysis in real time that impact on investment and other decisions on financial assistance.

AI could enhance accountability by speeding up the design, monitoring, and impact assessment of new climate technologies through comprehensive internet of things (IoT) data and analysis in real time aiding informed decisions in policy and investment.

Today, of the 169 targets of the UN's Sustainable Development Goals (SDGs), only 138 can be evaluated using data. Only 15% of those are on track, nearly 48% have deviated negatively, and 37% have not shown any progress towards 2030.[65]

Similarly, COP28 enabled the first global stock take (GST)[66] of nationally determined contributions and actions under the Enhanced Transparency Framework (ETF).[67] With limited data, and despite net-zero commitments made by countries, demonstrating achievement of the Paris Agreement goals adopted by COP21 in 2015 will be a challenge.[68]

DATA COOPERATIVES FOR INSIGHTS

As individuals continue to prioritise privacy and transparency in personal data management, the concept of sharing anonymised data for analysis may gain traction within the next decade. In this context, data cooperatives, which focus on selling insights rather than the data itself, are emerging as socially responsible business models.

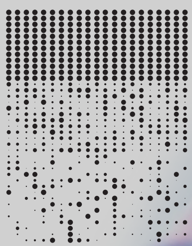
By 2030, a ten-fold increase in data created since 2020 to 660 zettabytes[69] underscores the vast scale that data will reach in the near future.

The global big data market, valued at $272 billion in 2022, is projected to reach $308 billion by 2030, growing at a CAGR of 13.5%.[70] This growth is being mirrored in the MENA region's big data analytics market, which is expected to expand at a CAGR of 13%, from nearly $13 million in 2022 to nearly $27 million by 2028.[71]

By 2030, there will be a

tenfold

increase in data to 660 zettabytes



MEGATREND 3
TECHNOLOGICAL VULNERABILITIES

Biotechnology, gene editing, new therapies in medicine and agriculture, ubiquitous digitalisation and automation, and the spread of IoT-enabled wearables are all ripe for exploitation. Vulnerabilities and risks will become more complex as they cross industries, technologies, and geographies, directly impacting on every aspect of life and work.

KEY SECTORS THAT MAY BE IMPACTED

Agriculture & Food
Communication Technologies & Systems
Government Services
Healthcare
Professional Services

KEYWORDS

Biotechnology
Cloud Platforms
Cyberbiosecurity
Digitisation
Internet of Things (IoT)
Malware
Quantum Proofing
Ransomware
Zero Trust
Cybersecurity

CYBER-RISK INSURANCE

Cyberattacks will continue to increase and become more sophisticated, posing a critical challenge for insurance models, which must adapt to the evolving threat landscape and mitigate the growing financial impact of cyberthreats.

Insurance-related data and models will need to respond to these advanced threats with agility, ensuring appropriate coverage and exclusions.

The global cyber-insurance market was valued at nearly $6 billion in 2019 and is projected to increase to $33 billion by 2027. [83]Concurrently, cybercrime costs, which were $3 trillion in 2015, are expected to reach $10.5 trillion by 2025.[84]

In the Middle East, the average cost per data breach in 2023 (around $8.1 million) is significantly higher than the global average ($4.45 million per incident).[85]

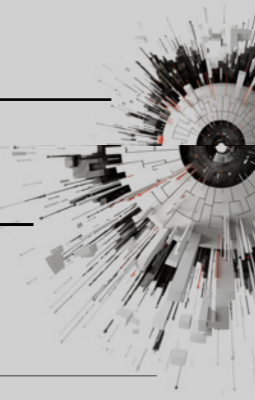
The cost per data breach

$4.45 M

Global average

$8.1 M

Middle East



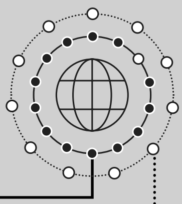
Currently the world has some

14 billion

IoT devices, with this number expected to exceed

25 billion

by 2030



CYBERSECURITY FOR THE IOT

The diverse, interconnected, and complex ecosystem of the IoT increases the vulnerability of devices to attacks and can lead to undetected security issues for prolonged periods with the need to advance research and approaches to cybersecurity.[78]

While an average network prior to the IoT could have had up to 500,000 endpoints – where data is sent and received on IoT devices[79] – with the IoT, a network could involve up to tens of millions.[80]

Currently the world has some 14 billion IoT devices, with this number expected to exceed 25 billion by 2030.[81]

In the UAE, the IoT market, valued at nearly $21 billion in 2022, is anticipated to grow at a CAGR of just over 17% from 2023 to 2028.[82]

PROTECTING AGAINST CYBER-PHYSICAL ATTACKS

Cybersecurity, traditionally focused on protecting computer systems, networks, digital applications, and data, is increasingly confronting threats targeting physical computing systems. These cyber–physical attacks, which often evade standard detection measures, are on the rise.

Industrial cyberattacks are an increasing issue. Compared to 2021, attacks increased by 140% in 2022 impacting on 150 industrial sites around the world.[72]

At this rate, 15,000 industrial sites may be attacked by 2027.[73] USB-borne malware, which constitutes 52% of industrial cybercrime, is a key area of risk causing loss of operational control.[74]

The frequency of cyber–physical attacks and the number of affected sites are growing rapidly, increasing tenfold every 2.5 years.[75] Moreover, a significant proportion of these attacks (74%) take the form of ransomware.[76] This emphasises the urgent need for robust and comprehensive cybersecurity strategies particularly in the case of critical infrastructure.[77]

Compared to 2021, attacks increased by 140% in 2022 impacting on

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At this rate,

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MEGATREND 4
ENERGY BOUNDARIES

Energy is imperative to everyday life and will continue to be so in the future. Technological advances and the growing demand for energy will drive exploration and the pursuit of new and alternative sources of energy. Novel materials and machine intelligence will enhance the generation of existing sources of energy and their transmission and distribution to any place on Earth or in space, pushing the boundaries of the energy ecosystem to levels previously unseen.

KEY SECTORS THAT MAY BE IMPACTED

Automotive, Aerospace & Aviation
Energy, Oil, Gas & Renewables
Logistics, Shipping & Freight
Professional Services
Utilities

KEYWORDS

Battery Technology
Biofuels
Fission
Fusion
Hydrogen
Hydropower
Lithium
Metallic Foam
Solar Photovoltaics
Renewables

SMART GRIDS FOR SUSTAINABLE DEVELOPMENT

Energy has always been one of the more data-intensive sectors. However, advanced machine intelligence and the IoT present a set of opportunities to further enhance efficiency, sustainability, and connectivity paving the way for comprehensive energy management systems capable of real-time monitoring and control.

Since 2015, investment in grid-related digital technologies has grown by over 50%, and this area was expected to constitute 19% of total grid investment in 2023.[93]

To globally attain net-zero targets, smart grid investments need to more than double – from around $300 billion per year to nearly $600 billion per year by 2030 – particularly in emerging markets.[94] The number of smart power meters worldwide surpassed 1 billion in 2022, marking a tenfold increase since 2010.[95]

In the Middle East, the smart grid market is forecast to expand at a CAGR of around 29% between 2020 and 2025, with the UAE and Saudi Arabia expected to lead this growth.[96]

To globally attain net-zero emissions, smart grid investments need to more than double to

$600 B
2030

from

$300 B
Today

Algae are the oldest living microbes on Earth, dating back
3.5 billion years

FROM AGROWASTE TO GRAPHENE

Renewable energy, pivotal in the energy transition, is increasingly including the use of organic materials for energy, such as algal biomass for biofuels, with applications in the automotive and aviation industries. The challenge lies in identifying suitable organic materials for biofuel conversion, a process in which artificial machine intelligence can play a crucial role in both identifying candidates and enhancing conversion methods.

Algae, the oldest living microbes on Earth, dating back 3.5 billion years,[90] is one example. They have a growth rate 20 times faster than that of traditional energy crops (such as maize and rapeseed) making them a highly efficient biofuel source.[91]

Despite expected transformational impacts, scaling graphene production – as a highly conductive carbon-based material that can boost energy efficiency – remains a challenge. Just like in biofuels, there is an opportunity to explore agrowaste for graphene as it is mostly comprised of long chains of carbon, as high as 55% by weight.[92] However, also like in biofuels, the challenge lies in identifying efficient and eco-friendly techniques for conversion.

QUANTUM BATTERIES

As battery technology evolves to meet increasing demand, there is a significant focus on overcoming resource limitations and enhancing performance. Quantum mechanics is paving the way for the development of quantum batteries, a promising area with the potential to substantially improve performance and address current storage limitations.[86]

While a fully operational model is yet to be realised, quantum batteries capable of charging 200 times faster than traditional batteries[87] are expected to transform energy storage within five years.[88] Relying on quantum mechanics as opposed to chemical reactions in batteries today, quantum batteries could play a crucial role in advancing wireless charging, augmenting energy storage capacity, and increasing solar power efficiency.[89]

Quantum batteries are capable of charging
200 times faster
than traditional batteries

MEGATREND 5
SAVING ECOSYSTEMS

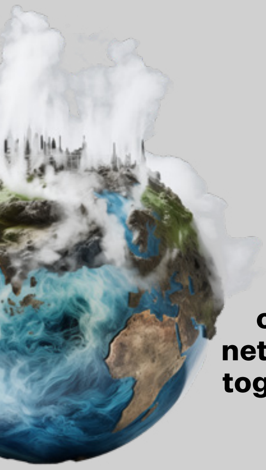
Driven by resource scarcity, climate change, and shifts in social values, environmental impact management will increasingly move towards the holistic management of ecosystems. Approaches to conservation will be more interdisciplinary and future-focused, taking into account both societal and environmental factors and with the goal of maintaining biodiversity while meeting basic human needs.

KEY SECTORS THAT MAY BE IMPACTED

Agriculture & Food
Energy, Oil, Gas & Renewables
Infrastructure & Construction
Manufacturing
Travel & Tourism

KEYWORDS

Adaptive Management
Carbon Footprint
Ecological Economics
Environmental, Social and Governance (ESG)
Food–Water–Energy Nexus
Forests and Mangroves
Green Finance
Net Positive
Net Zero
Sustainable Smart Cites



140
countries have set net-zero targets that together cover some
88%
of global emissions

CARBON NEUTRALITY EVERYWHERE

Numerous countries, alongside major corporations such as Apple, Google, Ikea, and Walmart, as well as educational institutions under the Race to Zero education initiative,[97] have committed to achieving carbon neutrality or becoming carbon positive.

These net-zero commitments have the potential to significantly reshape and amplify climate response efforts if they are universally adopted by other entities as well ranging from small businesses to schools and publicly listed companies.

The UAE's Net Zero 2050 charter was signed in March 2023.[98] A further 140 countries – including major emitters such as China, India, the United States, and the countries of the European Union (EU) – have set net-zero targets that together cover some 88% of global emissions.[99]

The global transition to net-zero emissions represents an investment opportunity that will total almost $200 trillion by 2050, which translates to nearly $7 trillion annually.[100]

CLIMATE IN EDUCATION

The climate narrative is spreading in educational systems and institutions, but there is a growing opportunity to weave climate education across all disciplines, beyond standalone courses or extracurricular activities. Integrating climate education into various subjects – such as physics, mathematics, statistics, and history – can provide students with diverse perspectives and foster interdisciplinary solutions to climate challenges.

Despite the outreach efforts of initiatives such as Climate without Borders,[101] only half of the world's national education curricula currently reference climate change.[102]

In 2023, the UAE, UNICEF, and UNESCO formed a landmark climate education partnership to train over 1,400 head teachers and 2,800 teachers in sustainability practices, which exemplifies the global shift towards comprehensive climate education.[103]

Only half
of the world's national education curricula currently reference
climate change

Supply chains account for
60% of global emissions

SUPPLY CHAINS AS AN ECOSYSTEM

The consumer goods sector is increasingly focused on minimising carbon footprints, not only within its own operations but also throughout its extensive supply chains which link cities and span national borders. Currently, supply chains account for 60% of global emissions and are 5.5 times more carbon-intensive than other areas in a business's value chain.[104]

To reduce carbon emissions, many businesses are using or looking at technological advances and innovations such as biofuels, renewable energy, re-engineering and quality improvements for decarbonisation and reducing waste.[105]

However, a data collective, enhanced by the IoT and advanced machine intelligence, could enable more detailed analysis of emissions and climate data at different stages of the supply chain.

In the UAE, national initiatives such as Etihad Rail, expected to transport 50 million tonnes of freight annually across 11 cities and regions, aim to reduce carbon emissions in the road transport sector by 21% by 2050.[106]

MEGATREND 6
BORDERLESS WORLD – FLUID ECONOMIES

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

KEY SECTORS THAT MAY BE IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Communication Technologies & Systems
Data Science, AI & Machine Learning
Financial Services & Investment

KEYWORDS

3D Printing
Cellular (5G, 6G) and Broadband Networks
Cryptocurrencies
Digital Economy
Gig Economy
Legal Transformation
Migration and Immigration
Non-fungible Token (NFT)
Remote Work
Robotic Surgery

COLLABORATIVE PATENTS

In 2022, the global patent grew for the third year in a row, with 3.46 million patents filed,[114] continuing a trend of annual increases from 3.4 million patents filed in 2021.[115]

Patents involving global collaboration, where inventors are from different countries, tend to bring stronger innovations through the impact of patents, compared with those developed by a single player.[116]

This suggests that diverse, cross-border teams can produce more impactful technological advances, especially on general-purpose or cross-cutting technologies that are important for addressing societal challenges, such as climate and health.[117]

There is an opportunity to further enable global collaborative patenting and innovation by forming cross-border teams and patent classification initiatives. An example is the Cooperative Patent Classification (CPC) joint initiative[118] between the EU and the United States, which has clear frameworks for patent filing and technology transfer across borders. Along with updates to patent classifications that came into place in January 2024, as of May 2023 there were 74 joint active projects under the CPC joint initiative.[119]

In 2022,

3.46 M

patents were filed,

continuing a trend of annual increases for the third year in a row from 3.4 million patents filed in 2021

SOFTWARE DEVELOPMENT FOR INTEROPERABILITY

In the European Union, citizens could save up to

24 million hours

per year through improved data interoperability

Software development is growing across industries,[110] and interoperability will remain a significant challenge. This issue is particularly pronounced with the advancement of Web3, the IoT, and AI and is compounded by evolving regulations around AI and data privacy.

Lack of interoperability could lead to reduced economic value and confidence in software systems. For example, in the EU, citizens could save up to 24 million hours per year through improved location data interoperability.[111]

For businesses in the EU, a fully established interoperable economy would lead to time savings of up to 30 billion hours per year and monetary savings of up to $620 billion[J] annually.[112]

In the public sector, a Boston Consulting Group survey found that 100% of successful digital transformations involved interoperable data and digital platforms, highlighting the critical need for seamless integration across technological systems.[113]

'GLOBAL SOCIAL RESPONSIBILITY'

Corporate social responsibility (CSR) is evolving, reflecting the changing relationship between consumers and companies. With the digital economy's growth, CSR is expanding its reach globally and aligning with the international nature of interconnected digital stakeholders.

Globally, eight out of ten consumers would pay more – four would pay up to 10%, one would pay up to 30% for sustainably produced (fully or partially) goods.[107]

The shift in CSR focus to include global communities necessitates a new international framework and approach to ensure social impact. Globally, over 24,000 organisations are participating in the United Nations' Global Compact.[108] In the MENA region, 80% of businesses plan to increase their CSR efforts.[109]

Globally,

8 out of 10

consumers would pay more for sustainably produced goods.

[J] Based on the Euro–US dollar exchange rate on 20 November 2023.

MEGATREND 7
DIGITAL REALITIES

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 even improved in 3D and 4D environments. The emergence and spread of 5G and 6G networks will enhance autonomous and IoT applications as they offer more reliable, cost-effective and secure high-speed connectivity. As quantum technologies become scalable and reliable, from quantum computing, communications, and sensors, immersive experiences will start to feel like reality.

KEY SECTORS THAT MAY BE IMPACTED

Art, Media & Entertainment
Communication Technologies & Systems
Cyber & Information Security
Digital Goods & Services
Professional Services

KEYWORDS

Cellular (5G, 6G) and Broadband Networks
Augmented Reality (AR) and Virtual Reality (VR)
Blockchain
Brain–Computer Interfaces (BCIs)
Cryptocurrencies
Digital Communities
Gaming
Internet of Things (IoT)
Metaverse
Wearables

The augmented reality market, valued at $42 billion in 2022, is expected to grow to

$1 trillion

by 2030

ENHANCING THE DIGITAL WITH THE PHYSICAL

An area of opportunity lies in the possibility of bringing the physical aspect to digital-only products and services to create enriched experiences.

A form of augmented reality (AR) haptics, for example, can enhance customers' experiences in various fields, including construction and engineering.

In these and other fields, blueprints and informational content can be interactively 'felt', book pages can be turned, and artworks can be experienced tangibly.

The AR market, valued at $42 billion in 2022,[120] is expected to grow exponentially to $1 trillion by 2030.[121]

'GREEN' DIGITAL REALITIES

While Web 3.0 technologies (including extended reality) and blockchain are expected to enhance efficiency and optimise energy and resource use in various sectors,[122] as these technologies gain traction concerns are arising about their actual environmental impact, notably in terms of energy consumption and carbon footprint.[123]

There will be opportunities to enhance energy efficiency in systems related to Web 3.0 by addressing the high energy consumption of blockchain networks and using innovation within algorithms, through reinforcement learning, for example.[124]

Additional strategies include adopting renewable energy sources and managing electronic waste through sustainable manufacturing and recycling. [125]

The internet consumed 800 TWh of electricity in 2022, a figure which is expected to double by 2030, with AI adding 2.5% to global electricity demand.[126] By 2030, the IT industry could use up to 20% of global electricity generated and be responsible for 5.5% of the word's carbon emissions.[127]

By 2030, the technology industry could use up to

20%

of global electricity generated

GENERATIVE 'REALITIES'

GenAI has the potential to contribute up to

$4.4 trillion

in economic value

Generative AI (GenAI), as a multimodal technology that accepts inputs and generates outputs in various forms, is designed to enhance the search experience, along with the generation, presentation, and use of information and content.

Beyond content generation, translation, data analysis, and forecasting, GenAI may power up digital realities by improving decision-making, allowing analysis of various scenarios in real time as well as the personalisation and automation of tasks.[128]

GenAI has the potential to contribute up to $4.4 trillion in economic value with the greatest impact on customer service and software engineering sectors, adding up to 5% to revenues in banking and pharmaceutical sectors.[129] The biggest players are anticipated to be Google, Microsoft (through OpenAI), Meta, and IBM.[130]

MEGATREND 8
LIFE WITH AUTONOMOUS ROBOTS AND AUTOMATION[K]

While a robot is a machine designed to sense, process, act, and communicate, automation refers to technology that executes tasks with minimal human input enabling the functioning of robots as well as reasoning and decision-making systems. Driven by profound progress in engineering design, materials science, advanced machine intelligence, and advanced communication networks, robots and automation will increasingly enter many, if not all, industries beyond the automotive, manufacturing, supply chain logistics, and services sectors. This will provide opportunities for efficiency and innovation although there will also be ethical and societal challenges.

KEY SECTORS THAT MAY BE IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Consumer Goods, Services & Retail
Infrastructure & Construction
Logistics, Shipping & Freight

KEYWORDS

Automated Guided Vehicles (AGV)
Autonomous Robots
Biosensors
Collaborative Robots (Cobots)
Internet of Things (IoT)
Nanobots
Natural Language Processing (NLP)
Robot Skin
Service Robots
Social Robots

[K] Slightly amended from 2023

MARINE ROBOTS

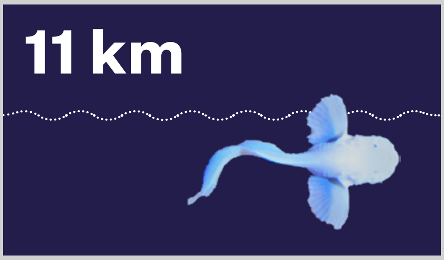
Robots are increasingly valued for their ability to operate in hazardous conditions, mitigating risks to humans, particularly in urban, industrial, and service sectors. The global underwater robotics technology market was worth nearly $4.5 billion in 2022 and is expected to reach around $13 billion by 2030, growing at a CAGR of 14.5% from 2023 to 2030.[140]

The field of aquatic and bionic fish robotics is expanding, although it faces unique challenges from the effects of water on the electronics and communication, to the environmental safety in the event of underwater malfunctions under water.

While advances in sensor technology and materials science are enhancing aquatic robots used for research, deep-sea exploration, and cleaning, these improvements will need to be complemented by advances in control systems, sensing abilities, and the application of reinforcement learning.[141]

In 2021, a team of researchers from China designed and sent a snailfish-inspired, polymer- and silicone-covered robotic fish to the Mariana Trench, the deepest point in the Pacific Ocean at 11 km below sea level.[142]

In 2021, a snailfish-inspired, polymer- and silicone-covered robotic fish was sent to the Mariana Trench, the deepest point in the Pacific Ocean at 11 km below sea level.



Climate robotics accounted for

less than 1%

of total robotics venture funding over the past five years

ROBOTS FOR CLIMATE

Addressing climate challenges is critically dependent on efforts around climate adaptation, mitigation, and ecological restoration. However, climate robotics accounted for less than 1% of total robotics venture funding over the past five years.[135]

Customising robots to become durable, environmentally friendly, and climate-focused with adequate control systems and sensors,[136] would create economic opportunities and aid in the development of new business models and regulations.[137]

Prototype robotic planting and monitoring systems have been shown to plant trees in desert areas with a survival rate of over 95%.[138] Another example is a robot in solar farm construction tripling panel installation speed and accelerating the energy transition generating twice as much energy within the same footprint as today.[139]

ENHANCING THE SOCIAL IMPACT OF ROBOTS

Collaborative robots (cobots) and social robots are designed to support humans in their work tasks and personal lives. Meant to be helpers and companions, they present psychological and sociological challenges related to their acceptance and appreciation, but also to the sense of loyalty that humans may feel towards them.[131]

The cobot market is still a small part (7.5%) of the whole industrial robot market.[132] Whether cobots are accepted and adopted may be linked to their impact on human stress levels[133] and their ability to promote happiness.[134] It will therefore be important for further research to determine which design features most effectively enhance these outcomes.

The cobot market is still
a small part (7.5%)
of the whole industrial robot market

MEGATREND 9
FUTURE HUMANITY

Human potential is unlimited. With advanced machine intelligence, brain–computer interfaces (BCIs), technological developments 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.

KEY SECTORS THAT MAY BE IMPACTED

Art, Media & Entertainment
Communication Technologies & Systems
Consumer Goods, Services & Retail
Education
Travel & Tourism

KEYWORDS

Brain–Computer Interfaces (BCIs)
Creative Economy
Future of Education and Higher Education
Future of Work
Ideation and Innovation
Mental Health
Personalisation
Self-Realisation
Digital Realities
Sharing Economy

SUSTAINABLE BASE OF THE PYRAMID ENTREPRENEURSHIP

Microloans

have encountered challenges, including unsustainable repayments and difficulties in fostering innovation at the bottom of the pyramid

If entrepreneurship is a pyramid, those at the base are low-income individuals. They engage in entrepreneurial activities for necessity and subsistence – for survival. Efforts towards financial inclusion and microloans have been key to supporting these entrepreneurs.

However, while financial account ownership globally increased from 51% to 76% between 2011 and 2021,[143] microloans have encountered challenges, including unsustainable repayments and difficulties in fostering innovation at the bottom of the pyramid,[144] particularly after the onset of the COVID-19 pandemic.[145]

There is an opportunity to empower entrepreneurs at the base of the pyramid, aiding their transition from mere survival to fully fledged entrepreneurship, leading to both personal and community prosperity. Bridging the digital divide and leveraging digital platforms can help connect entrepreneurs globally with entrepreneurs at the base of the pyramid to jointly offer solutions and opportunities for them to move beyond simply income generation.[146]

EVOLVED UNDERSTANDING OF DIGITAL LITERACY

Technology continues to expand across the globe in many sectors, from education and health to entertainment and sport. Between 2005 and 2023, internet usage rose from 16% of the global population to 67%.[147]

Just as traditional literacy (the ability to read and write in order to acquire knowledge and engage in work and life) is important, digital literacy (the ability to use technology for the same purposes) is increasingly vital for people across the globe.

Over 85% of companies surveyed by the World Economic Forum (WEF) in 2023 identified increased adoption of new and frontier technologies and broadening digital access as the trends most likely to drive transformation in their organisation.[148]

Digital literacy is the seventh most important reskilling focus for the future of jobs between 2023 and 2027.[149] As a result, there is a need to further develop[150] objective methods[151] to evaluate digital literacy beyond self-assessment and to revise existing frameworks to reflect digital literacy's multifaced nature and its influence on work and life, particularly in the context of education and learning.

Internet usage rose from
16% in 2005
of the global population to
67% in 2023

If countries made a combined effort to introduce policy measures aimed at inclusivity, sustainability, and resilience, an additional

32 million jobs

could be created for young people by 2030

CO-CREATION FOR YOUTH EMPLOYMENT

The impact of technology on the future of work will be significant. If countries made a combined effort to introduce policy measures aimed at inclusivity, sustainability, and resilience, an additional 32 million jobs could be created for young people by 2030.[152] In addition, Generation Z are the second most common priority group for the diversity, equity, and inclusion programmes of companies surveyed by the World Economic Forum, with two out of three respondents, on average, identifying young workers as a priority.[153]

Young people can co-create early career strategies with organisations empowered by an innovative co-creation framework that would involve four collaborative stages: generating ideas, designing programmes, implementing them, and collecting and interpreting the data.[154]

MEGATREND 10
ADVANCED HEALTH AND NUTRITION

Progress in advanced machine intelligence, nano- and biotechnology, additive manufacturing, and the IoT will change both what we mean by health and nutrition and how they are experienced. Stemming from the unprecedented developments that will be required to respond to climate change, resource scarcity, and the desire for longevity, this megatrend will improve health in both younger and older people. It will reduce, if not eradicate, some communicable and non-communicable diseases and enhance the sustainable use of and access to water and food.

KEY SECTORS THAT MAY BE IMPACTED

Agriculture & Food
Materials & Biotechnology
Consumer Goods, Services & Retail
Sports
Insurance & Reinsurance
Utilities

KEYWORDS

Additive Manufacturing
Agritech
Cell-Based Manufacturing
Entomophagy
Genomics
Longevity
Nanotechnology
Nutrition
Personalised Medicine
Tissue Engineering
Nanomedicine

DEEP LEARNING TO COMBAT COGNITIVE AGEING

As lifespans continue to increase and the growing global population transitions to older age, understanding healthy cognitive ageing remains important.[168]

Currently more than 55 million people have dementia worldwide and 60% of them live in low- and middle-income countries.[169] Every year there are nearly 10 million new cases globally,[170] and in 2019 the prevalence of dementia was 777 per 100,000 people in the MENA region (3% higher than in 1990).[171]

Further research is needed into the factors that influence healthy cognitive ageing.[172] Machine learning and deep learning algorithms could enhance our ability to predict and manage cognitive decline. Advances in electroencephalography (EEG)[173] and IoT could help to overcome data bias and model validation challenges, and increasing data diversity and validation of approaches used in interpretation will be essential to pave the way for wider clinical adoption.[174]

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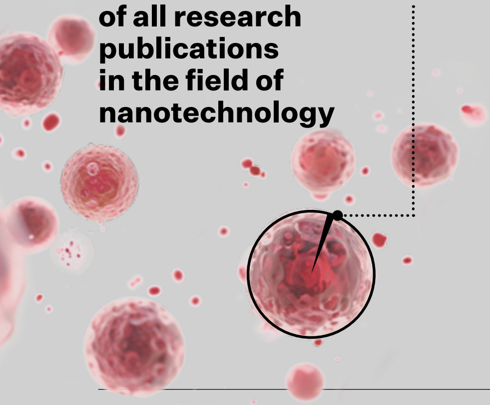
Nanomedicine accounts for

some 5%

of all research publications in the field of nanotechnology



NANONUTRACEUTICALS FOR GUT HEALTH

Nanomedicine accounts for some 5% of all research publications in the field of nanotechnology worldwide.[161]

At the intersection of nutrition and pharmaceuticals sit nutraceuticals, the aim of which is to prevent diseases through nutrients, enhanced food preservation, and improved delivery.[162] Nanotechnology holds potential in this field,[163] enhancing the solubility, stability, and bioavailability[164] of the key active components that make a difference. In this way, and with their antioxidant properties and anti-inflammatory benefits, nutraceuticals can enhance the treatment of chronic diseases such as cancer.[165]

Nanonutraceuticals are showing great promise in the field of gut health. These tiny, food-based materials can change the way conventional probiotics and prebiotics work and, in the future, might even be used to deliver vaccines, gene therapies, and drugs through plant-derived tiny bubbles.[166] While the market for microbiome-based treatments is still in its early days, with forecasts ranging from $115 million in 2021 to over $1 billion by 2030, it is expected to expand into a multi-billion-dollar industry in the future.[167]

DIET CHOICES BY GEOGRAPHY

Alternative food choices, including veganism, have gained popularity worldwide not just as diets but as lifestyle choices encompassing ethical, environmental, and health considerations. This shift, though it may come with some risks, is part of a broader movement to lower the environmental impact of our diets.[155] For example, many meat alternatives have a fifth to less than a tenth of the environmental impact of their meat-based equivalents.[156]

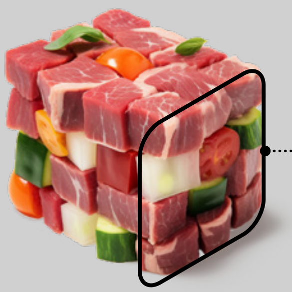
While the main motivations for switching to veganism include ethical concerns (animal rights), health, taste, dietary needs, religious beliefs, and environmental factors,[157] the effectiveness of veganism varies according to economic, demographic, and geographical factors.
For example, in Iceland, adopting veganism may lead to increased crop importation and impact on local industries (such as fishing), challenging the assumption that it is a more sustainable option.[158] In addition, as affordability is important to the global population, on average and per pound, plant-based meat is twice as expensive as beef and more than three times as expensive as chicken.[159]

Although doubling between 2019 and 2022, research on veganism remains limited, and determining the impacts of veganism from ethical, environmental, social, and health perspectives is essential to optimise its impact.[160]

Many meat alternatives have

10%–20%

of the environmental impact of their meat-based equivalents



NAVIGATING THE GLOBAL 50 REPORT

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.

BOX 4

TIPS	
PONDER THE UNKNOWN	Delve into the uncertainties, assumptions, and megatrends and think about the expected and unexpected, the favourable and the unfavourable in your field and sector.
ASSESS THE BALANCE	Reflect on whether greater impact can be derived from leveraging benefits or managing risks.
IMAGINE INNOVATION ACROSS SECTORS	Visualise how opportunities from other sectors might be adapted in yours and brainstorm new opportunities.
ENVISION GLOBAL PARALLELS	Consider communities, cities, nations, and regions around the world that share similar challenges, vulnerabilities, and opportunities to yours. Recognise the global landscape of opportunities and risks.
CONSIDER IMPACTS	Contemplate impacts on your stakeholders and recognise your role in navigating and managing the spill over effects of those impacts.
EMBRACE FLEXIBILITY	Keep an open mind and maintain an adaptable mindset. Be open to changing your perspective in response to evolving circumstances and insights.

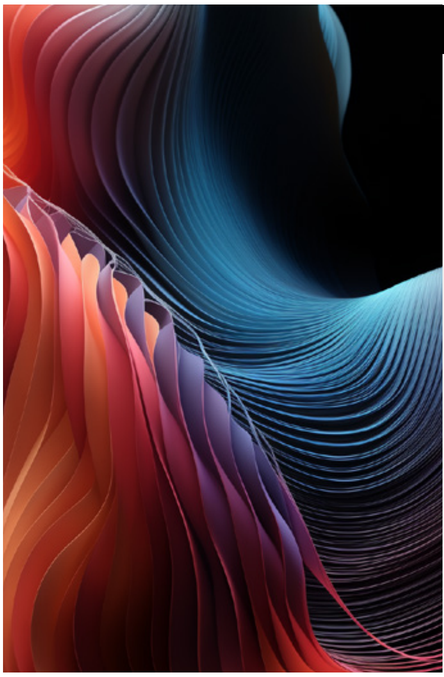
NAVIGATING OUR VIEW OF THE FUTURE

As outlined in the introduction, 'The Global 50' is a blueprint for the future, offering pathways to explore the uncertainties, assumptions, and megatrends and turn them into future opportunities worth pursuing for future growth, prosperity, and well-being.

In an era of quantum shifts (see Box 1), where the future could take many different paths, preparing for what lies ahead requires more than simple contemplation. It is crucial to be resilient: to consciously take action, putting the right systems in place that can comprehensively respond to what comes our way, whether this is expected or unexpected, and plan for a desirable future.[175] At the same time, we must keep an eye on shorter-term trends and signals so as to identify immediate initiatives and ensure our readiness for a range of possible futures.

The uncertainties, assumptions, and megatrends in 'The Global 50' provide a basis from which to start – or a source of reflection if you already have a foresight strategy and future initiatives in place. Alternative futures and views of the future might emerge over time and the exact nature and timing of related changes is uncertain. What is clear is that humanity's core needs and the drive for self-realisation will remain important.[176]

As a result, people are at the centre of our view of the future and it will be important to foresee the opportunities and risks that might emerge in people's everyday lives. Inspired by the guiding principles published by the DFF in 2023,[177] we suggest exploring the following questions (Box 5) when reading our view of the future.



BOX 5

GUIDING PRINCIPLES FOR NAVIGATING THE ERA OF QUANTUM SHIFTS[178]

1. How are **people's expectations** changing and what new risks and opportunities will people face in their daily lives in the era of quantum shifts?
2. Technological progress is hard to predict. However, in addition to drawing on the assumptions in this report, what **technological advances** should we anticipate as potentially playing significant roles in nations' growth and development?
3. Which aspects of the **uncertainties** are we already well equipped to face and which will require new capacities or fresh solutions?
4. Which **global megatrends** and trends could have the most impact on models of work and life? For example, if advances in productivity – through automation or advanced machine intelligence – disrupt employment for large groups in society, what measures could ensure people still feel engaged in and recognised by their community?

NAVIGATING THE OPPORTUNITIES

There is more than one way to imagine the future but 'The Global 50' suggests how a view of the future can be translated into opportunities that can be used to explore what to do today for the benefit of tomorrow.

The opportunities shared in this report are not exhaustive – they present some of the potential pathways to future growth, prosperity, and well-being. They offer possibilities for major advances in our quality of life while raising profound questions for society to resolve. Some opportunities may seem more pertinent than others – some contexts will have the conditions in place to share in the benefits of certain opportunities while others will not. Equally, the risks relating to some opportunities might not be limited to those countries or organisations that can benefit from the opportunities directly: risks often travel faster than benefits.[179]

Numerous approaches, schools of thought, and technologies exist in the domains of ideation and innovative thinking. While we do not necessarily favour one over another, the approach outlined in Box 6 is one way to begin considering the opportunities, depending on your stage in the foresight journey. As such, and in some cases, it might be more beneficial for those in higher education and research centres to explore not just the opportunities but the underlying basic science or foundation research.

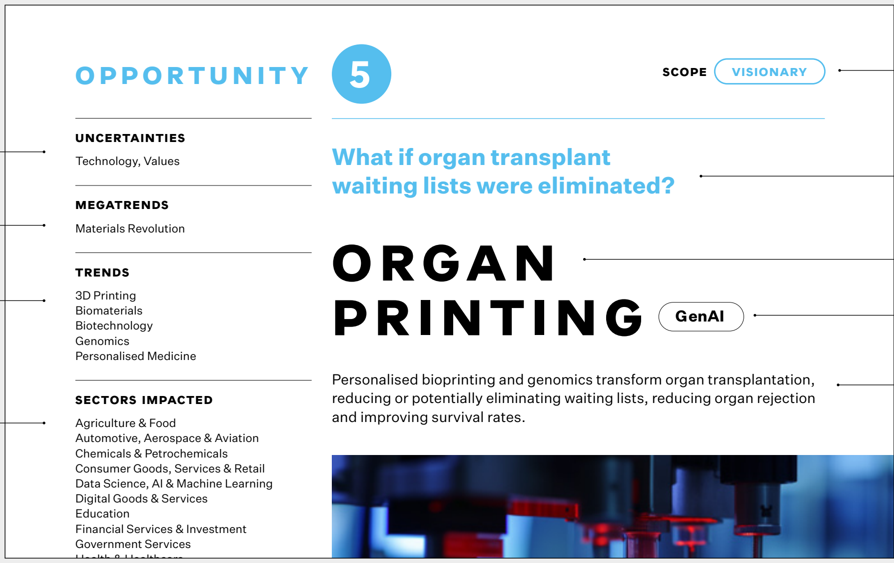
Schematic of the Opportunities

Each opportunity includes a question for the future with a tagline that succinctly covers the most essential aspects of the opportunity, enough to spark curiosity and prompt further questions. Additionally, each opportunity includes the most significant megatrend relevant to it – because of the interrelated nature of the megatrends, some may be more prominent than others at different times.

In this year's edition, we included uncertainties that are most likely to have an impact on the underlying drivers and conditions for the opportunity to materialise. We have also added scope, which provides a general indication of relevance and futures horizon as inspired by Bill Sharpe's Three Horizons framework. Opportunities within reach are likely to be relevant within 2 to 3 years as they address specific challenges. Opportunities labelled as transitional are likely to be relevant within 10 years and tied to advances in technology. Opportunities labelled as visionary are likely to be relevant beyond 10 years either because they depend on technologies that are still in early development or are part of a complex system of drivers and factors.

BOX 6

A GUIDE TO NAVIGATING THE OPPORTUNITIES


OPPORTUNITY 5

SCOPE VISIONARY

UNCERTAINTIES
Technology, Values

MEGATRENDS
Materials Revolution

TRENDS
3D Printing
Biomaterials
Biotechnology
Genomics
Personalised Medicine

SECTORS IMPACTED
Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Financial Services & Investment
Government Services

What if organ transplant waiting lists were eliminated?

ORGAN PRINTING GenAI

Personalised bioprinting and genomics transform organ transplantation, reducing or potentially eliminating waiting lists, reducing organ rejection and improving survival rates.

Uncertainties that impact on the viability of the opportunity

Most significant Megatrend

Areas to look for relevant signals

Sectors that can impact on or be shaped by the opportunity

Scope (futures within reach, transitional, visionary)

Question for the future

Opportunity title

Opportunity inspired by GenAi

Opportunity

REVIEW OPPORTUNITIES

Examine all the opportunities in 'The Global 50' from 2022 to 2024 (150 in total) and categorise them into those that relate to your sector, those that relate to linked sectors, and those unrelated to either.

A. WITHIN YOUR SECTOR

For each opportunity, read the question for the future and the brief description.

Do they align with your country's, city's, organisation's or team's strategic vision, value proposition, purpose, or objectives?

B. LINKED TO YOUR SECTOR

Assess the benefits and risks.

Could they affect your ability to fulfil your strategic vision, value proposition, purpose, or objectives?

C. NOT LINKED TO YOUR SECTOR

Assess the question for the future, can it be adapted to your strategic vision, value proposition, purpose, or objectives?

Ideate

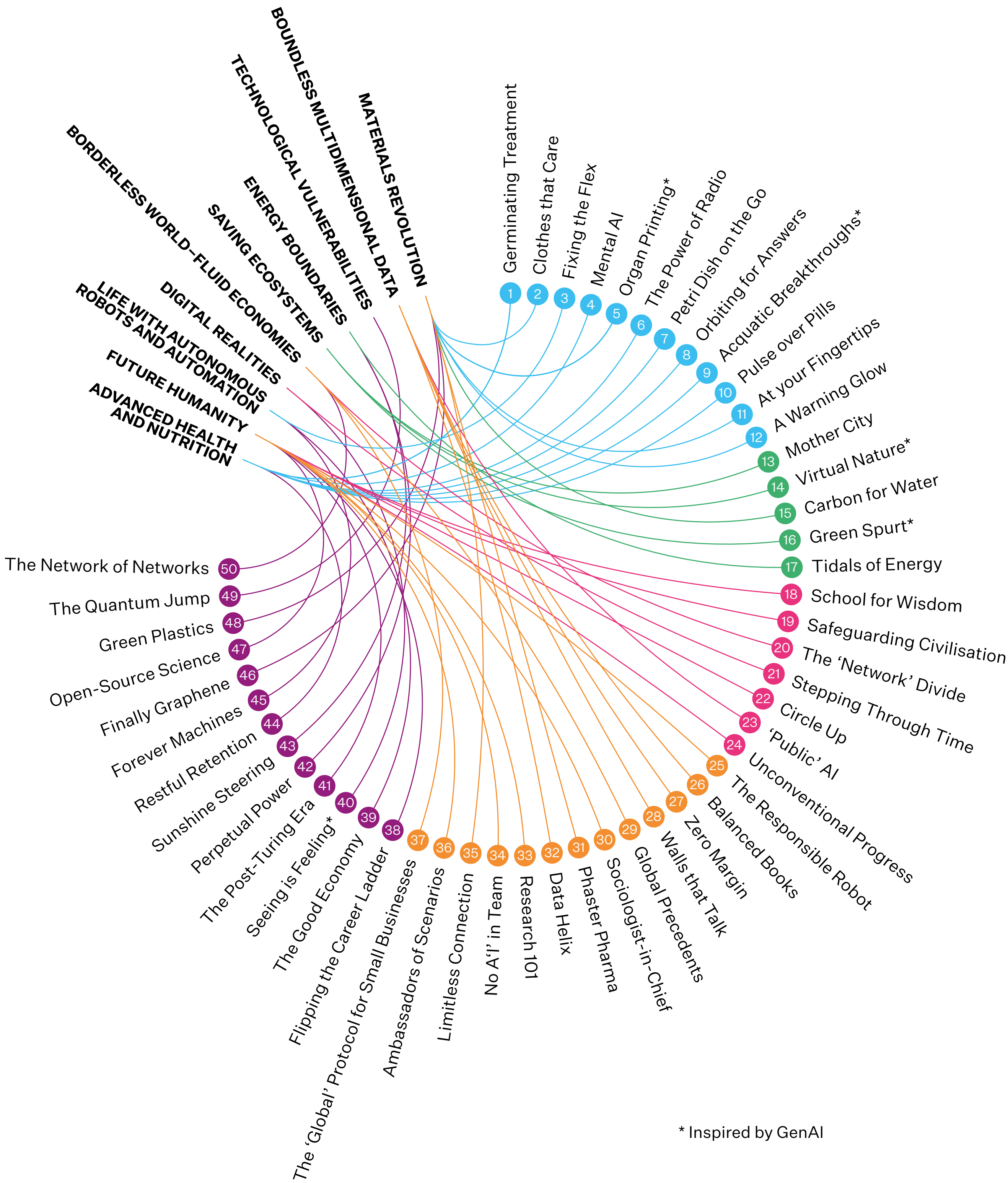
Capture Opportunities

Manage Risks

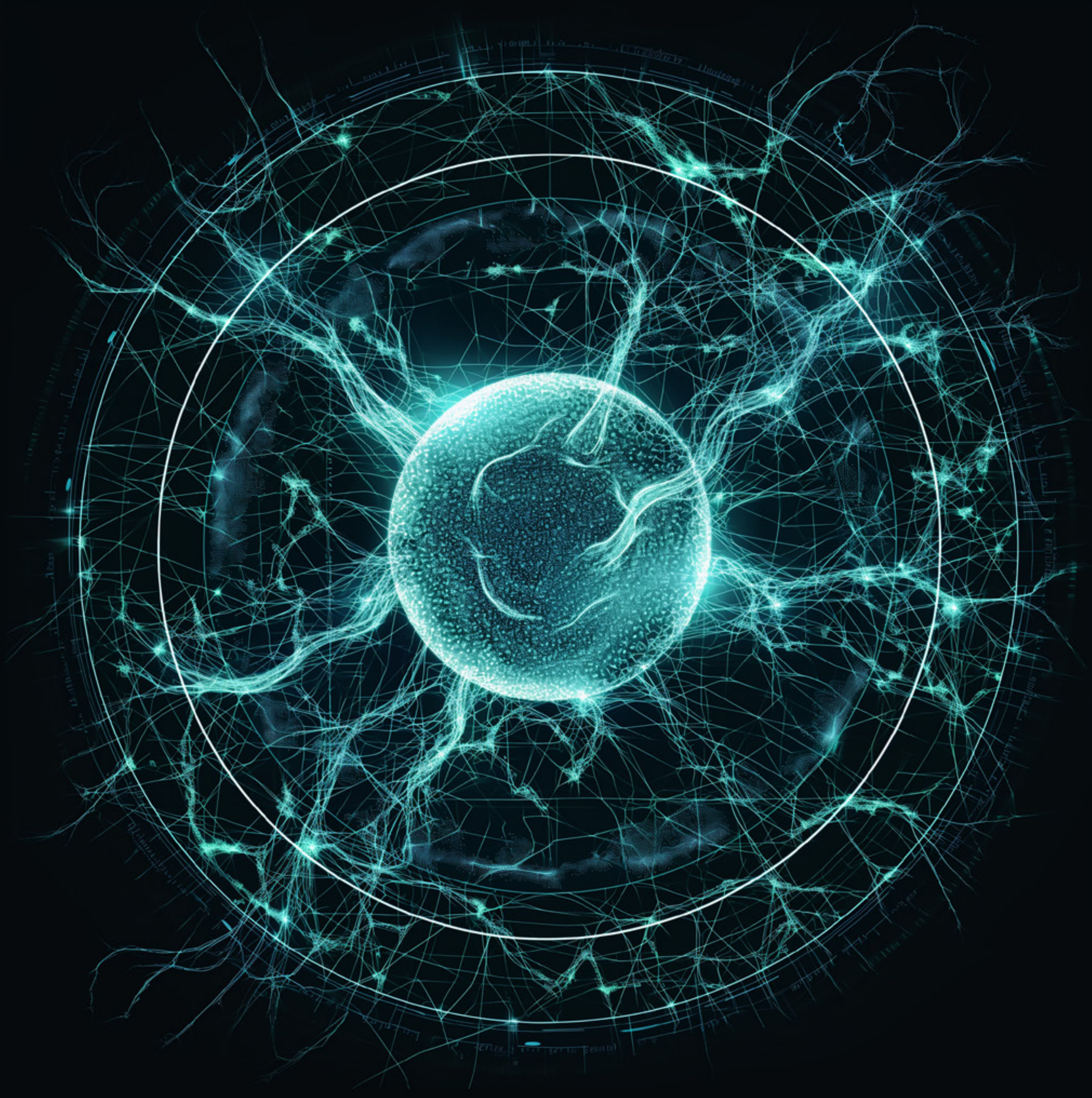
The trends, signals, benefits, risks, and data mentioned within each opportunity are non-exhaustive and were based on information available at hand at the time of publication.

Ideas and content within this report are by the DFF. GenAI was used to aid in 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.

OPPORTUNITIES MAP



* Inspired by GenAI



HEALTH REIMAGINED

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

OPPORTUNITY 1

SCOPE VISIONARY

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Artificial Intelligence
Biotechnology
Genomics
Open Data
Personalised Medicine

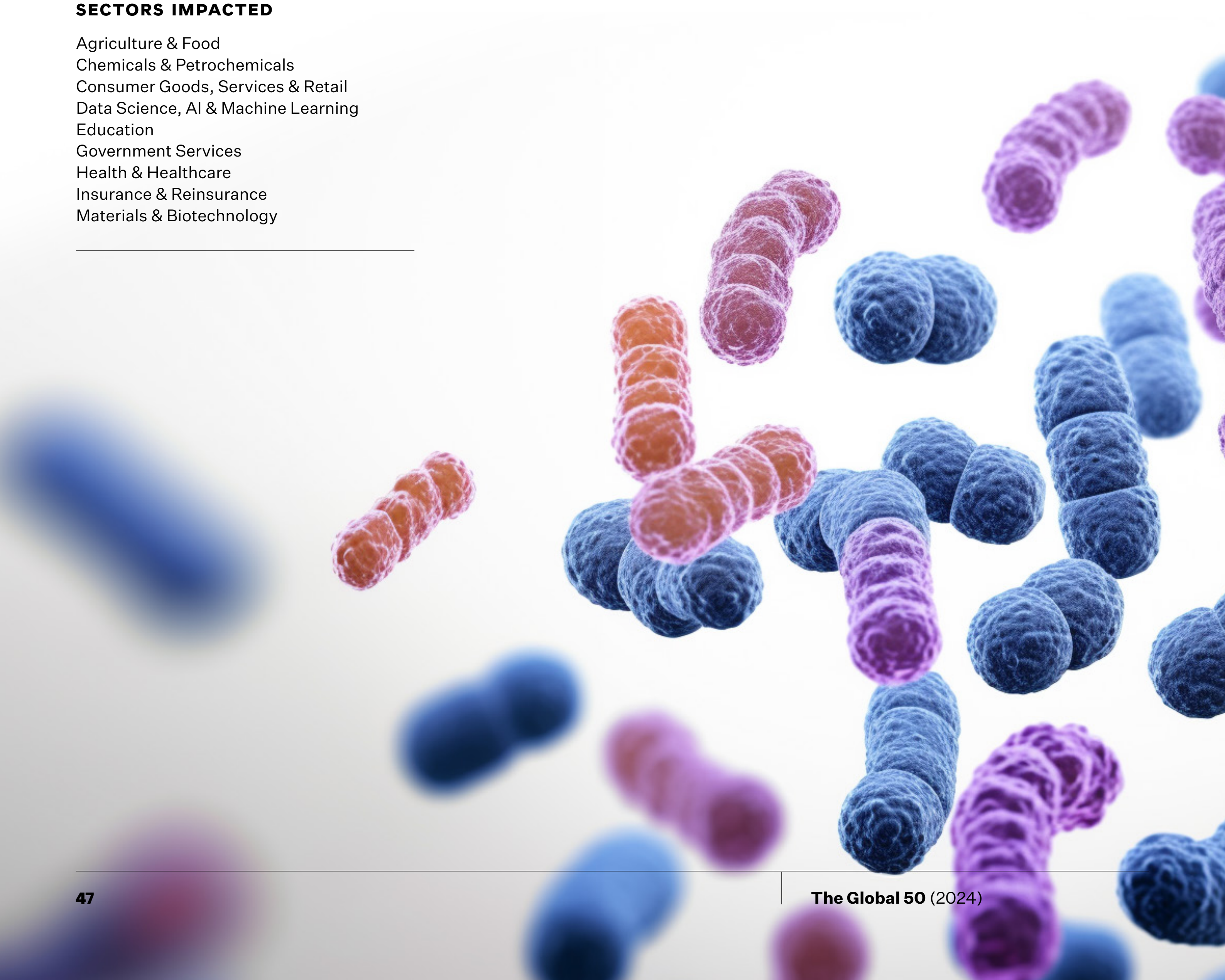
SECTORS IMPACTED

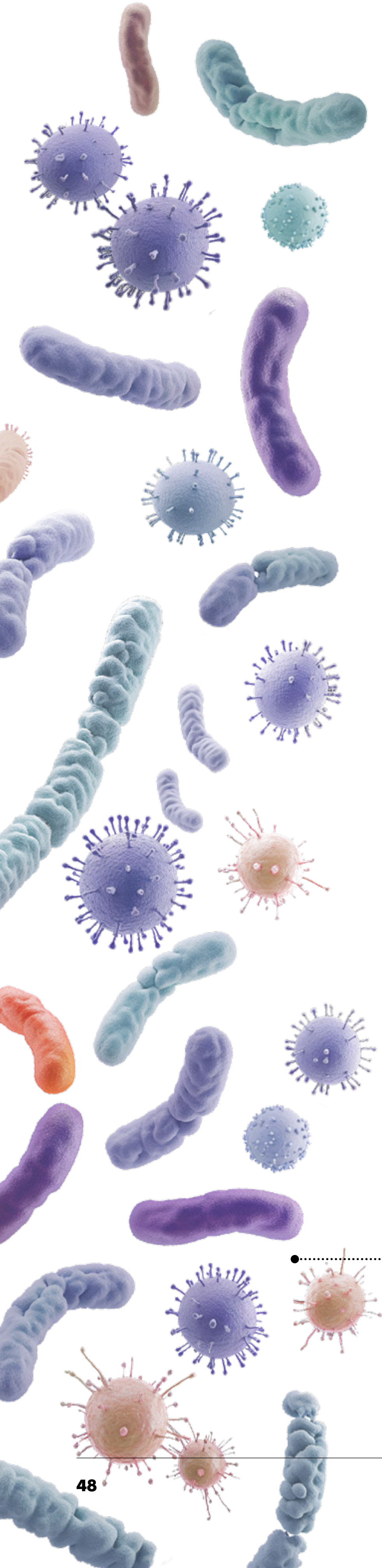
Agriculture & Food
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Education
Government Services
Health & Healthcare
Insurance & Reinsurance
Materials & Biotechnology

What if bacteria was a cure?

GERMINATING TREATMENT

A global databank of bacterial strains from humans and the environment aids personalised treatments and novel therapies for various diseases.





WHY IT MATTERS TODAY

The 2019 landmark Global Burden of Disease Study found that over 10% of deaths worldwide, and nearly 60% of sepsis-related deaths, were caused by only 33 types of bacteria,[180] guiding possible prevention strategies, better antibiotics, and possible vaccines.[181]

Beyond just bacteria, numerous studies highlight the critical role of microbiota in health and disease.[182] Microbiota includes fungi, yeast, and viruses living in various areas in the human body, including the gut, mouth, lungs, and skin.[183] Microbiota tells us a lot of information about how these organisms interact within specific environments and play a role in health and disease.[184] As a diverse ecosystem, microbes interact with various bodily systems, perform essential biological functions, and contribute to metabolic, immunological, and other functions.[185] The composition of the microbiota can protect or harm health and an imbalance could potentially lead to autoimmune diseases, chronic inflammation, diabetes, obesity, atherosclerosis, neurological disorders,[186] cardiovascular diseases, cancers, and respiratory illnesses.[187]

More extensively studied than others, the gut microbiome – which more broadly refers to genetic microbial structures and environmental conditions[188] – is known to comprise trillions of microbiota and to host up to 1,000 bacterial species, each with a unique role, contributing significantly to health or potentially causing disease.[189] A healthy gut microbiome – of which bacteria are the foundation – is important for both physical health and cognitive function and mental well-being.[190] Certain species of intestinal bacteria can synthesise key neurotransmitters, including serotonin,[191] which is a vital regulator of cognitive health (learning and memory), mood stability, and sleep.[192] In addition to studying the interactions with other microbiota, current bacterial mapping efforts for the human gut are already revealing new species of bacteria[193] with the potential for new disease indicators and treatments.[194]

60%

of sepsis-related deaths, are caused by only

33 types of bacteria

OPPORTUNITY

A global bacterial strain databank – including both human samples and bacterial DNA from a network of nanosensors in soils and oceans – would enhance our understanding of the human microbiome and how microorganisms interact with the surrounding environment. Powered by advanced machine intelligence, known and new bacterial strains and their properties would be mapped and modelled to identify potential treatments for chronic illnesses and diseases.[195]

Mapping the unique bacterial make-up of individuals[196] across different geographies, ages, and geno- and pheno-types (genetic and physical features of microorganisms), together with genetic mapping, would enable the development of personalised treatments informed by an individual's unique bacterial and genomic profile, enhancing efficacy and bacterial survival within the body. Bacterial transplants would modify the microbial environment in the human body to restore healthy microbial function and balance, thereby addressing the root cause of some diseases.

BENEFITS

Once identified, bacteria that contribute to improving physical and mental health are cultured (grown) for use in treatments or prevention. Better understanding of bacteria supports personalised nutrition, the development of new antibiotics, and more targeted use of antibacterials.

RISKS

The identification of new bacterial pathogens with the potential to cause harm. Unintended consequences of introducing novel or engineered bacteria into humans.

Gut microbiome – which more broadly refers to genetic microbial structures and environmental conditions – **is known to comprise**

trillions of microbiota and to host up to 1,000 bacterial species

OPPORTUNITY 2

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Materials Revolution

TRENDS

Biomaterials
Longevity & Vitality
Mobilising Innovation
Nanomedicine
Personalised Medicine

SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Government Services
Health & Healthcare
Manufacturing
Materials & Biotechnology

What if clothes kept us healthy?

CLOTHES THAT CARE

Smart fabrics with nanobiomaterials autonomously deliver health-boosting nutrients that meet minimum daily requirements, promote wellness, and address nutritional deficiencies.

WHY IT MATTERS TODAY

In 1912, biochemist Casimir Funk linked diseases like scurvy and rickets to specific vitamin deficiencies.[197] Initially sourced solely from food, vitamins became available as commercial supplements from the 1930s.[198]

Even though vitamins are considered crucial for growth, health, and disease prevention,[199] vitamin deficiency is a significant public health issue in many countries around the world. For example, almost one billion people worldwide have a vitamin D deficiency,[200] even in countries of relative sunshine abundance.[201] Iron, folate, and vitamins B12 and A deficiencies can lead to serious health issues such as anaemia, which affects an estimated 42% of children under five years and 40% of pregnant women globally.[202] Vitamin A deficiency, a leading cause of preventable childhood blindness, also heightens the risk of severe infections that cause diarrhoea or measles, for example.[203]

Wellness clothing[204] and textile coating for wellness[205] are not new. Beyond sustainability and comfort, innovators have, for at least 15 years,[206] been working on infusing clothing with what makes people feel better, from vitamins[207] and collagen[208] to antimicrobials[209] and antioxidants.[210] For example, smart fabrics from Fi Milano claim to allow sunlight to filter through and provide the UVB rays needed to produce vitamin D.[211] Similarly, Textile-Based Delivery states that its fabrics release consistent doses of medicines, vitamins, and supplements, creating laundry-safe, reusable healing garments and textile products.[212] Nevertheless, there are limitations in terms of scope, and research has not validated the effectiveness of some of the products to date[213] or the ability to manage waste in an environmentally friendly way.[214]

One billion

people worldwide have a vitamin D deficiency

OPPORTUNITY

Smart fabrics, made possibile by nanobiomaterials, release nano doses of vitamins and minerals that are subsequently absorbed through the skin to meet minimum daily requirements and promote wellness. These fabrics can also be enhanced through synthetic biology,[215] wearable biosensors,[216] or a combination of both[217] to address nutritional deficiencies to prevent, manage, or even – when safe to do so – reduce the effects of disease treatment.[218]

As metamaterials,[219] these innovative fabrics can adapt to their environment and autonomously make decisions[220] to deliver the needed vitamins and minerals in a personalised way. Blending nanotechnology, biomaterials, and biosensors into clothing or even blankets, for example, could be a solution that can be delivered in places where malnutrition is prevalent.

BENEFITS

Vitamin-infused fabrics using nanobiomaterials offer a scalable, global solution for nutrient delivery that is especially beneficial for those with dietary challenges or specific health conditions and aim to prevent macronutrient deficiencies and associated diseases.

RISKS

Despite advances, the efficacy of this approach is uncertain. Vitamins may degrade over time, particularly with frequent washing of fabrics. There is also a risk of toxicity due to malfunction in sensor technologies or the accumulation of unneeded vitamins.

OPPORTUNITY 3

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Values

MEGATRENDS

Living with Robots and Automation

TRENDS

Advanced Computing
Biomaterials
Longevity & Vitality
Nanomedicine
Personalised Medicine

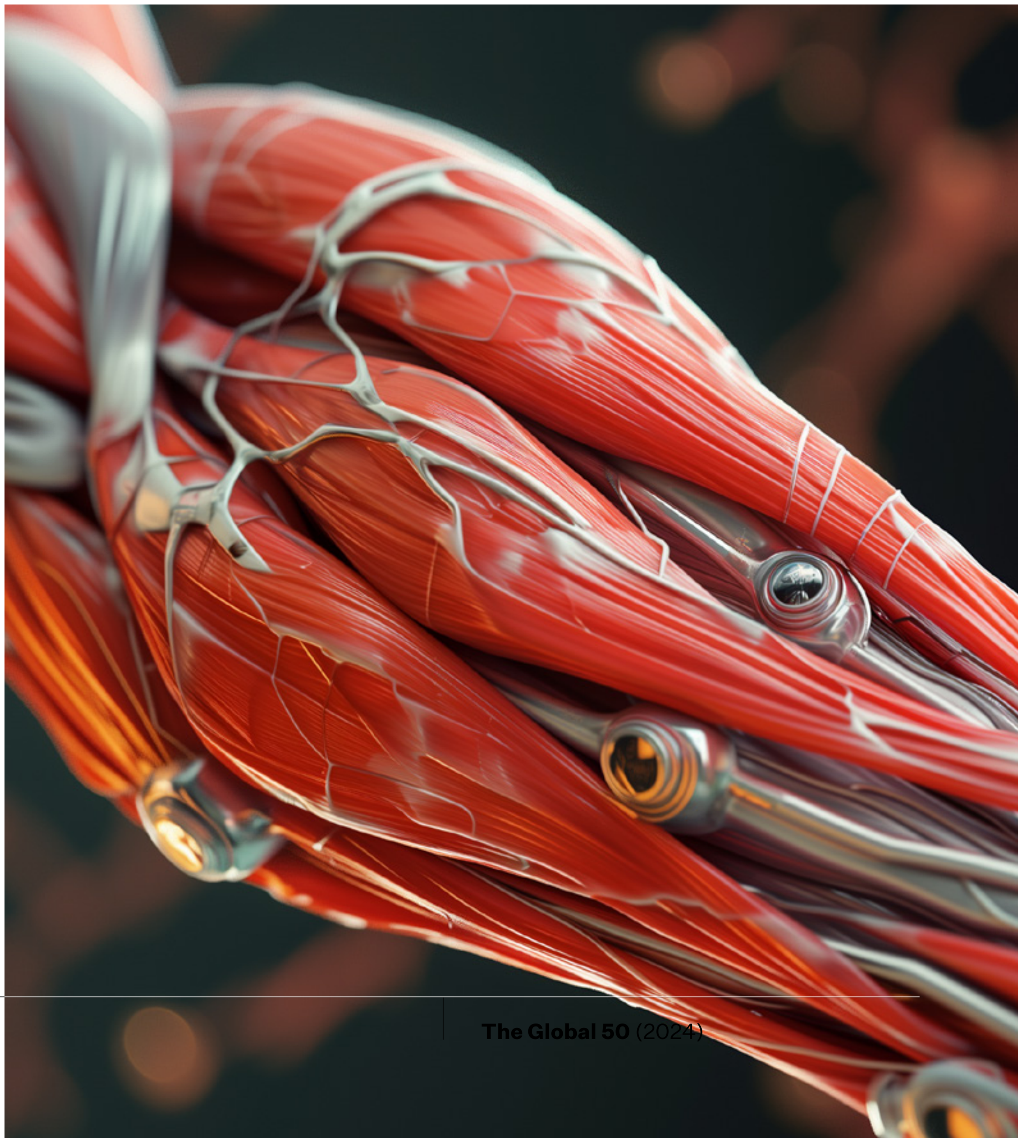
SECTORS IMPACTED

Agriculture & Food
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Financial Services & Investment
Government Services
Health & Healthcare
Insurance & Reinsurance
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Sports
Travel & Tourism

What if we stayed physically strong?

FIXING THE FLEX

Nanobots engineered for muscle repair and regeneration, prevent age-related muscle deterioration and provide targeted therapy for musculoskeletal pain and disease.



WHY IT MATTERS TODAY

As pain often persists into adulthood, musculoskeletal pain in young people can also impact on

future health, education, and employment

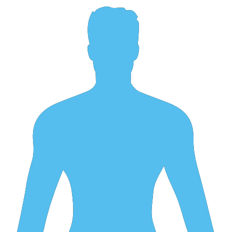
Skeletal muscle composition varies by age, gender, race, and activity levels, making up 40%–50% of body mass.[221] Musculoskeletal pain affects people of any age.[222] Lower back pain alone afflicts 619 million people (nearly 10% of the world's population), a number expected to reach 843 million by 2050.[223]

Persistent musculoskeletal pain affects 40%–60% of older adults, often leading to disability, falls, and cognitive issues, with treatment costs in 2019 estimated to be $300 billion in just the United States.[224] By 2050, the number of people in the world aged 60 and over is expected to double.[225] Musculoskeletal pain will continue to be a key area of concern because, as well as reduced mobility and higher levels of frailty, it can cause depression and dementia among the elderly.[226]

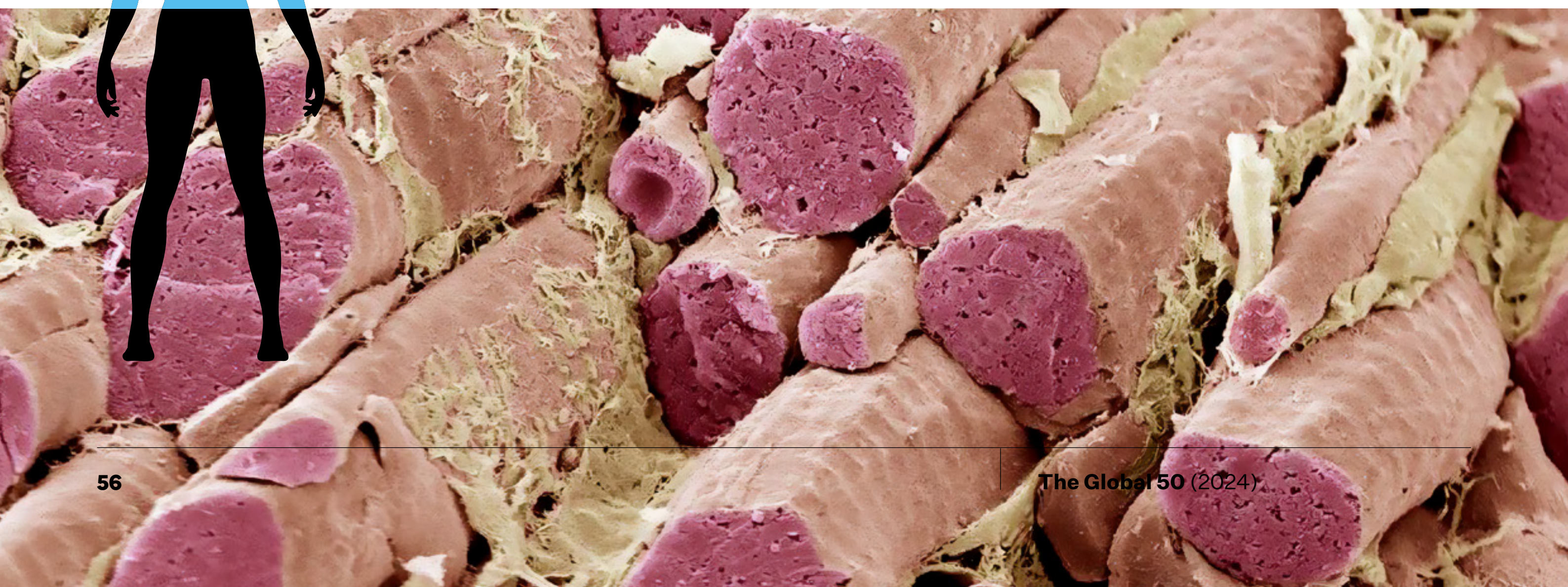
Musculoskeletal pain is also experienced by young people. Associated with more sedentary lifestyles in adolescents,[227] musculoskeletal pain can lead to obesity, cardiovascular disease,[228] psychological impacts, and pain anxiety.[229] As pain often persists into adulthood, it can also impact on future health, education, and employment.[230] A 2007 study in the United Kingdom indicated that 22% of children aged 11–14 experienced lower back pain,[231] and in a 2019 study in Poland nearly 56% of 10- to 19-year-old children experienced lower back pain and 74% back pain in general.[232] Data from 2019 in Portugal[233] showed that prevalence increased with age (aged 9 to 19)[234] and common causes included heavy lifting, carrying backpacks, and prolonged sitting (70.7%, 67.4%, 67.8%).[235]

Skeletal muscle composition varies by age, gender, race, and activity levels, making up

40%–50% of body mass



While real-world clinical applications of nanobots have been limited, they have been piloted in vaccine development[236] and cancer treatment and diagnoses.[237] Nanobots are tiny robots of nanoscale size (100nm or less)[238] that are programmed to convert energy into mechanical forces to fulfil a specific task. As part of nanomedicine, nanobots can be used for diagnoses and treatment.[239]



OPPORTUNITY

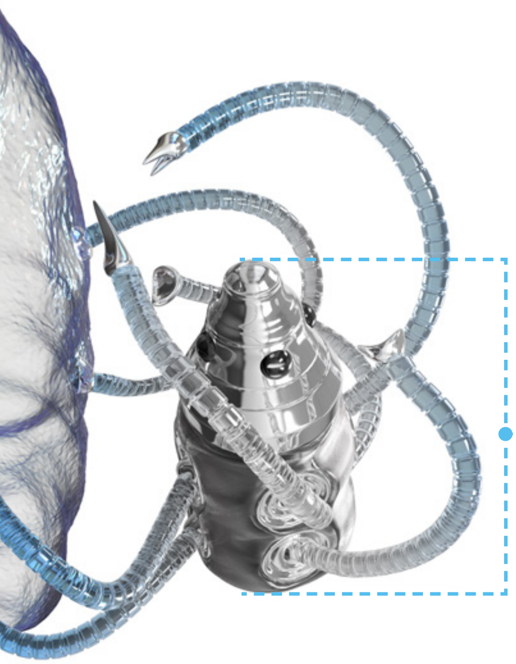
Nanobots are engineered to interact with cells for muscle restoration, repair, or regeneration of muscle damaged or lost because of injury or age-related deterioration. This may include electrical muscle stimulation,[240] muscle stem cell activation,[241] conductive hydrogels,[242] and, although with mixed results, targeted delivery of platelet-rich plasma[243] or platelet-rich fibrin.[244] With further advances in genomics, personalised medicine, and nanotechnology-based therapies,[245] nanobots can one day be used to prevent muscle deterioration and to slow ageing in the first place, preserving life-long mobility and strength, making sarcopenia[246] – a reduction in muscle mass and functionality – a thing of the past.

BENEFITS

Preserving and restoring muscle strength contributes to overall levels of fitness and well-being. Across all age groups, nanobots can help prevent disability and loss of quality of life, potential earnings, and productivity.

RISKS

Nanobots meant to repair or preserve muscles may inadvertently affect other organs and biological systems, increasing, for example, cardiovascular risks. Lower efficacy might be due to lack of understanding of the interaction of nanoparticles with cells, considering factors like age and gender.



Nanobots are tiny robots of
nanoscale size
(100nm or less)

OPPORTUNITY 4

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Values

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Artificial Intelligence
Cross-sectoral Partnerships
HealthTech
Mental Health
Mobilising Innovation

SECTORS IMPACTED

Communication Technologies & Systems
Data Science, AI & Machine Learning
Digital Goods & Services
Government Services
Health & Healthcare
Insurance & Reinsurance
Professional Services

What if AI in mental health was empathetic and culturally informed?

MENTAL AI

Multidisciplinary teams advance AI in mental health through benchmark datasets that incorporate empathy and diverse cultural perspectives, laying the foundation for toolkits for AI in mental health and algorithm validation.

WHY IT MATTERS TODAY

Globally,

1 in 8

individuals have a mental health disorder

including

1 in 5

adolescents

In 2001, it was estimated that a quarter of the world's population would experience mental or neurological disorders during their lifetime.[247] By 2023, that estimation doubled to half the world's population.[248] Despite this increase, only 2.1% of government health expenditure is allocated to mental health,[249] limiting access to affordable mental health services,[250] a situation made worse by people's reluctance to seek help because of stigma and perceived discrimination.[251]

Globally, one in eight individuals have a mental health disorder.[252] This includes one in five adolescents,[253] influenced by various social, familial, and individual factors and whose developing brains are particularly vulnerable to external influences like violence, poverty, stigma, and technology use.[254] Untreated, these mental health conditions often continue into adulthood.[255]

Telehealth, introduced in the 1990s, has been valuable in treating depression and anxiety.[256] The COVID-19 pandemic shifted 36% of mental health treatments to telehealth, leading to increased investments and associated regulatory changes[257] despite challenges such as quality of care and therapist shortages.[258]

AI in mental health is a promising area of advancement,[259] potentially disseminating high-quality clinical knowledge worldwide, facilitating cross-cultural psychiatry, improving global mental health,[260] and advancing diagnostics, data analysis, and patient monitoring.[261] The future of mental health could see AI and human practitioners working together, leveraging AI's efficiency and the empathy of humans.[262]

Today, examples of AI in mental health include applications that use natural language processing to detect changes in language that correlate with mental health issues and chatbots – such as Woebot – that adapt to user personalities and can talk users through a variety of therapies and talking exercises.[263] Generative AI (GenAI) has also been used in mental health counselling but the focus has been on ensuring that outputs are grammatically and syntactically correct,[264] and responses still lack the necessary depth of understanding and counselling.[265]

OPPORTUNITY

A multidisciplinary team of AI researchers, clinical psychologists, software developers, and data scientists work on designing benchmark datasets[266] with empirical analysis, solid theoretical underpinnings, and experiences in clinical psychology that also integrate diverse cultural perspectives.[267] These datasets lay the groundwork for the application of a universal toolkit for AI in mental health enhancing mental healthcare globally across different cultures and cultural world views beyond the biases of the developers or the training data for the models.[268]

BENEFITS

Enhanced validation and assessment of AI in mental health improving access, and assurance, to good quality services in mental health.

RISKS

Overusing AI for mental health leads to loss of aspects of human interactions considered core components of mental healthcare provision, such as empathy and trust.[269] Despite validation, solutions for AI in mental health do not deliver on expected benefits, with humans outperforming AI in diagnosis and treatment.[270] Reliance on a limited amount of objective data and on retrospective studies[271] fails to meaningfully advance AI in mental health and reflect the complexity of mental disorders. Potential risk for privacy breaches and data security.

AI in mental health
is a promising area of advancement,
potentially disseminating high-quality clinical knowledge worldwide, facilitating cross-cultural psychiatry, improving global mental health, and advancing diagnostics, data analysis, and patient monitoring

Estimate of the percentage of the world population that would **experience mental or neurogical disorders during their lifetime**

25% 2023

50% 2100

OPPORTUNITY 5

SCOPE VISIONARY

UNCERTAINTIES

Technology, Values

MEGATRENDS

Materials Revolution

TRENDS

3D Printing
Biomaterials
Biotechnology
Genomics
Personalised Medicine

SECTORS IMPACTED

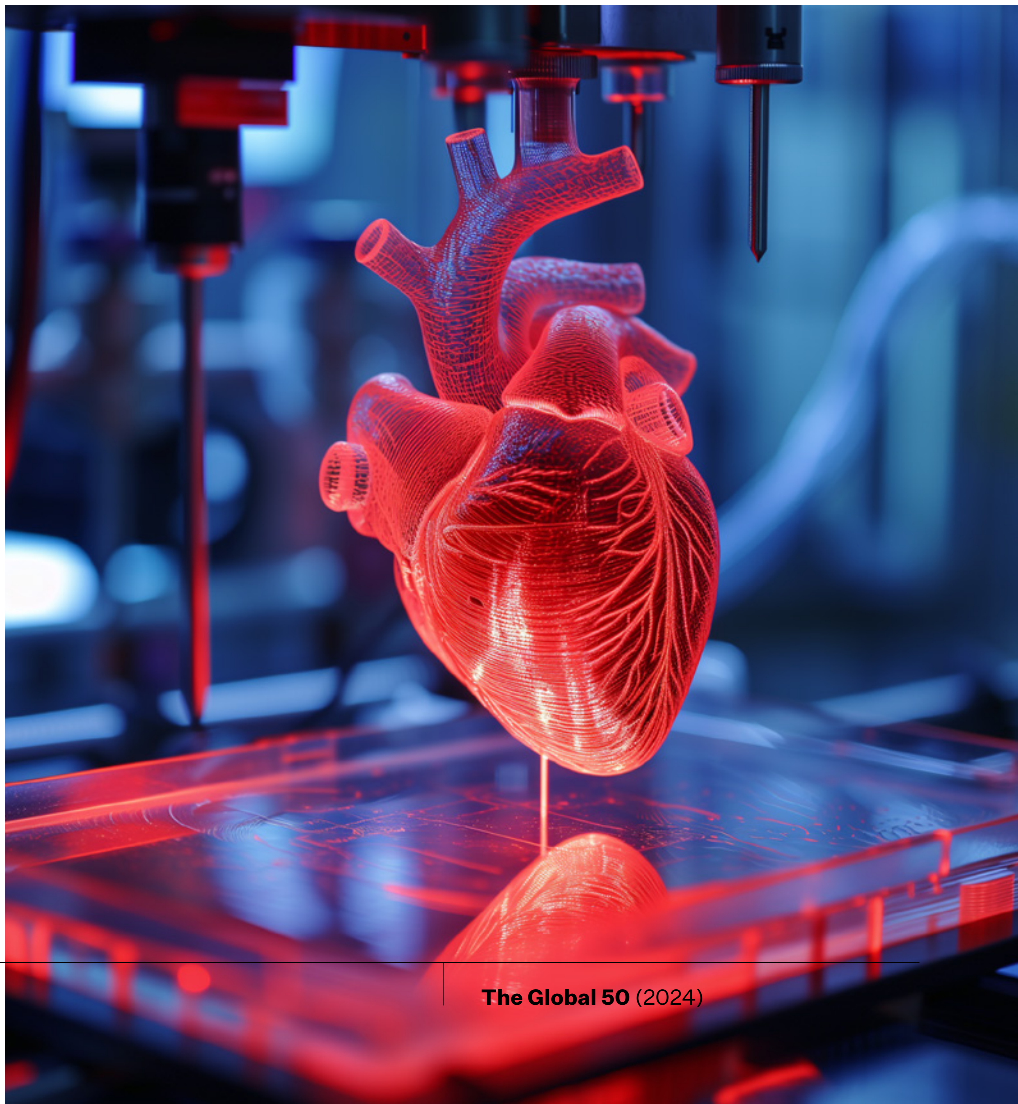
Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Financial Services & Investment
Government Services
Health & Healthcare
Infrastructure & Construction
Insurance & Reinsurance
Materials & Biotechnology
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if organ transplant waiting lists were eliminated?

ORGAN PRINTING

GenAI

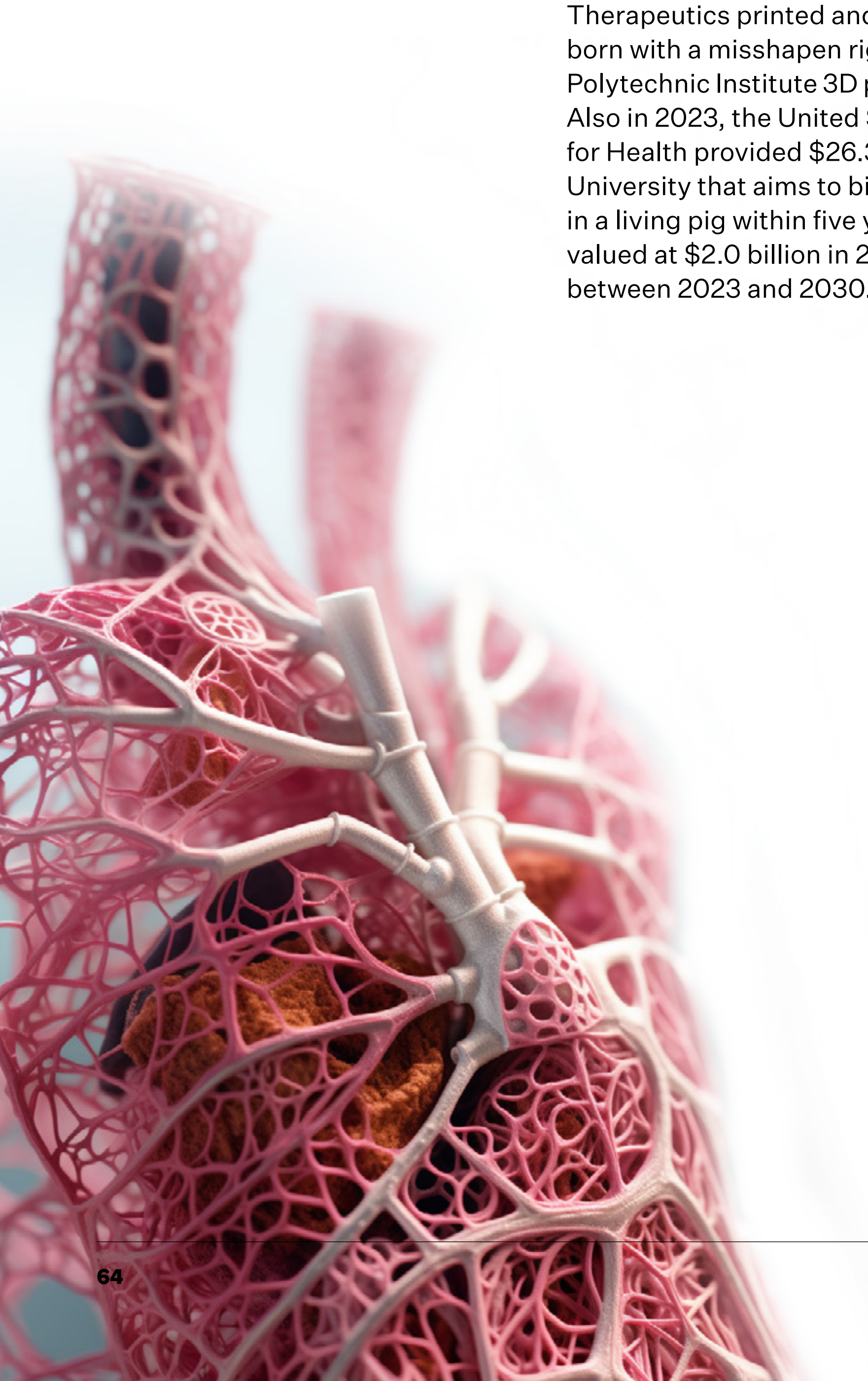
Personalised bioprinting and genomics transform organ transplantation, reducing or potentially eliminating waiting lists, reducing organ rejection, and improving survival rates.



WHY IT MATTERS TODAY

There is a critical organ donor shortage globally. In the United States alone, there are over 100,000 people on organ transplant waiting lists.[272] Seventeen of those people die every day while awaiting a transplant.[273] In 2022, 157,494 organs were transplanted worldwide, an 9.1% increase compared with 2021.[274] Only 3 in 1,000 people die in a way that allows deceased organ donation,[275] and organ rejection affects 10% of recipients.[276]

Amidst increasing demand for organ donations, global recognition of the prospects of bioprinting – patterning and assembling biological materials to fulfil a biological function – is increasing.[277] In 2022, 3DBio Therapeutics printed and transplanted a 3D printed ear for a woman born with a misshapen right ear.[278] In 2023, researchers at Rensselaer Polytechnic Institute 3D printed hair follicles in lab-cultured human skin.[279] Also in 2023, the United States' Advanced Research Projects Agency for Health provided $26.3 million in funding to a project at Stanford University that aims to bioprint a working human heart and implant it in a living pig within five years.[280] The global 3D bioprinting market was valued at $2.0 billion in 2022 and is forecast to grow at a CAGR of 12.5% between 2023 and 2030.[281]



OPPORTUNITY

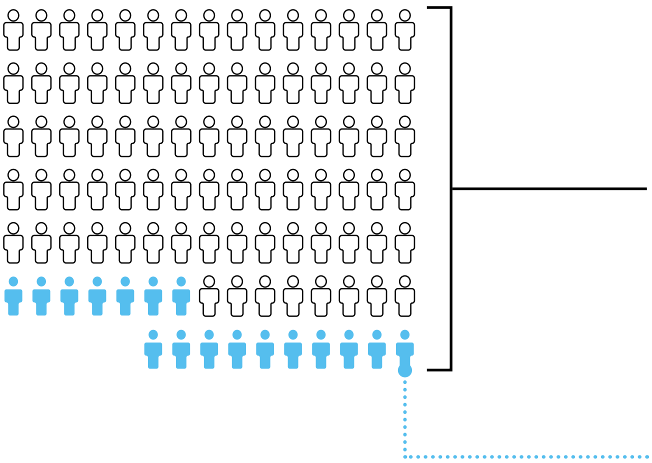
Personalised bioprinting transforms organ and tissue transplantation, reducing or eliminating transplant waiting lists and rejection risk. People in need of an organ donation can receive a 3D bioprinted transplant almost immediately, decreasing their risk of mortality and increasing their long-term health and quality of life. Powered by genomics, 3D printed patient-identical tissues could be used to restore retinal health, repair heart muscle, and treat burns, significantly improving patient outcomes.

BENEFITS

Those in need of transplants will no longer be dependent on organ donations or require anti-rejection treatment for the rest of their lives. Quality of life will increase throughout society as new solutions to organ- and tissue-related medical challenges are discovered.

RISKS

There may be unforeseen long-term health effects of personalised bioprinting. The technology may also be medically or ethically misused to manipulate human physical capacities.



In the United States alone, there are

over 100,000

people on organ transplant waiting lists.

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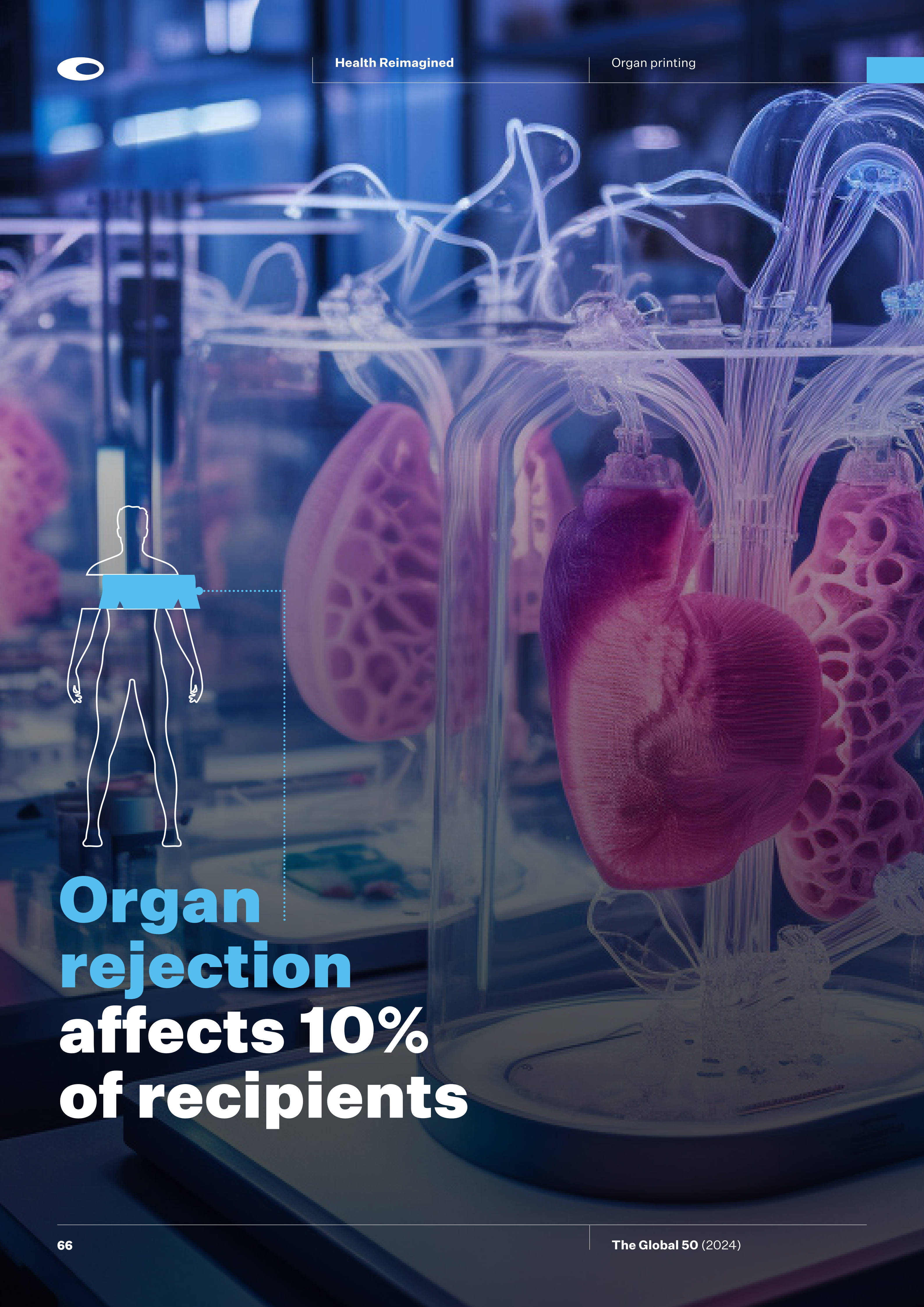
die every day while awaiting a transplant



Organ rejection affects 10% of recipients

OPPORTUNITY 6

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Values

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Artificial Intelligence
Genomics
Human–Machine
Personalised Medicine
Sensor Technologies

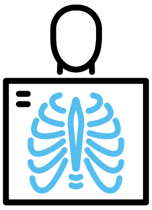
SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Financial Services & Investment
Government Services
Health & Healthcare
Insurance & Reinsurance
Materials & Biotechnology
Professional Services

What if the future of radiology was personalised?

THE POWER OF RADIO

Advances in imaging, genomics, and advanced machine intelligence enable personalised radiology, improving diagnoses, treatment, and public health policies on communicable and non-communicable diseases.



Radiology is set to be at the forefront of new avenues

for integrated diagnosis (the integration of radiology, pathology, and genetics)

WHY IT MATTERS TODAY

Global deaths from chronic diseases increased from 67% in 2010 to 74% in 2019,[282] and the World Health Organization projects that chronic diseases will cause 86% of deaths annually by 2050.[283] Effective prevention and management are crucial for enhancing health.

Medical imaging involves creating visual representations of the human body's structure and function.[284] It encompasses various technologies, such as X-ray, computed tomography (CT), magnetic resonance imaging, positron emission tomography, and ultrasound, essential for diagnosing and treating diseases.[285] While not all techniques – electroencephalogram and electrocardiogram, for example – create images, they all provide valuable data.[286] The worldwide market for diagnostic imaging was estimated to have had a value of $36.5 billion in 2023 with a CAGR of 4.2% between 2023 and 2033 forecast.[287]

The rise in chronic disease, together with lifestyle changes and ageing populations, has increased the demand for imaging examinations.[288] The global population aged 65 and over is expected to more than double by 2050, increasing from 761 million in 2021 to 1.6 billion.[289] However, there is a global shortfall in radiologists as well as limited training capacity, burnout, and gaps in subspecialisation.[290]

While still emerging, AI is expected to play a key role in radiology as in all other areas of medicine. For example, AI systems developed at the University of Adelaide can analyse CT scans to predict patients' probability of dying within the next five years. Trained on a sample of 16,000 images, the systems have been 69% accurate.[291]
A survey among European Society of Radiology's members shows that 67% of radiologists are already incorporating AI in clinical practice.[292]

With full sequencing of the human genome in 2022,[293] the expected proliferation of genomic data,[294] and the anticipated rapid growth of AI in the healthcare market (CAGR of 36.4% between 2024 and 2030),[295] radiology is set to be at the forefront of new avenues for integrated diagnosis (the integration of radiology, pathology, and genetics).[296]

OPPORTUNITY

Besides better imaging technologies driven by advances in diagnostic imaging techniques (X-ray, CT, ultrasound, etc.),[297] camera technologies,[298] and nanotechnology and evidenced in neuroimaging,[299] the integration of imaging data, genetic information, and advanced machine learning[300] allows personalised radiology to provide detailed insights into an individual's health. This integration improves the accuracy of diagnosis and treatment, and enables better public health policies and efficiencies of scale and scope, from symptoms to diagnosis.

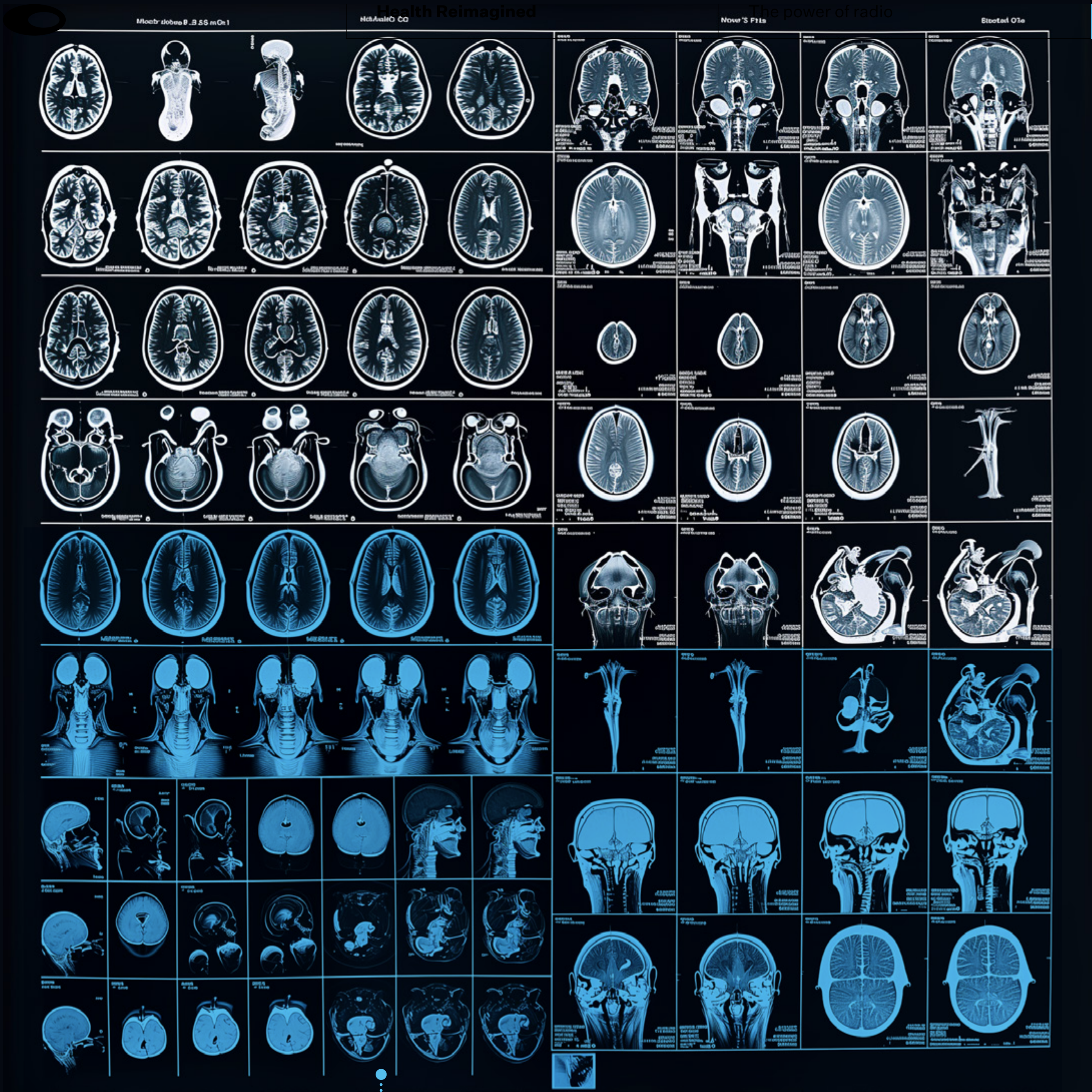
The integration eventually leads to the automation of reporting, highlighting key aspects for further analysis and shifting the radiologists' main focus from reading images and extracting anomalies to analysing anomalies and making connections, supporting clinical decisions.

BENEFITS

Personalised radiology improves treatment, facilitates the development of improved public health policies, and allows greater efficiencies in the process of diagnosis.

RISKS

Besides the usual concerns regarding data privacy and confidentiality in healthcare, over-reliance on advanced machine learning could overlook exceptions and anomalies, potentially increasing health risks for patients. Moreover, the complexity of combining high-quality medical images with genetic markers and information might restrict implementation and benefits to wealthier nations.



A survey among European Society of Radiology’s members shows that

67% of radiologists are already incorporating AI in clinical practice

OPPORTUNITY 7

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Collaboration

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Artificial Intelligence
Biotechnology
Mobilising Innovation
Nanotechnology
Sensor Technologies

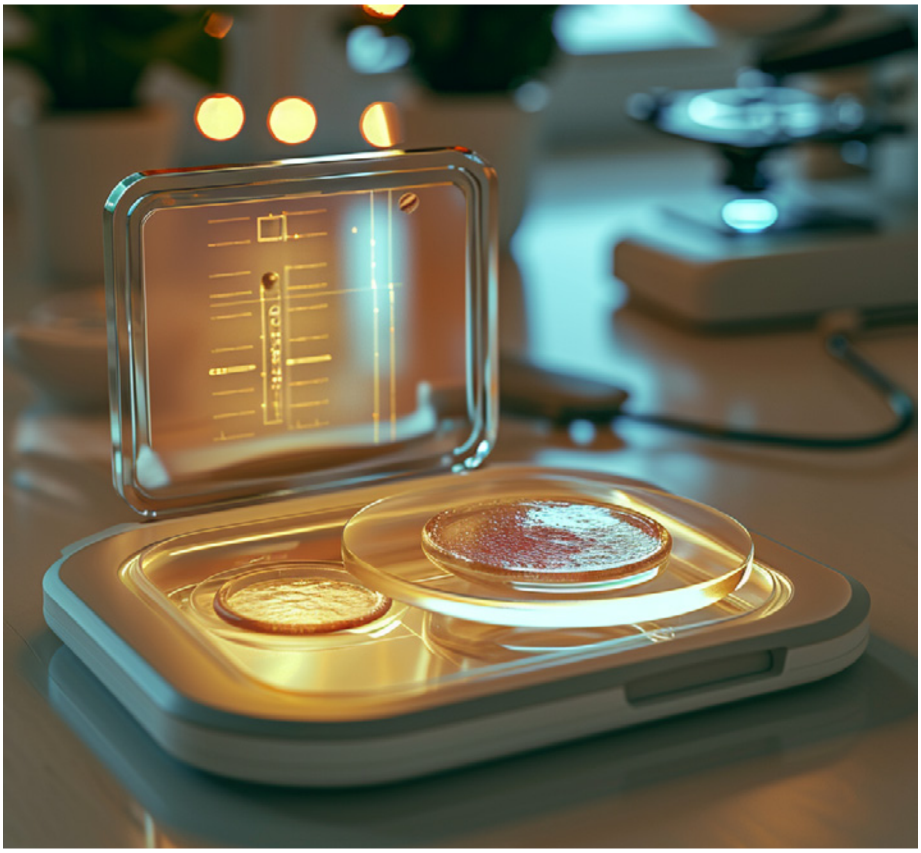
SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Health & Healthcare
Manufacturing
Materials & Biotechnology

What if we knew about infections in seconds?

PETRI DISH ON THE GO

Portable devices and advanced nanotechnology allow real-time identification of bacteria, enabling more precise and timely treatment and the bypassing of lengthy bacterial culture tests.

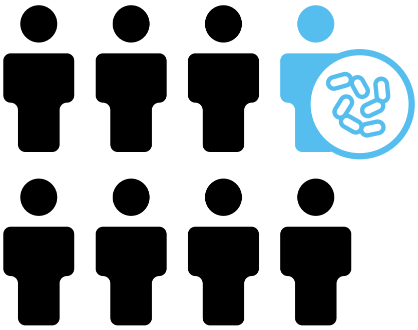


WHY IT MATTERS TODAY

Although they have saved millions of lives, the overuse and misuse of antibiotics in humans and animals have given rise to antimicrobial-resistant strains of bacteria.[301] Recent global estimates put deaths related to antimicrobial resistance at 1.27 million in 2019, with a further 4.95 million indirect deaths.[302] Bacterial infections, both antimicrobial susceptible and resistant, cause 1 in 8 deaths worldwide annually, the second leading cause of death after ischaemic heart disease.[303] Over half of those deaths were due to five types of bacteria, including Staphylococcus aureus, Escherichia coli, and Streptococcus pneumoniae.[304]

To accurately identify the bacteria causing an infection, a culture test is usually conducted through a sample or swab taken from the throat, nose, urine, phlegm, blood, stool, or wound.[305] The key to a bacterial culture test is that a substantial number of bacterial cells are needed, which most initial samples lack.[306] Thus, these samples are cultivated in a laboratory for one to five days or more until sufficient cells are grown for testing.[307] Samples cultivated for tuberculosis typically take 40 days.[308]

Besides delayed diagnosis because of testing, 47% of the global population have little or no access to diagnostics for infectious or communicable diseases.[309] There is a need to improve the quality of laboratory testing accuracy,[310] particularly in medium- to low-income countries, and to reduce turnaround times in efforts to resolve antimicrobial resistance and reduce deaths due to infections.[311]



Bacteria causes 1 in 8 deaths worldwide annually

OPPORTUNITY

Portable devices enable the immediate and precise identification of bacterial strains without the need for long culture testing and growth. Miniaturisation, advanced computing, and advanced machine intelligence with access to a global microbiome database make real-time identification of bacterial infection and treatment strategies a possibility.

While approaches may differ depending on where the infection is present,[312] there are some advances that hold promise. Molecular diagnostics are meant to provide faster, more sensitive alternatives to traditional culture tests at the molecular level, i.e. DNA, RNA, or proteins recently illustrated in polymerase chain reaction (PCR) testing during the COVID-19 pandemic.[313] A next-generation Raman (spectroscopy) microscope[314] also holds promise in picking up different biological markers on cells and tissues,[315] and inkjet printing technology has inspired a new technique whereby the light reflecting from bacterial cells in dots of blood is isolated and amplified by nanotechnology, allowing, by machine learning, identification of bacteria from the spectra.[316]

BENEFITS

Affordable, portable testing devices improve healthcare in lower-income and remote areas. Rapid diagnosis reduces the costs and negative impacts of unnecessary antibiotic treatments, limiting the spread of antimicrobial-resistant strains and contributing to improved global health outcomes.

RISKS

Increased ease of testing, without corresponding advances in antibiotic development, results in the broader use of a variety of antibiotics, which in turn leads to more prevalent antimicrobial resistance. Misdiagnoses result from false-positive or false-negative test results, i.e. type I or type II errors.

47%

of the global population have little or no access to diagnostics for infectious or communicable disease

OPPORTUNITY 8

SCOPE WITHIN REACH

UNCERTAINTIES

Values, Collaboration

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Cross-sectoral Partnerships
Future of Space
International Collaboration
Longevity & Vitality
Mental Health

SECTORS IMPACTED

Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Government Services
Health & Healthcare
Immersive Technologies
Insurance & Reinsurance
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Travel & Tourism
Utilities

What if we used lessons from space to better handle loneliness on Earth?

ORBITING FOR ANSWERS

A global consortium of interdisciplinary experts – academics, clinical psychologists, space psychologists, and neuroscientists – bridge insights from astronaut isolation and space habitat studies to enhance understanding and management of loneliness on Earth, contributing to mental healthcare advances on Earth.

WHY IT MATTERS TODAY

Loneliness negatively affects well-being

and is associated with an increased risk of various health issues

Loneliness negatively affects well-being[317] and is associated with an increased risk of various health issues, such as deteriorating heart health, dementia, and early death.[318]

While loneliness and social isolation rates differ globally and across racial, ethnic, and social groups, they are of concern.[319] In adolescents, Southeast Asia reports the lowest rates,[320] while the eastern Mediterranean has the highest rates. Eastern Europeans experience more loneliness than people from northern Europe.[321] In Australia, 34% of adults are lonely and in the United States, 43% lack companionship, feel their relationships lack meaning, or feel isolated.[322]

Emotional regulation, along with preventing and managing depression and anxiety, is critical for astronaut mental health and mission success.[323] Isolation and monotony in space, coupled with a confined environment, pose risks to astronauts' well-being leading to symptoms like fatigue and sleep disturbance; spacecraft features, including light, noise, and temperature, also impact on mental health.[324] NASA's Human Research Program lists seven aspects vital for optimal psychological health and assists astronauts in managing stress and challenging scenarios.[325] Its extended research and technology development impacts on both mission success and astronauts' health post-mission.[326]

From the artificial intelligence tool iVOICE from the Centre for Space Medicine at University College London, which detects astronaut fatigue, to a toolkit for space psychologists that uses strategies from various isolated professions to combat loneliness and stress,[327] tackling loneliness in space is vital before, during, and after space missions. Efforts are already underway to simulate and study life during a Mars mission through NASA's Crew Health and Performance Exploration Analog habitat.[328]

OPPORTUNITY

The field of aerospace research has the potential to usher in a new frontier in the realm of mental health advances. A global consortium for space–Earth loneliness research, composed of an interdisciplinary group of academic researchers, clinical psychologists, space psychologists, and neuroscientists, could expand understanding of loneliness by bridging research on loneliness in space and on Earth.

Researchers unpack the experiences of astronauts enduring prolonged periods of isolation on the International Space Station and during space travel,[329] cross-examining them with environmental factors like noise, lighting, air quality, nature, privacy,[330] social interactions, and other factors that contribute to issues such as anxiety, depression, and stress, which are already well documented on Earth.[331] This would offer insights into managing loneliness on Earth. For example, resilience-building exercises that astronauts use to withstand the psychological pressures of space, such as stress management techniques and cognitive-behavioural strategies, could be integrated into mental health practitioners' treatment efforts.

BENEFITS

Integrating mental health insights from space exploration with research on Earth innovatively addresses loneliness, enhancing social cohesion and boosting productivity and well-being.

RISKS

Translating space-based mental health solutions to Earth's varied cultural, social, and economic settings is challenging. It may not fully address the social stigma associated with loneliness or replicate space research conditions.

In Australia,

34%

of adults
are lonely

In the
United States,

43%

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companionship,
lack meaning,
or feel isolated.

OPPORTUNITY 9

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Biomaterials
Biotechnology
Blue Economy
Food Innovation

SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Education
Financial Services & Investment
Government Services
Health & Healthcare
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology

What if oceans unlocked innovations in health and food?

AQUATIC BREAKTHROUGHS

GenAI

Oceans, with their vast unexplored biodiversity, offer opportunities in marine biotechnology and pharmacology, enabling advances in medicine and food industries.

WHY IT MATTERS TODAY

By 2030,
climate-related health issues, such as malnutrition, malaria, diarrhoea, and heat stress, could cause

250,000
extra deaths annually

As global temperatures rise, ecosystems and disease landscapes shift. New wildlife species migrate north, while novel pathogens emerge, affecting everything from Arctic mammals to plants worldwide.[332] This ecological transformation signals a risk of unpredictable pandemics in a warming world.[333]

While more socially inclusive research covering a wide range of infectious diseases is needed for a better understanding of the impacts of climate change,[334] by 2030 climate-related health issues, such as malnutrition, malaria, diarrhoea, and heat stress, could cause 250,000 extra deaths annually with health-related costs possibly reaching up to $4 billion each year.[335] Developing countries with fragile health systems are especially vulnerable.[336]

As the global population is predicted to grow to 8.5 billion by 2030 and 9.7 billion by 2050,[337] the need for effective, safe, and better treatments and drugs in response to evolving infectious and non-infectious diseases will be needed. In addition to climate shifts impacting on infectious diseases, by 2050 non-infectious diseases like heart disease, cancer, diabetes, and respiratory conditions will constitute 86% of the annual 90 million deaths – a 90% rise from 2019 figures.[338]

By volume, the oceans represent 99.5% of the Earth's biosphere,[339] and an estimated 80% of the planet's biodiversity calls the ocean home.[340] With an annual economic value estimated at $2.5 trillion, ocean-linked sectors, or the 'blue economy', are equivalent to the world's seventh largest economy.[341] However, only 5% of the oceans have been explored.[342]

OPPORTUNITY

From fish traversing the open sea to sea snails nestled in coral reefs and the smallest microbes on the ocean floor, the oceans offer countless opportunities for scientists to discover the potential of marine biotechnology.[343] The marine environment, rich in unique microorganisms, offers vast potential for bioactive chemicals with applications in food processing.[344] Pharmacological research on marine organisms is largely untapped, presenting a vast, diverse source of new drugs for diseases like cancer and malaria.

The marine ecosystem, abundant in aquatic flora and fauna, is explored for insights and learnings related to their antibacterial, immunomodulatory, antifungal, anti-inflammatory, anticancer, antimicrobial, neuroprotective, analgesic, and antimalarial properties[345] for practical applications.

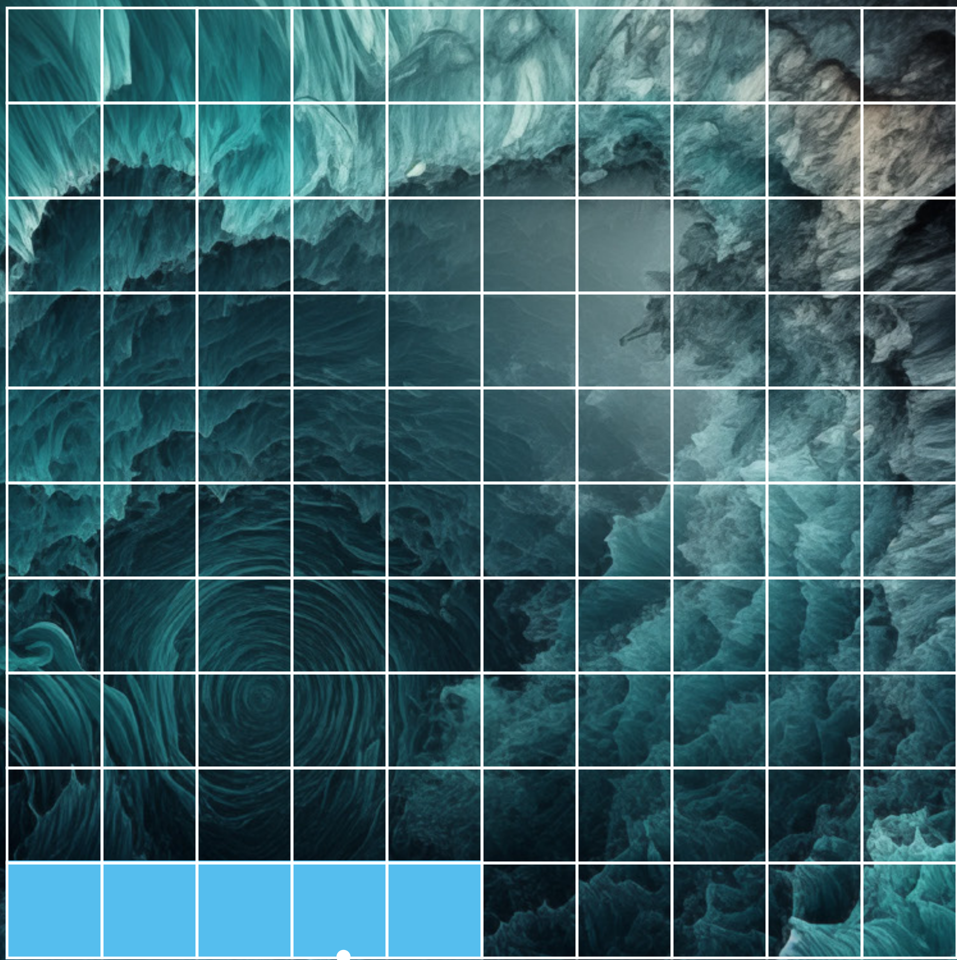
BENEFITS

Biotechnology discoveries support the health and well-being of people worldwide and create new economic opportunities. With more exploration of the oceans comes greater understanding and appreciation of the vital ecosystems that populate it, motivating sustainable blue economy technology and practice.

RISKS

Overuse of marine resources damages ocean ecosystems, threatening livelihoods dependent on them. Discoveries require more comprehensive research to prove efficacy[346] and innovative strategies to ensure the sustainability of oceans and marine ecosystems.[347]

The oceans offer countless opportunities for scientists to discover the potential of marine biotechnology



Only 5% of the oceans have been explored

OPPORTUNITY 10

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Values

MEGATRENDS

Advanced Health and Nutrition

TRENDS

HealthTech
Longevity & Vitality
Mental Health
Mobilising Innovation
Neuroscience

SECTORS IMPACTED

Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Health & Healthcare
Immersive Technologies
Insurance & Reinsurance
Materials & Biotechnology
Art, Media & Entertainment
Professional Services

What if treatment for depression was drug-free? [L]

PULSE OVER PILLS

Advances in neuroscience, neuromodulation technologies, miniaturisation, advanced computing, and advanced machine intelligence bring new, affordable, and drug-free treatments for depression.

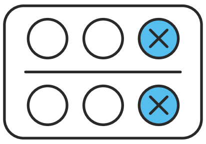
[L] Medical opinions may vary and this may not be the case in every situation for every individual.

WHY IT MATTERS TODAY

Around

30%

of those receiving treatment for depression have an inadequate response to at least two antidepressants



Since 1990, mental health disorders have increased by 48%.[348] The World Health Organization estimates that 280 million people around the world suffer from depression.[349] Despite the prevalence of depression and available treatments, many sufferers remain undiagnosed or inadequately treated.[350]

While enhancing existing therapies and combining them with cost-effective, non-pharmacological methods is crucial for bridging the treatment gap,[351] in some cases it could be an inadequate response to treatment.[352] One definition of what an inadequate response may be is a lack of impact despite the use of at least two antidepressants; around 30% of people with depression fit this criteria.[353]

Globally, some $3.7 billion is allocated annually to mental health research, accounting for an estimated 7% of the total global health research funding, but over half of this investment (56%) is directed towards basic research as opposed to clinical or applied research.[354]

Exploring drug-free approaches through Transcranial Direct Current Stimulation (tDCS) have been trialled in patients with depression for several years.[355] Its positive effects have been noted in several small trials; however, its clinical application remains limited, partly because of the lack of a clear model or understanding of the mechanism by which it alters brain function in depression,[356] with limited peer-reviewed publications[357] and mixed results.[358]

Flow Neuroscience, for example, recently announced results from clinical trials that showed treatment via the tDCS headset it is developing was twice as effective as the most commonly prescribed antidepressants.[359] Similarly, transcranial magnetic stimulation (TMS) has been found to reduce treatment time and achieve a rapid reduction in depressive symptoms.[360] The UCLA TMS Clinical and Research Service reports that two-thirds of patients get substantially better after treatment.[361] Nevertheless, one study was halted, in spite of there being a significant decrease in depression scales over time, because of a build-up of adverse events, notably skin lesions warranting further research.[362]

OPPORTUNITY

Advances in neuroscience, combined with miniaturisation, advanced computing, and advanced machine intelligence lead to the design of an effective closed-loop system to autonomously deliver drug-free neuromodulation for depression. Materials science enables future solutions to be comfortable and compatible for application in real settings.

Through tDCS, neuromodulation based on an electric current[363] or magnetic stimulation[364] targets the physical areas of the brain – left, right, or medial areas of the prefrontal cortex – that are involved in emotion regulation.[365] With immediate feedback, therapies are delivered as and where needed to deliver optimum effects.

tDCS may one day allow people struggling with depression, including those who do not adequately respond to antidepressants,[366] to treat or reduce symptoms without the use of pharmaceuticals.[367] Investment in making tDCS more accessible and affordable mobilises this innovation into regions that have a shortage of mental health services, as part of broader mental health policies.

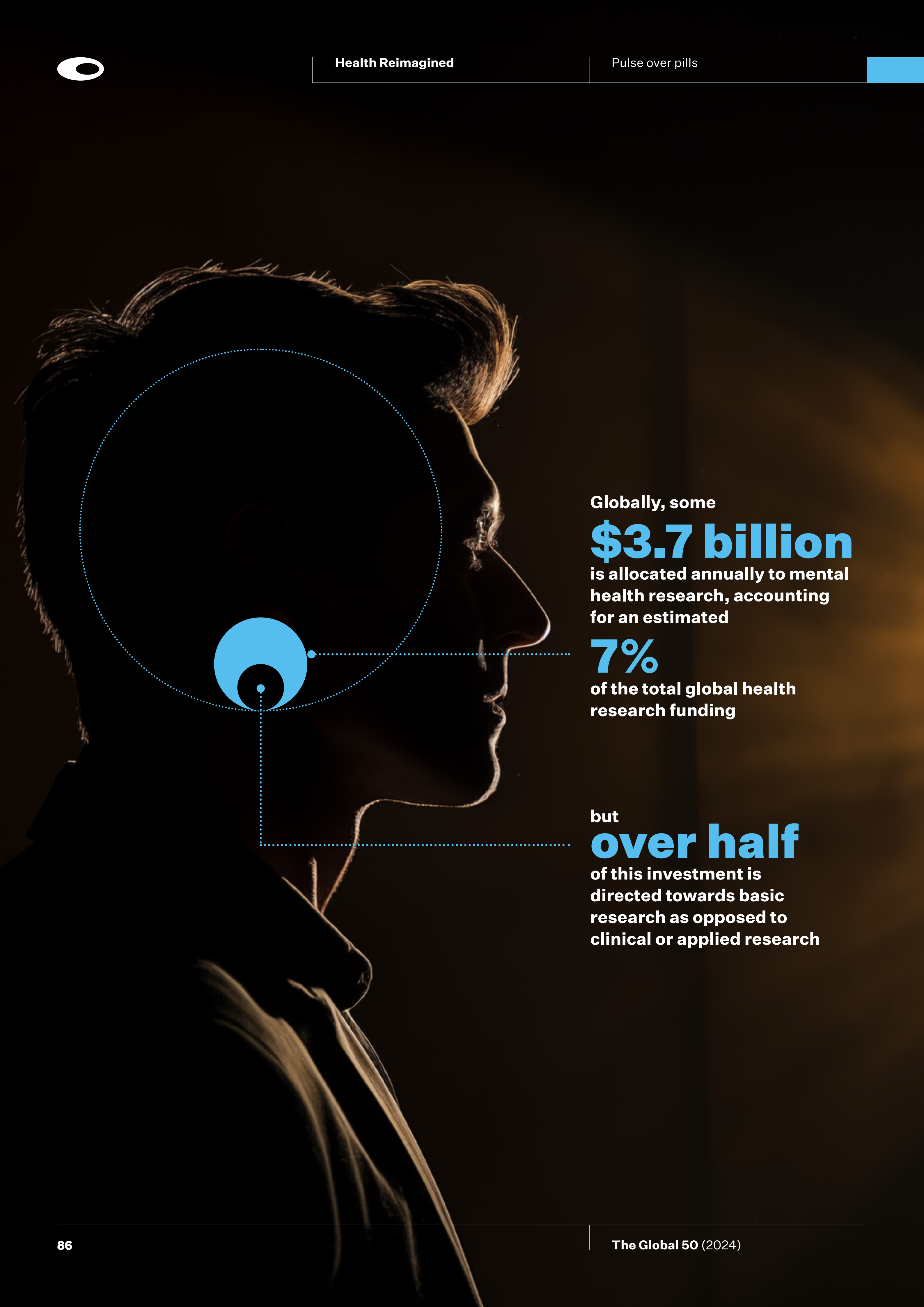
Clinical trials have demonstrated that, in some cases, treatment with a tDCS headset was twice as effective as the most commonly prescribed antidepressants

BENEFITS

Better treatment and fewer side effects from pills. Innovative, non-invasive, affordable, and possibly portable devices offer targeted treatment for depression, enhancing patient autonomy and potentially reducing the number of untreated cases.

RISKS

Treatments targeting the physical determinants of depression in the brain could have unforeseen immediate and long-term effects, some of which may be irreversible. Varying effects and inconsistent results warrant further investigation, research, and clinical trials, limiting expected impact. Treatment may initially be too costly limiting accessibility.



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OPPORTUNITY 11

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Values

MEGATRENDS

Materials Revolution

TRENDS

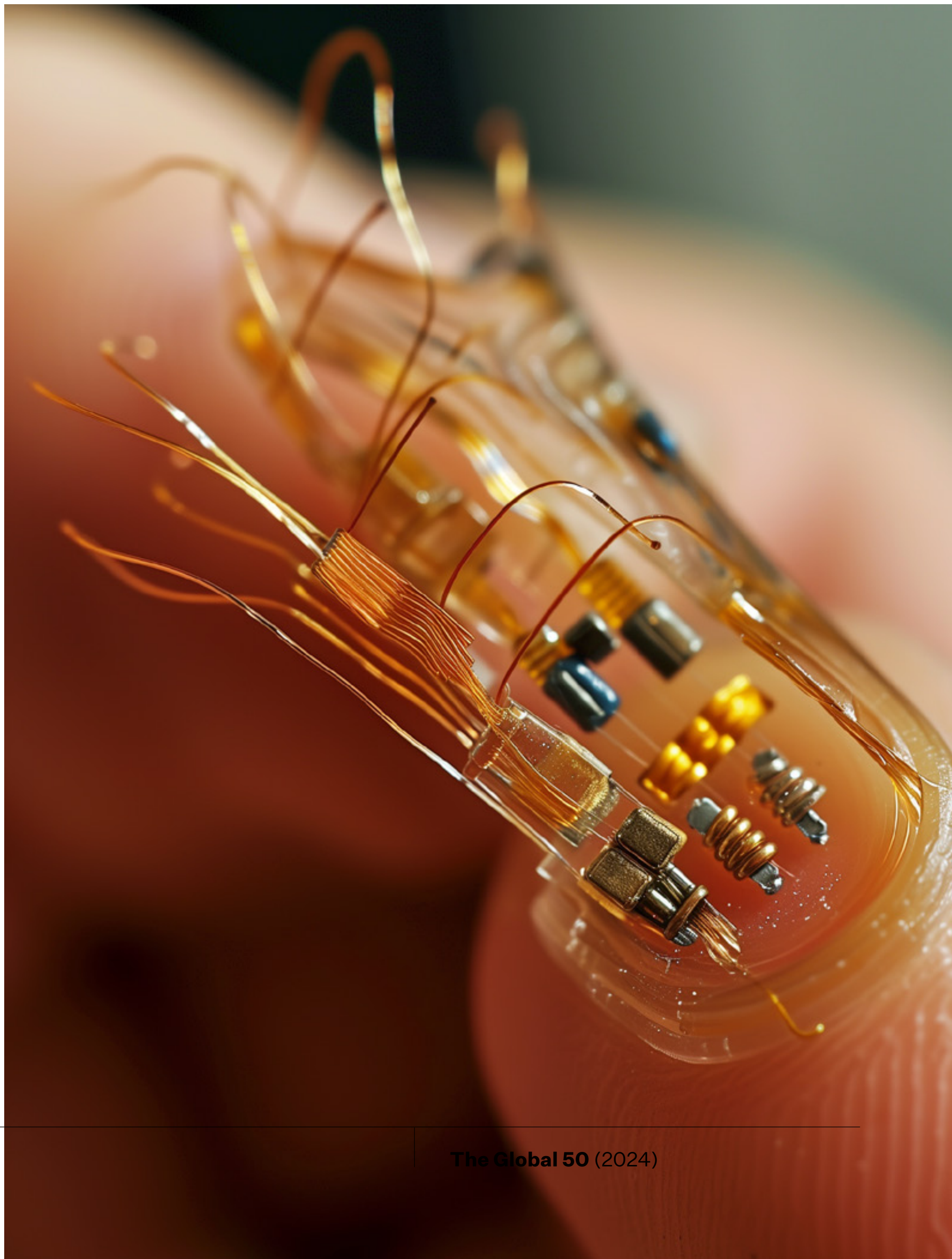
Biomaterials
Brain–Computer Interfaces (BCI)
Immersive Technologies & Wearables
Longevity & Vitality
Neuroscience

SECTORS IMPACTED

Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Travel & Tourism

What if we restored a lost sense of touch?

AT YOUR FINGERTIPS



WHY IT MATTERS TODAY

Tactile receptors in the skin have a crucial role in sensing[368] and motor control.[369] Paralysis, diabetes,[370] and multiple sclerosis (MS), as well as tumours, arthritis, vitamin deficiencies,[371] and certain medications and surgeries, can lead to the partial or total loss of sense of touch[372] or peripheral neuropathy.[373] Peripheral neuropathy, a condition affecting some 2.4% of the global population and up to 7% of those over 45 years of age, impairs the peripheral nerves responsible for translating external information into brain signals.[374]

Getting an up-to-date understanding of global spinal cord injuries is not easy.[375] Nevertheless, there were an estimated 9 million cases of spinal cord injuries worldwide in 2019, a 53% increase compared to that in 1990,[376] with the majority resulting from preventable causes such as road traffic accidents, falls, or violence.[377] In the United States, about 5.4 million individuals live with paralysis, affecting nearly 1 in 50 people,[378] and just under 300,000 live with generalised spinal cord injuries.[379]

In terms of disease prevalence, multiple sclerosis (MS), which affects cognitive, emotional, motor, sensory, and visual functions, is caused by the immune system attacking the brain and spinal cord[380] and affects over 1.8 million people globally, predominantly young adults and women.[381] In 2021, some 529 million people globally had diabetes, 6.1% of the global population.[382] The highest rates were observed in Oceania and the Middle East and North African (MENA) regions, at 12.3% and 9.3% respectively.[383] The illness caused 2 million deaths in just 2019 alone.[384] Type 2 diabetes, which accounts for 96% of cases, is predominantly linked to high Body Mass Index (BMI) and this correlation increased by 24% from 1990 to 2021.[385] Projections suggest over 1.3 billion people will have diabetes by 2050.[386]

Peripheral neuropathy affects about 2.4% of the global population

and up to 7% of those over 45 years of age

OPPORTUNITY

Battery-powered or wireless power-transferred[387] implantable tactile sensor systems,[388] together with nanomedicine, regenerate the central nervous system[389] to help individuals restore their sense of touch.

Like implanted cardiac pacemakers, implanted devices for glucose monitoring, cochlear implants, and deep brain simulators for Parkinson's disease, these implantable tactile sensor systems offer solutions for a better quality of life for those affected. These components can be placed anywhere in the body where the loss of sense of touch has been encased in materials such as titanium, alumina, and fused silica, with output from the sensor encoded via brain microstimulation for tactile feedback.[390]

BENEFITS

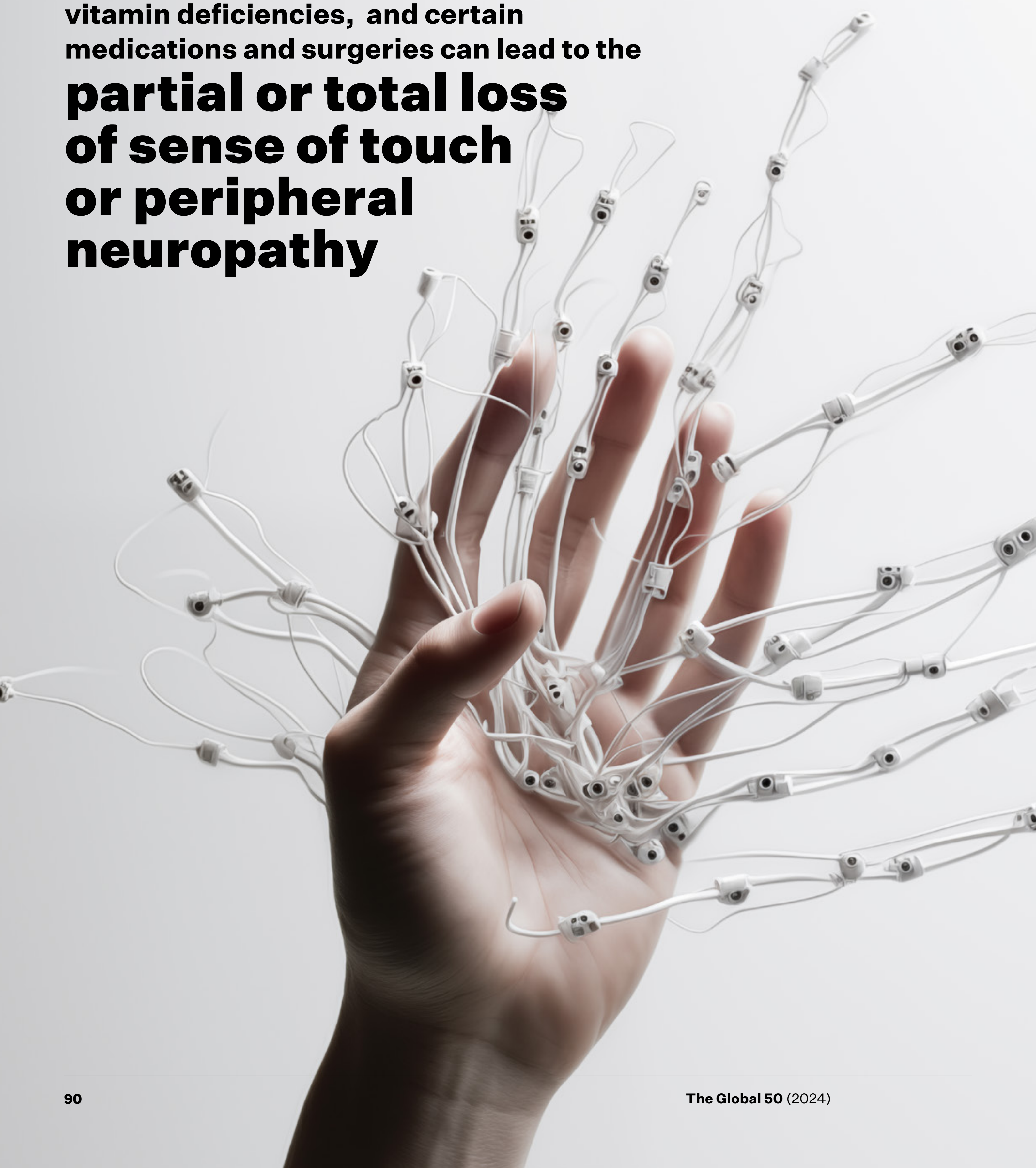
People suffering from full or partial sensory loss recover their sense of touch, enhancing independence, quality of life, and productivity.

RISKS

Infections at the implant site, technical malfunctions such as disruptions in wireless power systems, and challenges related to sealing, biocompatibility, and the size of the implantable sensor.

Paralysis, diabetes, and multiple sclerosis (MS), as well as tumours, arthritis, vitamin deficiencies, and certain medications and surgeries can lead to the

partial or total loss of sense of touch or peripheral neuropathy



OPPORTUNITY 12

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Values

MEGATRENDS

Materials revolution

TRENDS

Biomaterials
Biotechnology
Food Innovation
Mobilising Innovation
Sustainable Waste Management

SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Health & Healthcare
Materials & Biotechnology

What if expiry dates were unnecessary?

A WARNING GLOW

GenAI

Bioluminescent food packaging materials detect food deterioration and contaminants, extending shelf life and reducing waste, transforming food safety in retail, restaurants, and homes.

WHY IT MATTERS TODAY

Some 600 million people a year (almost 1 in 10 people worldwide) are affected by contaminated food.[391] Food safety failures caused 420,000 deaths and a loss of 33 million disability-adjusted life years in 2010.[392] Over 40% of those carrying the food-borne disease burden are children under the age of five, 125,000 of whom die every year.[393] The losses to productivity and in medical costs are an estimated $110 billion per year.[394]

Food can be damaged or contaminated along the entire value chain, from processing to storage and transport and in stores. The main sources of food contamination are toxins or microorganisms (e.g. chemicals, viruses, bacteria, or parasites). The World Health Organization identifies over 200 diseases related to contaminated foods.[395]

Current food labelling systems use the precautionary principle, often using sell-by and use-by dates that are too cautious, meaning retailers and consumers dispose of food unnecessarily. Reported in 2021, around 931 million tonnes of food are wasted each year, of which 61% is in households, 26% in restaurants, and 13% in retail.[396]

Around
931 million tonnes
of food are wasted each year

in retail **in restaurants** **in households**

OPPORTUNITY

Packaging materials include bioluminescent elements to detect and signal deteriorating foodstuff and/or the presence of toxins or harmful microorganisms. As several mechanisms are behind bioluminescence – the natural production and emission of light by living organisms – proteomics, genomics, and bioinformatics advance how underlying proteins and enzymes can be used in packaging materials for food safety.[397]

This helps avoid restrictive expiry dates,[398] extends the shelf life of food items, and reduces waste. Crates of staples like rice or wheat, for example, can be equipped with bioluminescent markers that indicate the presence of contaminants such as pesticides or metals. This technology elevates safety standards in retail and restaurants by alerting staff to spoiling food and enables consumers to monitor food safety at home, further minimising waste without having to throw out food early. Additionally, this smart bioluminescent packaging can be adapted for other sensitive products, such as pharmaceuticals or cosmetics, and can also aid in monitoring of environmental impacts.[399]

BENEFITS

Bioluminescent packaging offers a universally understandable indicator of food safety, protecting health and reducing food waste, contributing to improved food security.

RISKS

Malicious or accidental damage to packaging might trigger false positives or even prevent bioluminescence in order to attack food retailers or communities. Biomaterials used to create bioluminescence may contaminate food, and upon reaction with food, cause harmful by-products.

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.

OPPORTUNITY 13

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Saving Ecosystems

TRENDS

Biomaterials
Cross-sectoral Partnerships
Net Zero
Repurposing Assets
Urban Design

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Education
Health & Healthcare
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Travel & Tourism

What if cities mirrored nature?

MOTHER CITY

Nature-inspired solutions, guided by biological sciences and advanced machine intelligence, are used in early urban planning to transform cities into becoming sustainable and self-regenerating with lower maintenance costs, for optimal impact.

WHY IT MATTERS TODAY

For some 3.8 billion years, animals and plants have been the natural prototypes for countless solutions to enable us to live sustainably on Earth

In 2021, the World Health Organization (WHO) reduced its recommended limits for air pollutants in order to protect public health.[400] While not legally binding, these guidelines provide benchmarks for global cities. As per the WHO, 99% of the global population breathe air that exceeds the WHO guidelines and nearly 7 million people die from combined indoor and outdoor air pollution each year.[401]

Biomimetic innovations are technologies that imitate nature.[402] For some 3.8 billion years, animals and plants have the natural prototypes for countless solutions to enable us to live sustainably on Earth.[403] Technologies that draw from nature's innovations have already been created. In 2023, a Boeing 777F was modified with AeroSHARK, a surface film that mimics shark skin to improve aerodynamics, fuel efficiency, and reduce emissions.[404] In their innovation efforts, Airbus – inspired by the way geese fly – piloted and entered a multi-party collaboration to test the operational feasibility of planes flying safely in close proximity on long-haul flights, potentially reducing emissions by up to 5%.[405] Biomimetic solutions can also be macro-scale. Not without challenges, Lavasa Hill Station, the first planned hill city in India, was meant to feature buildings that mimic a tree's taproot to address water scarcity in the dry season and drainage systems that mimic harvester ant nests to prevent flooding during the monsoon season.[406]

OPPORTUNITY

Biomimicry offers opportunities to discover fresh, disruptive design solutions.[407] Biomimetic innovations have already been driving advances in various fields, including, but not limited to, aerial vehicles[408] and robotics.[409] Derived from nature's forms, functions, and systems, biomimetic design is more likely to be nature positive.[410]

Biologists form part of the engineering team drawing on natural ecosystems and nature-inspired solutions for new urban and/or infrastructure planning[411] early on in the construction process[412] or in reconfiguring existing infrastructure. The integration of biomimicry improves sustainability, enables self-regeneration, and potentially reduces ongoing maintenance costs. Advanced machine intelligence drives optimal redesigns, and simulations depict the most effective steps needed.

BENEFITS

Nature-inspired transformation accelerates net-zero goals, creates new entrepreneurial markets,[413] and, when included in design and planning, enhances biodiversity, conserves natural resources, and improves air quality, making communities bioinspiration hubs.

RISKS

Nature-inspired engineering and infrastructure solutions, when not thoroughly planned, implemented, or managed, can negatively impact on the environment and biodiversity, potentially endangering species. Complex designs may be costly and minimally effective in terms of sustainability and climate action.

Delivered from nature's forms, functions, and systems, biomimetic design is more likely to be nature positive

OPPORTUNITY 14

SCOPE TRANSITIONAL

UNCERTAINTIES

Nature, Technology

MEGATRENDS

Saving Ecosystems

TRENDS

Artificial Intelligence
Climate tech
International Collaboration
Open data
Restoration

SECTORS IMPACTED

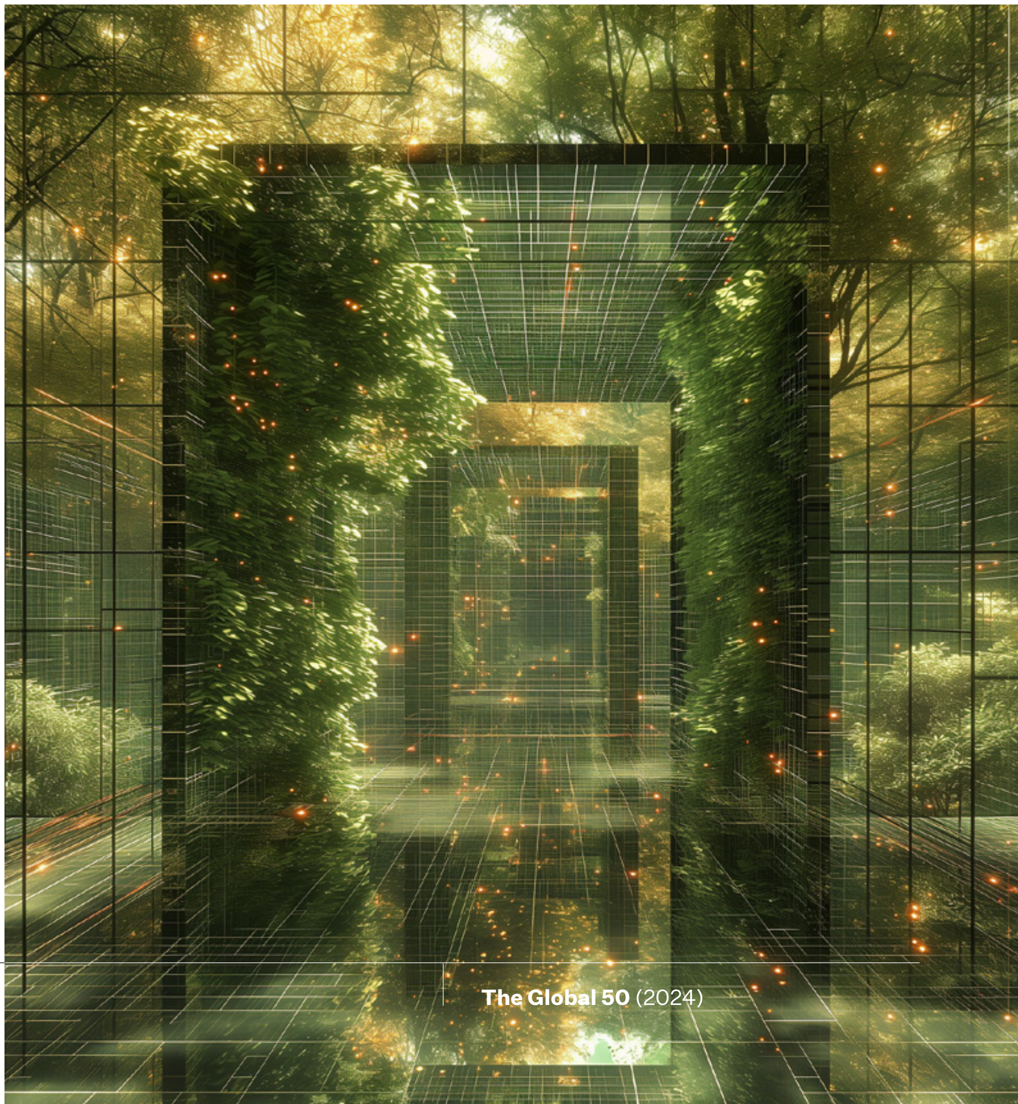
Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Travel & Tourism

What if digital biodomes shaped eco-policies?

VIRTUAL NATURE

GenAI

Digital biodomes, simulated using advanced machine intelligence, provide a basis for policies where nature conservation and restoration are a priority for the future, aligning human activities with nature's health.



WHY IT MATTERS TODAY

Nature is valued worldwide for many reasons: its economic resources, health benefits, beauty, and intrinsic value.[414] Despite this, global conservation action is lacking in some cases.[415]

Biodiversity is declining – there are more than 157,100 species on the International Union for Conservation of Nature Red List of Threatened Species, with more than 44,000 of those threatened with extinction.[416] Deforestation is also a serious conservation concern. Tropical primary forest loss in 2022 totalled 4.1 million hectares of forest. This produced 2.7 gigatonnes of carbon dioxide emissions, equivalent to India's annual fossil fuel emissions.[417] A better understanding of how valuable nature is to society and the planet is more urgent than ever.[418]

A biome is an area (e.g. tropical rainforest, desert) with unique conditions (e.g. temperature, soil, light, water) that hosts specific species within different ecosystems.[419] A biodome is a self-contained, self-sustaining, human-made biome replicating one or more ecosystems.[420] As an active laboratory of nature, this enclosed space can contain flora and fauna from a particular biome.

The University of Arizona's biodome, Biosphere 2, the world's largest, is a controlled environment dedicated to understanding the impacts of climate change.[421] The Montreal, Canada, biodome exposes people to nature and carries out various research and conservation initiatives in five ecosystems: a tropical rainforest, marine life, a maple forest, an Atlantic Ocean coast, and islands just north of the Antarctic.[422] Other examples include Burgers' Zoo, in Arnhem, the Netherlands,[423] and the Eden Project in Cornwall, in the United Kingdom.[424]

Besides the Green Planet in Dubai, a self-sustaining rainforest ecosystem in the desert city,[425] the UAE is building, as part of Mars 2117, the Mars Science City, which will include biodomes that simulate the ecosystem on Mars.[426]

A biodome is a self-contained, self-sustaining, human-made biome replicating one or more ecosystems

OPPORTUNITY

Virtual biodomes could guide conservation strategies that allow both nature and society to thrive harmoniously. Using virtual AI-simulated biodomes, which are more affordable than physical biodomes, yet still have a major impact, policymakers, businesses, and scientists alike can experiment with different variables to consider the needs, behaviours, and interactions of every living and non-living component. This approach would enable sustainable development to accommodate the needs of biodiverse organisms and align with climate goals.

Data from simulated biodomes could form the quantitative basis for economic and financial tools, such as taxes, funds, and bonds, that invest in nature[427] and both inform and become a mechanism of various nature-related scientific research around the world. Data and tools, adapted for the public, could also aid narratives that aim at encouraging society to adopt more sustainable mindsets, in line with the academic community, which recognises the importance of nature for human well-being.[428]

BENEFITS

AI-simulated biodomes provide a basis for environmentally sustainable decision-making and enable a greater appreciation of nature's intrinsic and extrinsic value. Shared output data aid diverse scientific communities by providing essential information for research on nature and climate.

RISKS

Limited funding and flawed biome models lead to misrepresented biological, ecological, and environmental behaviours, impacting on output quality and limiting updates to virtual biodomes. Analysis of virtual biodomes provides business intelligence that may encourage negative exploitation of nature.

There are more than

150,300 species

on the International Union for Conservation of Nature Red List of Threatened Species, with more than

42,100

of those threatened with extinction

OPPORTUNITY 15

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Materials Revolution

TRENDS

Biomaterials
Food-water-energy nexus
Mobilising Innovation
Nanotechnology

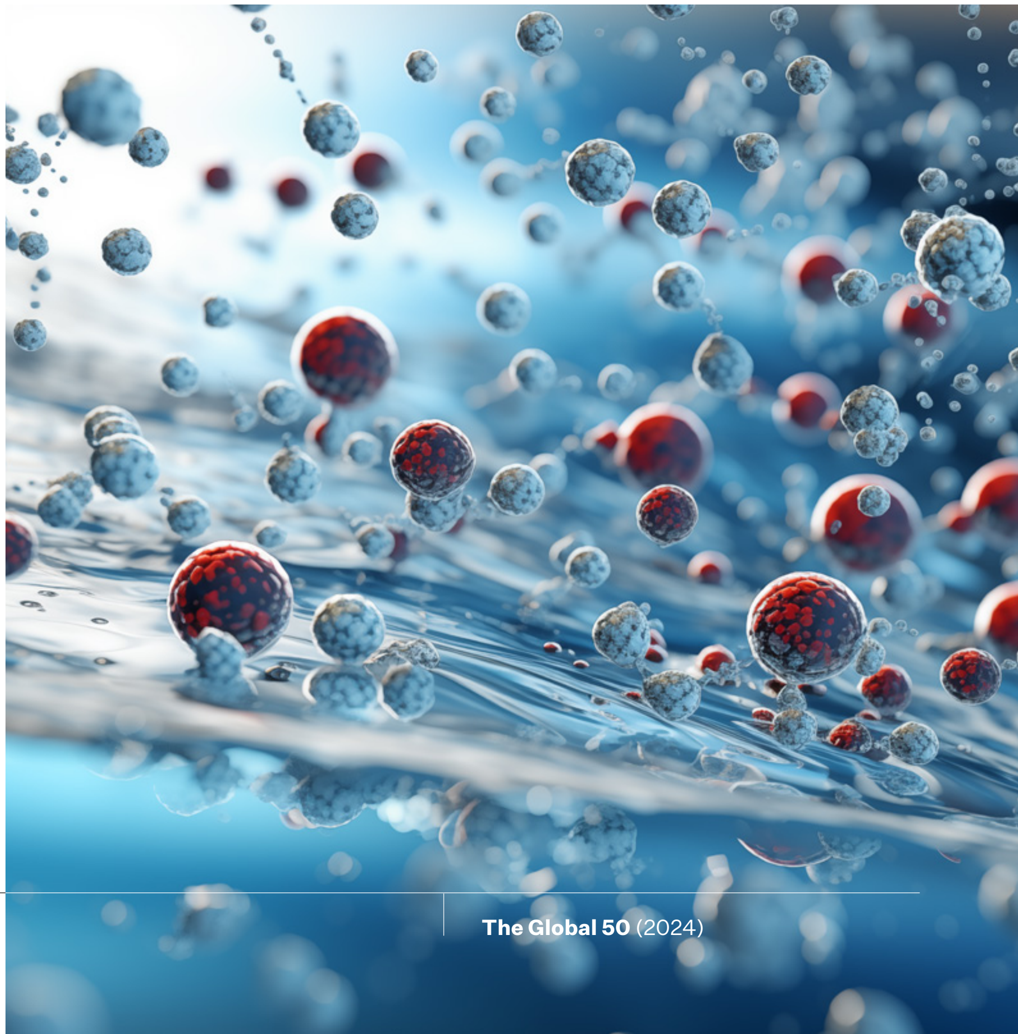
SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Energy, Oil, Gas & Renewables
Government Services
Health & Healthcare
Infrastructure & Construction
Materials & Biotechnology
Metals & Mining
Utilities

What if carbon nanomaterials ensured global access to clean water?

CARBON FOR WATER

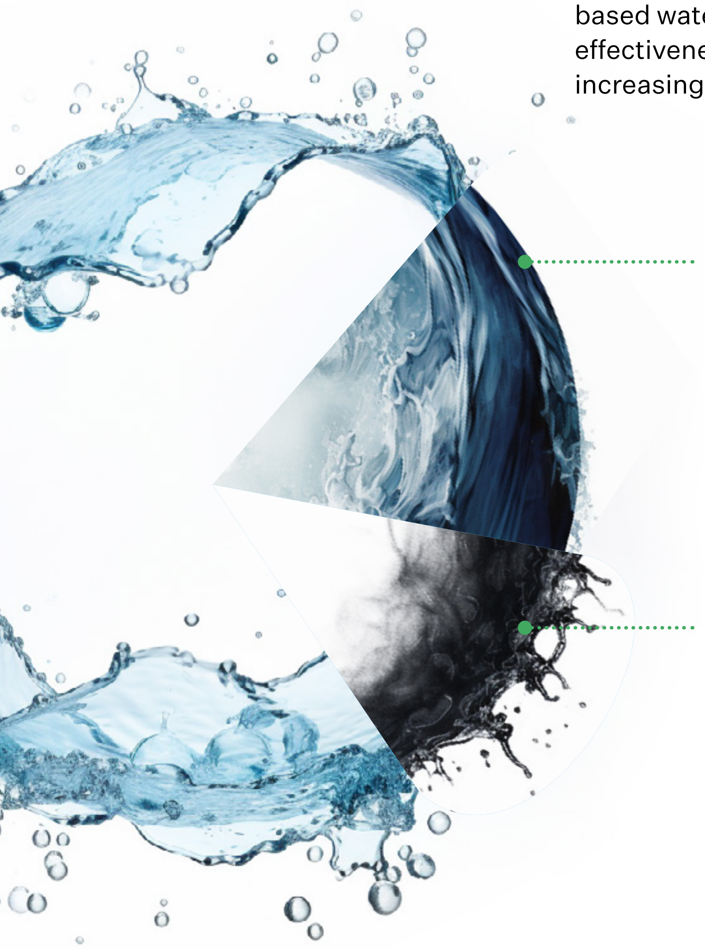
Carbon-based nanomaterials transform global access to potable water through their ability to effectively remove pollutants at the nanometre scale, in both small and large volumes, allowing for point-of-use applications and larger scale operations, reducing the cost and environmental impact of desalination processes.



WHY IT MATTERS TODAY

In 2020, 74% of the world's population had access to safe drinking water compared with 62% twenty years earlier.[429] But water scarcity continues to be a global challenge.[430] In 2021, 2.3 billion people lived in water-stressed countries,[431] and, in 2022, over 1.7 billion drank from contaminated water sources.[432] Just over half a million people die each year from diarrhoea as a result of unsafe drinking water, sanitation, and hand hygiene.[433] As demands grow for clean, safe water, the global market for water purification is forecast to rise from $30.62 billion in 2022 to $54.48 billion by 2030, with a CAGR of 7.6%.[434]

Almost 50% of educational institutions in sub-Saharan Africa and one in every four healthcare facilities worldwide are without basic water services.[435] In medium- to low-income nations, efforts to enhance clean water access face hurdles because of recontamination occurring between the point of collection and where it is used.[436] As a result, point-of-use or home water treatment technologies, which purify drinking water at the household level before consumption, address contamination risks both at the source and during transportation.[437] However, membrane-based water filtration and chlorine disinfectants are being used whose effectiveness is subject of debate because of toxic by-products and increasing pathogen resistance.[438]



2.3 billion people

lived in water-stressed countries in 2021

1.7 billion people

drank from contaminated water sources in 2022

1 in 2

of educational institutions in sub-Saharan Africa

and

1 in 4

healthcare facilities worldwide are without basic water services

OPPORTUNITY

Carbon-based nanomaterials transform access to potable water worldwide as they function at the scale of 1:100 nanometres (i.e. one billionth of a metre), making them effective at selectively capturing and removing heavy metals, organic compounds, and other pollutants.[439] From carbon nanotubes and graphene to carbon quantum dots and fullerenes, carbon-based nanomaterials hold particular promise in water filtration[440] and desalination, as they reduce the cost and environmental impact of desalination processes today.[441]

While carbon-based materials have been used for wastewater treatment,[442] they have not been scalable for water purification because of concerns regarding toxicity and environmental impacts.[443] At nanometre scale and with advances in materials science, advanced machine intelligence and computational modelling simulate and study the effect of physical and chemical particle characteristics[444] on toxicity patterns and recyclability.[445]

BENEFITS

In previously water-stressed regions, abundant clean water resources greatly enhance health, rejuvenate economies, and prevent disease. Reduce the cost and environmental impacts of desalination processes.

RISKS

Unintended consequences arise from incomplete knowledge about toxicity and the impact on human health and the environment. Damaged carbon nanomaterial filters or processes can cause nanotubes or nanofibres to pollute water supplies, leading to adverse health outcomes and lack of water purification.

The global market for water purification is forecast to rise to

$50.66 Billion

by 2029

$30.62 Billion

in 2022

OPPORTUNITY 16

SCOPE VISIONARY

UNCERTAINTIES

Nature, Technology

MEGATRENDS

Saving Ecosystems

TRENDS

AgriTech
Air Pollution
Biotechnology
Geoengineering
Restoration

SECTORS IMPACTED

Agriculture & Food
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Real Estate

What if nature grew and regenerated faster?

GREEN SPURT

GenAI

Advances in environmental science and biotechnology foster the development of plants, soils, and tools that accelerate nature's regeneration, promoting biodiversity, carbon sequestration, and ecosystem services.

WHY IT MATTERS TODAY

Half of the world's gross domestic product (GDP) is moderately to highly dependent on nature.[446] Adopting nature-positive pathways for global economic development can increase business value by $10.1 trillion and create 395 million jobs by 2030.[447] From an impact perspective, biodiversity loss and ecosystem degradation will cost the global economy some $5 trillion[448] and up to 18% of water-dependent agriculture is at risk.

Given this dependency, there are natural solutions can help nature regenerate itself.[449] Assisted natural regeneration (ANR), for example, is an approach that aims to eliminate human-induced environmental disruptions, like deforestation and forest fires, to speed up nature's ability to regenerate itself. ANR focuses on restoring ecosystem services, such as a robust water cycle, and can be tailored to fit the specific environmental, social, and economic context of a local area.[450]

Biotechnology also holds potential. Researchers at the University of Illinois Urbana-Champaign genetically modified enzymes in tobacco plants, chosen as an experimental crop, resulting in plants that grew 25% larger than unmodified ones,[451] inspiring potential solutions for climate challenges. Trees engineered to grow wood more quickly and sequester more carbon were planted in forests in the United States by Living Carbon, a biotechnology company, in early 2023, with modified poplars growing 50% faster than unmodified ones.[452]

In research at the University of Illinois Urbana-Champaign, genetically modified

tobaco plants grew 25% larger than controls

OPPORTUNITY

With advances in environmental science and biotechnology, genomics and bioinformatics enable reforestation to take place at a rate faster than global deforestation, sequestering more carbon and providing more habitats for plants and animals to flourish. This, in turn, can restore ecosystem services in areas affected by nature degradation. Trees and other plants with accelerated growth are customised for each geography they are planted in, allowing them to coexist healthily alongside existing flora.

BENEFITS

Climate change and nature degradation are addressed at the same time through a combination of natural and genetically engineered nature regeneration.

RISKS

Genetically modified species of plants have unforeseen interactions with naturally occurring species, undermining biodiversity and potentially leading to ecosystem imbalance.

In early 2023, modified poplars grew 50% faster than unmodified ones when engineered and planted to capture more carbon.

OPPORTUNITY 17

SCOPE VISIONARY

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Pushing the Boundaries of Energy

TRENDS

Transforming Energy
Mobilising Innovation
Net zero
New Materials

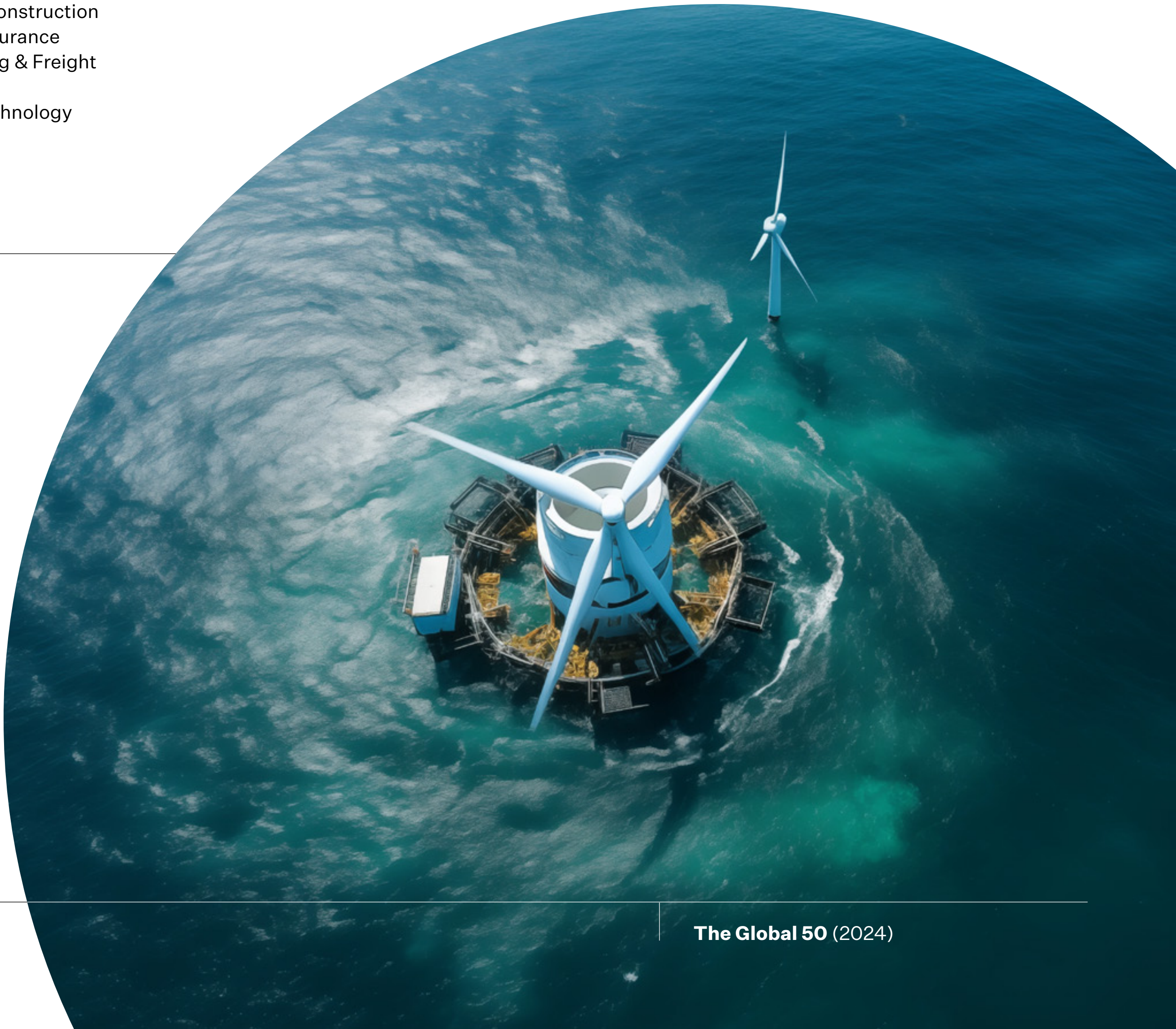
SECTORS IMPACTED

Agriculture & Food
Consumer Goods, Services & Retail
Energy, Oil, Gas & Renewables
Financial Services & Investment
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Metals & Mining
Real Estate
Travel & Tourism
Utilities

What if tidal energy took over solar and wind?

TIDALS OF ENERGY

Advances in turbine technology with advanced machine intelligence enhance tidal energy's cost-effectiveness and its resilience against rising sea levels, making it a sustainable and scalable power source.



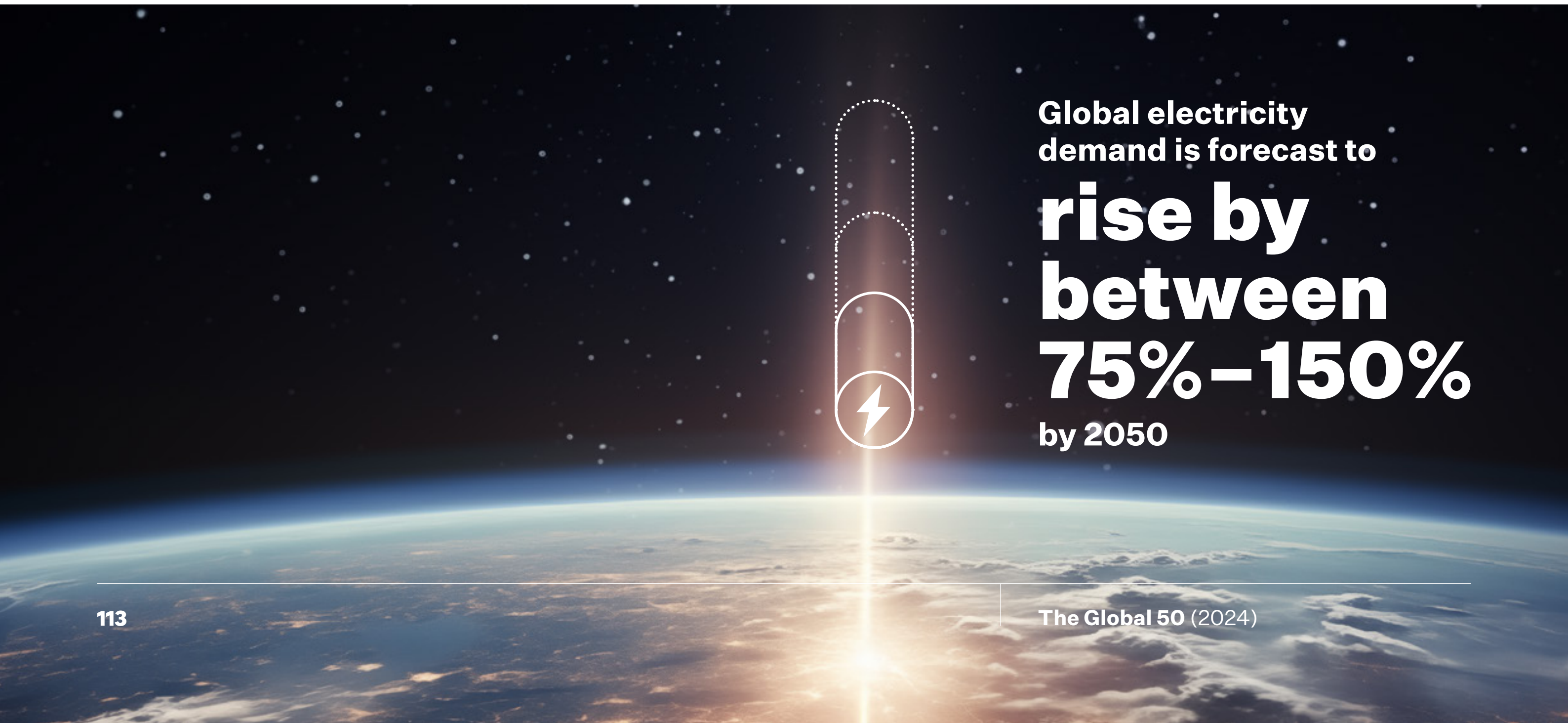
WHY IT MATTERS TODAY

Over 2.4 billion people around the world live within 100km of the sea.[453] Depending on the scenario,[M] global electricity demand is expected to rise by between 75% and 150% by 2050[454] to nearly 41,508TWh per year.[455] System flexibility is essential to meet that demand, a challenge for just solar and wind power, for which intermittence is a problem without massive advances in storage solutions.[456]

Tidal energy generators convert energy from tides into electricity.[457] The gravitational effects of the sun and the moon, the Earth's rotation, and the structure of the continental shelf result in semi-diurnal or diurnal tides, with typical water-level ranges of up to 12m, creating a continuous source of energy.[458] Like wind turbines, tidal turbines placed in tidal streams use rotating blades to generate electricity,[459] but unlike wind or solar, tidal energy generation is predictable and not dependent on weather conditions.[460]

However, the cost of tidal energy per unit is currently a multiple of solar or wind costs.[461] Building and maintaining tidal capacity at sea is more expensive than wind.[462] Tidal energy technologies today use tidal streams, dams or lagoons. New designs, such as dynamic tidal power,[463] which uses long tidal dams (30km to 60km), have bidirectional turbines that can double generation capacity. Long dams also require less tidal variation, making them suitable for more sites.

[M] Existing policies stated by governments (STEPS), the ambitious scenario of achieving net zero by 2050 (net-zero emissions), and announced pledges (APS) – see the IEA for further descriptions.



OPPORTUNITY

A combination of advanced machine intelligence and advances in turbine and transmission technologies can improve the cost-effectiveness and deployability of tidal energy generators. In addition to tidal energy's potential as a niche renewable energy source, particularly for coastal areas, these systems are engineered to be resilient to rising sea levels.

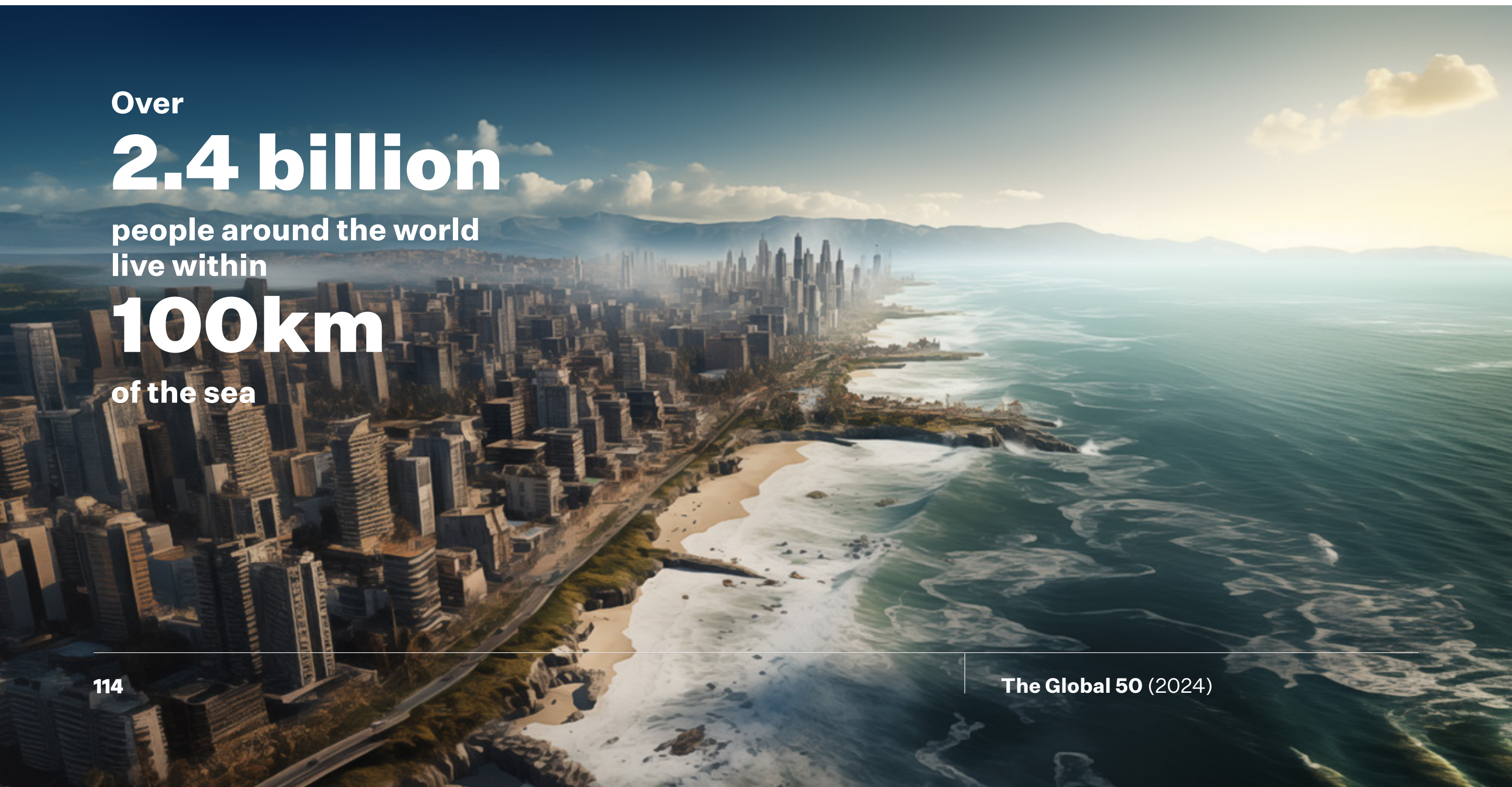
While some research shows that sea-level rises could impact on tidal power sites,[464] advanced machine intelligence could also better inform site selection. Lightweight, high-strength, and corrosion-proof materials,[465] combined with improved efficiencies in underwater cable conductivity, ensure that tidal energy infrastructure is affordable, scalable, and future-proof.

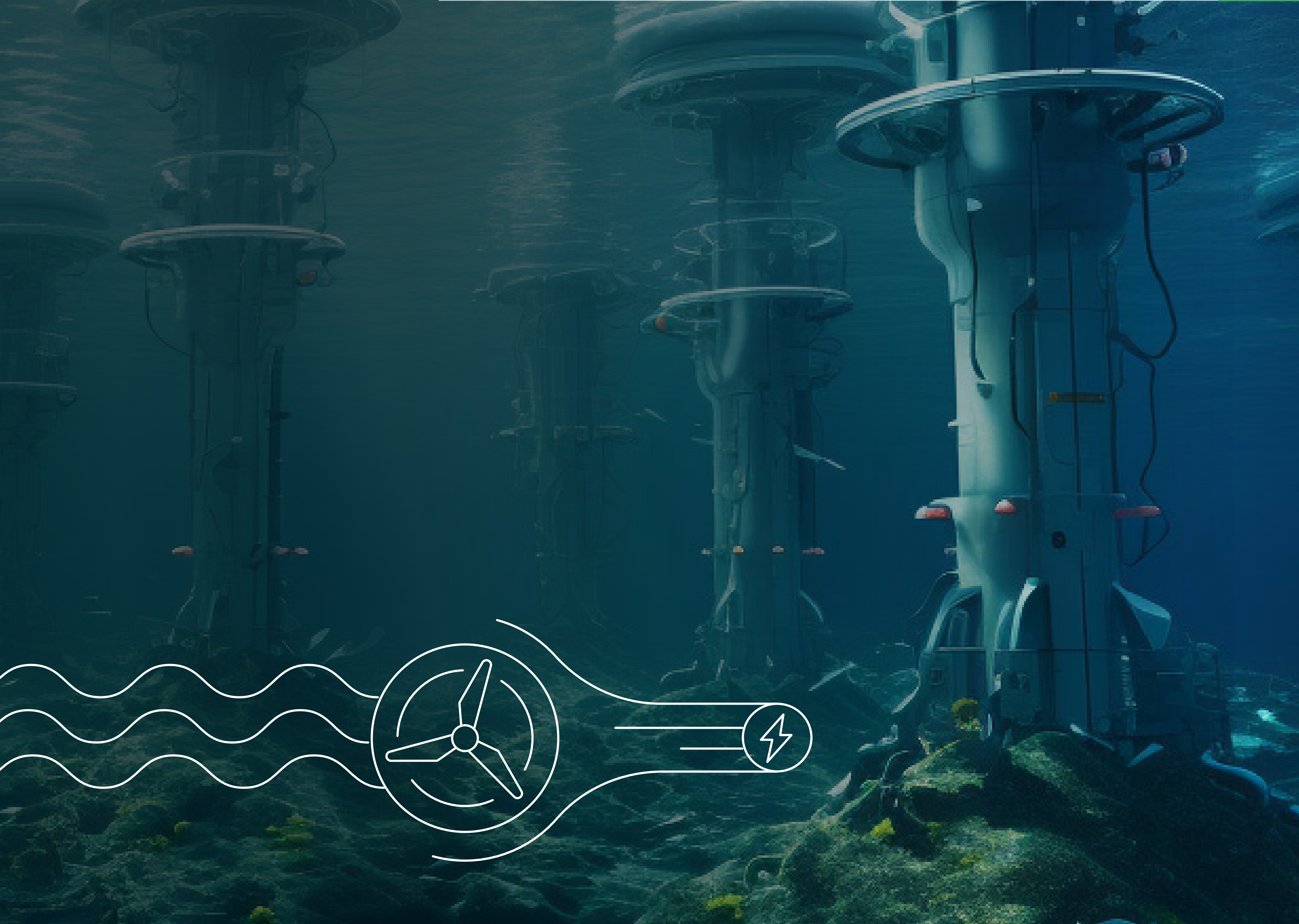
BENEFITS

Tidal power provides constant energy and coastal protection, fostering employment, mobility, and sustainable development in global coastal communities.

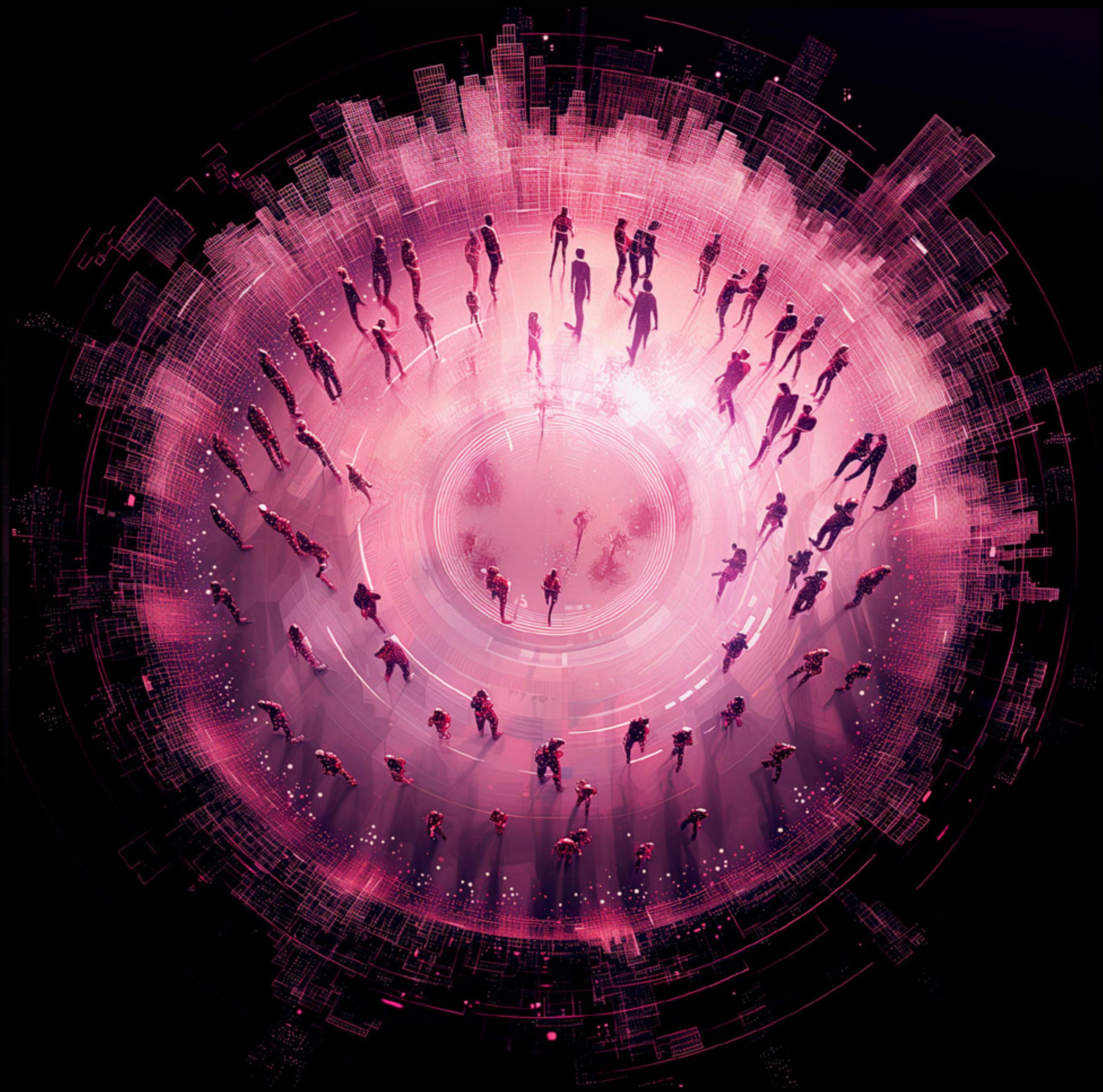
RISKS

Poorly designed installations can impact on marine ecosystems and shift erosion patterns.





Tidal energy generation is predictable and not dependent on weather conditions



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.

OPPORTUNITY 18

SCOPE TRANSITIONAL

UNCERTAINTIES

Values, Systems

MEGATRENDS

Future Humanity

TRENDS

Artificial Intelligence
Future of purpose & work
Generational & cognitive Diversity
Human–Human
Transforming Education

SECTORS IMPACTED

Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Education
Government Services
Health & Healthcare
Immersive Technologies
Art, Media & Entertainment
Professional Services
Travel & Tourism

What if wisdom was taught?

SCHOOL FOR WISDOM

Schools are transformed with wisdom-based education programmes, fostering culturally informed reasoning and skills to tackle complex challenges posed by emerging technologies for both young and old.

WHY IT MATTERS TODAY

The rapid development of advanced machine intelligence makes it likely that a great number of jobs that rely on human intelligence will be displaced or replaced over the coming decades. By 2027, digitalisation is expected to displace 26 million administrative jobs worldwide in roles such as accounting,[466] and the ability to synthesise information and knowledge may be less critical or no longer necessary.

As a multifaceted concept, wisdom involves diverse capacities and competencies and is evident in decision-making and action in complex social situations.[467] Increasingly relevant in an era of quantum shifts,[468] wisdom is the positive aptitude to make judicious decisions at the appropriate moment and the ability to deal with, through an integral viewpoint,[469] complex challenges associated with both societal shifts and emerging technologies.

Wisdom includes the capacity to regulate emotions, manage social behaviours and relationships, be self-aware, balance decisiveness and uncertainty, and advise others.[470] Intelligence or knowledge without wisdom leaves people less equipped to make complex decisions in their lives.

As the world grows increasingly more complex and interconnected, scientific, societal, and technological challenges and spill-overs will seemingly require sophisticated solutions[471] and wisdom will be more important than ever.

Wisdom is the positive aptitude to make judicious decisions at the appropriate moment and the ability to deal with complex challenges

OPPORTUNITY

Progress in wisdom research, together with advances in neuroscience and psychology, enable wisdom-based education programmes and new models of learning and education. Fostering human wisdom enables decision-making that is focused on societal and environmental betterment, aligned with real-world contexts.

As schools prepare students for higher education by teaching them how to acquire and synthesise knowledge, the essence of learning in universities has been about bridging the gap between knowledge and practice in industry.[472] As societal challenges demand more than just knowledge acquisition and job-related knowledge, models of education are redesigned with approaches that underscore the importance of wisdom.

While traditional knowledge-based education focuses on the transmission of data, information, and knowledge, wisdom-based education integrates ethical considerations, stakeholder values, emotions, and insights and acknowledges the fallibility of knowledge.[473] An educational framework that fosters wisdom development becomes central to making wisdom accessible.

BENEFITS

Wisdom-based decision-making ensures humanity's adept response to increasingly complex societal challenges.

RISKS

The underlying conceptual model is too complicated for implementation, loses relevance, or does not align with the wider approach to policy development. Completely overhauling education systems and ensuring teachers possess the necessary traits and skills to be able to teach wisdom are significant challenges.

OPPORTUNITY 19

SCOPE WITHIN REACH

UNCERTAINTIES

Values, Systems

MEGATRENDS

Future Humanity

TRENDS

Cross-sectoral Partnerships
Culture & Heritage
Government Agility
Restoration
Urban Design

SECTORS IMPACTED

Communication Technologies & Systems
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Government Services
Immersive Technologies
Art, Media & Entertainment
Travel & Tourism

What if culture was integral to policymaking?

SAFEGUARDING CIVILISATION

Incorporate culture into public policy for effective conservation of both tangible (physical aspects of culture) and intangible (cultural practices and rituals) heritage.

WHY IT MATTERS TODAY

Number of sites on the UNESCO World Heritage List

93	Arab States
59	Italy
57	China
52	Germany
50	Spain
42	India
35	Mexico
33	United Kingdom
31	Russia

Culture forms the essence of our identity and shapes who we are.[474] Maintaining cultural diversity and richness ensures that future generations around the world have access to, and an understanding of, their cultural roots.[475] Education initiatives,[476] coupled with the strategic use of digital technologies to enhance access to cultural archives,[477] have the potential to shape future generations' understanding and knowledge and support more open-minded, culturally sensitive societies.[478]

Since 2016, the European and North American regions together have continued to lead in the number of world heritage sites inscribed each year on the UNESCO World Heritage List, followed by Asia and the Pacific.[479] By country, Italy (59), China (57), Germany (52), Spain (50), India (42), Mexico (35), United Kingdom (33), and Russia (31) have the greatest total number of sites[480] and the Arab states[N] (93) have the greatest percentage of world heritage sites in danger at 41%, followed by Africa at 25%.[481]

Through the UN's Sustainable Development Goals (SDGs), culture for the first time has been recognised as core to sustainable development,[482] particularly in cities (as delineated in SDG11.4[483]). Across other SDGs, culture is segregated across four themes: environment and resilience, prosperity and livelihoods, knowledge and skills, inclusion and participation.[484] Over two years (2017–2019), a collaborative effort involving numerous institutions and professionals led to the first draft of the Thematic Indicators for Culture in the 2030 Agenda.[485] The new framework for measuring and collecting cultural data is vital for advocating culture's role in the SDGs and integrating an evidence-based approach to development plans and policies at national levels and within United Nations Development Assistance Frameworks.[486]

The UAE uses cultural diplomacy and a myriad of collaborations to preserve its own heritage and celebrate diverse cultural landscapes. For example, in 2023, Harees – a traditional dish – was inscribed into the UNESCO Intangible Cultural Heritage list.[487] It also showcases its own culture through the UAE pavilion at the Expo 2020 site in Dubai,[488] that has remained open for visitors and residents to visit and was repurposed for the COP28.[489] The Louvre Abu Dhabi bridges cultural histories from the UAE, the Gulf and the Middle East to Asia, Africa, and Europe.[490]

[N] Includes Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, State of Palestine, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, and Yemen.

OPPORTUNITY

Cultural considerations are integrated into public policy for the effective conservation and preservation of cultural heritage – both tangible and intangible.[491] This can be achieved through the creation of local cultural frameworks and policy toolkits that identify aspects of cultural heritage considered significant especially where technology forms a core part of a new or amended policy supporting the paradigm shift of 'Intelligent Heritage Management'.[492]

Culture can be embedded in policymaking by using technology for the preventive maintenance of heritage sites, surveillance of heritage sites, promoting of preservation efforts, and dissemination of cultural heritage[493] and by broadening the scope for public participation,[494] government funding of initiatives,[495] education and awareness programmes,[496] and digital preservation of artefacts and traditions.[497]

BENEFITS

Embedding cultural heritage into policymaking supports efforts to preserve and conserve cultural heritage. A range of policies incentivise businesses to integrate cultural preservation initiatives. Helps position cultural diversity as a source of competitiveness, international cooperation and intergovernmental dialogue enhancing cross-cultural understanding.

RISKS

Cultural homogenisation could occur unintentionally if complexity and distinctiveness of cultural variations and heritage are oversimplified or standardised. Cultural preservation might be perceived as either outdated or holding onto the past as the reason failing to develop innovative policies that challenge the status quo. Inability to find a way to balance global with the local cultural values.

OPPORTUNITY 20

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Values

MEGATRENDS

Borderless World–Fluid Economies

TRENDS

Digital Communities
Future of Purpose & Work
Human–Human
Mobilising Innovation
Cross-sectoral Partnerships

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if we designed inclusive networking economies?

THE 'NETWORK' DIVIDE

As the network-based economy grows and creates opportunities for its participants, design inclusive networks through strategies that emphasise synergy, cooperation, and progress, reducing exclusive dominance and enhancing innovation.

WHY IT MATTERS TODAY

Over the past four decades, the internet has brought significant gains in productivity, access to information, and employment.[498] As a network connecting people and organisations locally, regionally and globally, the internet has facilitated global platforms, some of which are the largest companies in the world: for example (with their Global 2000 ranking and market value) Alphabet #7, $1.34 trillion; Microsoft #9, $2.3 trillion; Meta #31, $600 billion; Amazon #36, $1.08 trillion).[499] Between 2013 and 2018, the number of online platforms in 28 countries in the Organisation for Economic Co-operation and Development (OECD) doubled from 541 to 1,096.[500] Measuring online platform activity is complex because of the lack of uniform data across platforms and because many studies rely on single-platform data.[501]

Network models may also enable individuals and organisations to pool resources and gain competitive advantages. Individuals can use them to find jobs, become entrepreneurs, for equity crowdfunding,[502] and for investment opportunities.[503] Even when it comes to research and innovation, open, collaborative innovation networks enable the sharing of knowledge and the creation of valuable innovations for consumers and businesses,[504] allowing companies to expand beyond borders and focus on customers rather than physical assets.[505]

Decentralised autonomous organisations (DAOs), a form of network economy, have grown significantly with treasuries increasing from $380 million to $16 billion in 2021 alone.[506] By June 2023, DAO treasuries totalled just over $18 billion.[507] Even with governance and transparency challenges,[508] DAOs are building communities dealing with issues such as climate change and societal challenges. As an example, VitaDAO, a DAO focused on longevity science, raised $4.1 million in 2023 and distributed 30% of its tokens to supply its 9,000-member community.[509] Despite governance challenges, they are funding research into life-extending drugs.[510]

OPPORTUNITY

As network-based economies enabled by technology continue to grow, society gains the ability to collaboratively explore opportunities in research, innovation, and business and to solve a wide range of global challenges. Inclusive networks prevent a scenario in which only a select few dominate and benefit, preventing echo chambers and reducing negative implications for future growth, prosperity, and well-being.

Strategies to create inclusive networking economies include understanding the groups that are most likely to be left out and implementing mechanisms to identify and intentionally reduce relevant barriers to those participants likely to add value who otherwise may have been missed out.

BENEFITS

Inclusive networks bring diversity, knowledge sharing, and increased opportunities for cross-border, cross-sectoral collaboration, which leads to innovative solutions to challenges and new opportunities. Such networks empower grassroot initiatives and encourage transparency.

RISKS

Instead of fresh perspectives, dominant views within the network persist. Possible conflicts of interest that might even be economically motivated. Issues related to inequality could still persist.

Network models enable individuals and organisations to pool resources and gain competitive advantages

Between 2013 and 2018 the number of online platforms in 28 countries in the OECD doubled from

541

to

1,096

OPPORTUNITY 21

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Values

MEGATRENDS

Digital Realities

TRENDS

Brain–Computer interfaces (BCI)
Culture & heritage
Extended Reality
Future of education
Immersive Technologies & Wearables

SECTORS IMPACTED

Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Government Services
Immersive Technologies
Art, Media & Entertainment
Professional Services
Sports
Travel & Tourism

What if digital realities provided deep insights into history and culture?

STEPPING THROUGH TIME

Digital realities enhanced by brain–computer interfaces change how we experience history and culture, providing real-time immersive insights into the development of communities and cities helping to enrich education and preserve cultural heritage.

WHY IT MATTERS TODAY

Extended reality dates from the early 1800s and the original concept of binocular vision.[511] Fast forward to the 21st century. In 2016, Pokémon GO, an augmented reality (AR) game, enabled users to find and capture Pokémon in their surrounding environment through their mobile devices.[512] In 2018, a collaboration between Google and CyArk, a non-profit in California, created online three-dimensional (3D) models of 26 heritage sites in 18 countries based on CyArk's documentation of the sites since 2003 using digital photography, drones, and 3D lidar.[513] In 2021, during COVID-19 restrictions, UNESCO launched its World Heritage Site Virtual Tours[514] in collaboration with Google Arts & Culture to enhance access to 12 cultural sites.

Other countries have also brought historical sites to life through AR that dynamically and interactively overlays information onto physical reality in real time, including:[515]

- Tower of London, UK[516]
- Fort Siloso, Singapore[517]
- Japan's many heritage sites during Expo 2020[518]
- Saudi Arabia's Royal Commission for AlUla

Museums have also begun integrating AR as a means of bringing objects or scenes to life, adding layers of information from detailed explanations to 3D artist information and additional narrations.[519] Accessible by smartphone, AR is transforming traditional displays, making them more interactive and engaging and attracting diverse global audiences.[520]

By 2030, the value of the metaverse could reach nearly $5 trillion,[521] offering a $20 billion opportunity for the travel industry.[522] Innovations in AR technology have also increased, with patent growth doubling between 2018 and 2022.[523] The AR market is expected to grow at a CAGR of some 24% until 2035.[524]

2016

Pokémon GO enabled users to find and capture Pokémon in their surrounding environment through their mobile devices

2018

A collaboration between Google and CyArk created online 3D models of 26 heritage sites in 18 countries

2021

UNESCO launched its World Heritage Site Virtual Tours

OPPORTUNITY

Enabled by extended reality (XR), advanced machine intelligence, and haptic technologies – and in the opportunity's more advanced form, BCI – digital realities transform how we experience and preserve history[525] and culture. Mixed reality technologies enable people to visualise historical contexts alongside the physical reality, instantaneously bridging the past and the present.

Educators and researchers could leverage these technologies to make historical accounts, culture, and scientific and technological transformations more tangible and engaging for students and develop a new form of ethnographic research.

Tourists would be able to obtain a richer understanding of the evolution of communities through time, adding substantial depth and context to their travels, while residents may discover a renewed appreciation and connection to their locales. Future generations could maintain a connection to historical landmarks, fostering an understanding of shared pasts and promoting discussions about collective futures.

BENEFITS

Experiencing the past in a more immersive manner enhances our understanding of the past and the present, offering essential perspectives for tackling contemporary and future challenges.

RISKS

Varying interpretations of the past lead to the emergence of new divisions in society instead of laying the foundations for dialogue. Increased tourism to sites and cities that adopt digital realities for history and culture poses additional tourism-related environmental issues[526] and carbon emissions.[527]

By 2030, the value of the metaverse could reach nearly

$5 trillion

offering a $20 billion opportunity for the travel industry

OPPORTUNITY 22

SCOPE WITHIN REACH

UNCERTAINTIES

Systems, Values

MEGATRENDS

Future Humanity

TRENDS

Community-based Solutions
Community Engagement & Volunteerism
Human–Human
Longevity & Vitality
Mental Health

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Health & Healthcare
Immersive Technologies
Materials & Biotechnology

What if neighbourhoods were key to accessible mental health?

CIRCLE UP

Community-based mental health support groups provide an informal and accessible option for adults to seek and share mental health concerns, reduce stigma, create social support, and foster social cohesion.

WHY IT MATTERS TODAY

Mental illness can affect anyone, regardless of age, gender, location, income, social status, race, or religion.[528] Barring spikes in mental health conditions caused by crises such as the Covid-19 pandemic, one in eight people around the world live with a mental health disorder[529] and one in four receive treatment for anxiety.[530] In a survey conducted worldwide, nine out of ten people believe mental health is as important as, if not more important than, physical health,[531] but barriers that people face, such as bias and stigma, mean they often hesitate to seek help.[532] Depression is particularly prevalent, and mental disorders worldwide result in one in every six years of life being lived with a disability.[533] A mental health disorder becomes a disability when it lasts a long time and hinders meaningful participation and engagement in everyday life and society.[534]

Around the world, low-income countries face a shortage of mental health staff, with fewer than 1 per 100,000 people compared to over 60 in high-income countries.[535] The number of mental health workers in high-income countries already highlights the need for more professionals, a similar case is seen in the Middle East and North Africa (MENA) region, indicating a global challenge. While obtaining accurate data on mental health in the MENA region is challenging because of under-reporting, lack of diagnosis, or low awareness,[536] the 2020 WHO Mental Health ATLAS reports 50 workers per 100,000 in the UAE suffering from mental health problems, followed by Lebanon with 42 workers per 100,000 people, Bahrain and Qatar with less than 30 workers per 100,000, Kuwait, Oman, and Saudi Arabia with less than 20 per 100,000 people each, and Egypt, Jordan, and Morocco with less than 6 per 100,000 each.[537]

Peer support, which can be considered as a form of mental health service, plays a crucial role in mental health[538] as peers often provide access to additional services such as legal help, housing or food[539] while also making an impact on the effectiveness of mental healthcare.[540] While the effectiveness of peer support for adolescent (14–24 years) mental health care requires further study,[541] in a survey in the US, 81% of respondents (adults) were interested in getting access to mental health services through an online peer support community,[542] and the Alliance for Rights and Recovery (formerly the New York Association of Psychiatric Rehabilitation Services (NYAPRS)) found an average reduction of over 43% in inpatient services for clients receiving peer support.[543]

OPPORTUNITY

There is growing demand for more mental health funding at the community level.[544] Beyond that, self-supporting community support groups that partner with mental health professionals and take place within walking or accessible distance enable adult residents to develop personal and community social capital for mental health. This, in turn, increases resilience and fosters a willingness to seek additional help when mental health challenges move beyond unemployment, stress, anxiety, and general day-to-day related mental health challenges towards a diagnosable medical mental disorder that is treatable or managed with medicine.[545]

BENEFITS

Communities globally foster safe spaces for sharing mental health experiences, enhancing health and social bonds, reducing stigma, and building resilience.

RISKS

Group membership may deter some from seeking vital medical treatment, risking harm and potentially worsening their condition. Community members' privacy is not guaranteed and may become a barrier to reducing stigma.

Low-income countries face a severe shortage of mental health staff, with **less than 1 per 100,000 people compared to over 60 in** high-income countries

9 out of 10

people surveyed worldwide believe mental health is as, or more, important than physical health

OPPORTUNITY 23

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Values

MEGATRENDS

Boundless, Multidimensional data

TRENDS

Advanced connectivity
Artificial Intelligence
Human–Machine
International Collaboration
Mobilising Innovation

SECTORS IMPACTED

Chemicals & Petrochemicals
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
Immersive Technologies
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Professional Services
Utilities

What if (part) of artificial intelligence (AI) was a public good?

'PUBLIC' AI

A framework and toolkit for AI as a public good that specifically addresses the challenges of sustainability and on-going performance applied to specific use cases related to global challenges from climate and food security to healthcare and sustainable development.

WHY IT MATTERS TODAY

United States

The CREATE AI Act aims to establish a national online source for AI research accessible to academics, researchers, and start-ups

Sweden

is funding the development of a large language model in Swedish and other major languages in the Nordic region

UAE

The Technology Innovation Institute launched Falcon, an open-source generative large language model for business and research use

AI is on its way to becoming ubiquitous in daily life.[546] AI can enable automated preparedness and relief planning[547] and has already provided innovations in predictive healthcare and adaptive education.[548] AI can also discover new materials, supercharging technological breakthroughs.[549]

By 2030, AI is projected to add as much as $15.7 trillion to the world economy,[550] surpassing the combined current economic output of China and India, with 42% coming from enhanced productivity and 58% from consumer advantages.[551] However, technological advances in the past have had uneven impacts on the economy and the same is the case with AI. From concerns related to potential job losses and implications for workers' rights,[552] making AI's benefits universally available is challenging, particularly because of uneven connectivity and digital literacy.[553] In addition, there is a shortage of skilled talent and issues related to funding, cybersecurity, regulation, compliance, and ethics.[554]

Public goods are typically funded by governments and are generally not driven by profit motives.[555] A public good is non-exclusionary and its use by some does not diminish its availability to others.[556] The broader internet and generative AI, for example, can only partially be considered as public goods because they can be exclusive and their benefits may be limited by access and connectivity. Cross-sectoral international partnerships such as AI for Good[557] try to ensure that access to AI is ubiquitous worldwide, reducing digital divides, sparking innovative solutions to local challenges, and contributing to the social progress of humanity with access to AI offline.[558]

In 2022, Google's philanthropy arm committed to the UN's Sustainable Development Goals (SDGs) of the United Nations, inviting AI innovators and funding 15 projects, each receiving up to $3 million.[559] Google announced a $25 million grant in 2023, focusing on AI's social impact.[560] These projects include innovative AI applications such as a machine learning toolkit for rural midwives, satellite imagery analysis for wetland knowledge, and an AI learning coach for children in India.[561]

In the United States, the CREATE AI Act has been introduced to establish a national online source for AI research accessible to academics, researchers, and start-ups[562]. Sweden is funding the development of a large language model in Swedish and other major languages in the Nordic region.[563] And in the UAE, the Technology Innovation Institute (TII) launched Falcon, an open-source generative large language model for business and research use.[564]

OPPORTUNITY

While there are efforts to deploy AI 'for good',[565] AI is generally not –at least not yet – a good candidate for a public good because of broader implications. These include significant ongoing funding required for managing its diminishing effectiveness through ongoing tuning and support. Given AI's trajectory and expected impact, however, it is important to use it, where relevant, for the public good.

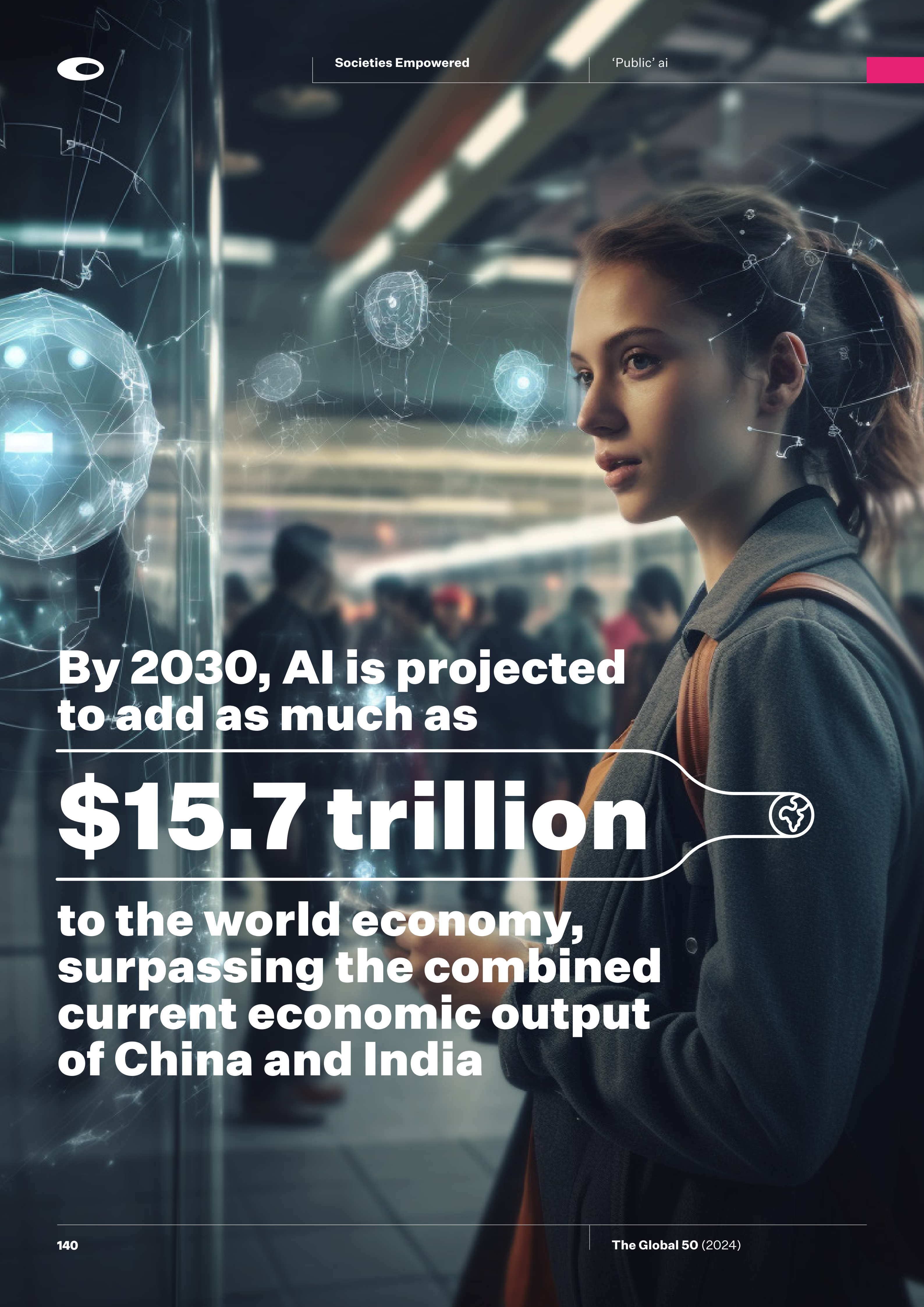
An alternative to making all of AI a public good would be to design a framework and toolkit for AI as a public good[566] that specifically deals with the challenges of sustainability and on-going performance that can be replicated for specific use cases. Such an approach would help harness AI's potential, along with a creative approach to funding and support as a public good. Use cases include climate action, food security, and health[567] to maximise its public benefit when and if needed.

BENEFITS

With some aspects considered a public good, AI can enhance the everyday professional and personal lives of people around the world.

RISKS

Rising costs and funding challenges make AI – as a public good – unsustainable. Intended goals are unmet because of ongoing access inequalities, infrastructure issues, and a persistent digital divide.



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to the world economy, surpassing the combined current economic output of China and India

OPPORTUNITY 24

SCOPE TRANSITIONAL

UNCERTAINTIES

Systems, Values

MEGATRENDS

Future humanity

TRENDS

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

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if the Global South inspired new models of growth, well-being, and climate response?

UNCONVEN-TIONAL PROGRESS

The Global South's unique pathways of progress offer global research and innovation opportunities which inspire new approaches to the response to global challenges and new models for growth, well-being, and climate response.

WHY IT MATTERS TODAY

There has been an ongoing call for a major shift in models of growth and progress for both people and the planet partly because gross domestic product (GDP) does not always equate to better well-being[568] and because there is insufficient clarity over the economic impact of climate policies or lack thereof.[569] One call is for a major shift in economic theory emphasising empirical, diverse models as economic shocks render traditional theories, with a predominant theoretical model, obsolete.[570]

The Global South stands to greatly benefit from technological adoption and collaboration. Connectivity and internet access are the building blocks of digitalisation,[571] and although some half of the world currently does not have access to high-speed internet,[572] latecomer development can follow new growth paths. This includes skipping some development stages or establishing entirely new trajectories based on existing knowledge and technology.[573] Developing economies may also have lower barriers to entry and fewer entrenched market dynamics, allowing them to take advantage of windows of opportunity emerging from major innovations (such as artificial intelligence (AI))[574] or changes in market demand.[575] Large populations of young people in parts of the Global South can drive entrepreneurship and take a leading role in establishing domestic and regional technology hubs.[576]

Modern innovations and collaborations will allow the Global South to foster an unprecedented degree of inclusivity and accessibility. For example, combining decentralised ledger technology[577] with digital investment marketplaces[578] can enable community-led, sustainable infrastructure (e.g. renewable energy systems). Public–private collaboration can reform digital spaces to bridge social divides.[579] Zooming out, south–south cooperation can further advance homegrown science and technology, build a foundation for technology hubs to flourish,[580] and ultimately catalyse economic transformation.[581]

Latecomer development can follow new growth paths, skipping some development stages or establishing entirely new trajectories based on existing knowledge and technology

OPPORTUNITY

The Global South pioneers unique paths for progress, offering rich opportunities for global research and innovation and aiding global policy making and transformation. Distinct challenges and perspectives in the Global South can be transformed into global solutions and policies, spanning higher education to approaches to well-being, to empowering future generations, and creating disruptive growth opportunities in emerging technologies.

Efforts to close economic gaps and digital divides in the Global South bring improvements to both the Global South and the rest of the world. Even if underlying motivations and structures differ slightly, a new, inclusive theoretical framework that recognises trans-regional variances could be possible, as is the case in ethical and responsible research and innovation.[582] The same could be applied in other economic, well-being, and climate policies.

BENEFITS

New models of progress allow people across the world to take advantage of emerging technologies and insights translated into better growth, well-being, and sustainability.

RISKS

Without adequate buy-in, understanding, and the necessary research funding, the translation of learnings and the global application of learned insights may be limited or improperly implemented.

SYSTEMS OPTIMISED

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

OPPORTUNITY 25

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Living with Autonomous Robots and Automation

TRENDS

Automation
Cross-sectoral partnerships
Human–Machine
International Collaboration
Mobilising Innovation

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Professional Services

What if sustainable development was central to robotics?

THE RESPONSIBLE ROBOT

Sustainable development drives robotics strategies and research, advancing sustainable agriculture, construction, disaster relief, and healthcare, aligning with global sustainable development goals.

WHY IT MATTERS TODAY

We are approaching an inflection point where various technologies – material science, battery life, network connectivity, and machine learning – will converge to make robots synonymous with social progress and problem-solving.[583] Next-generation robots will perform tasks with unprecedented precision and effectiveness.[584] They are also likely to be more affordable – the average cost of an industrial robot has fallen 50% over the past 30 years.[585]

Globally, robots and autonomous systems are projected to be adopted by 60% of companies by 2025.[586] Robots are already playing transformative roles in healthcare, agriculture, environmental sustainability, and construction.[587] Beyond these relatively more physical or industrial applications, robots can also fulfil intellectually demanding sustainable development needs, such as cooking meals,[588] providing education,[589] and even supporting the rule of law.[590] Globally, the robotics market reached approximately $25.2 billion in 2023 and is forecast to surpass $152.9 billion by 2033, growing with a CAGR of nearly 20%.[591]

Beyond their ever-improving affordability and physical functionality, robots' computational capabilities are enabling unparalleled human–machine cooperation and adaptability. The 2023 iteration of the AI for Good summit, the largest United Nations (UN) artificial intelligence (AI) event, showcased over 50 robots with uses in support of the UN Sustainable Development Goals (SDGs), most of which were capable of audibly and physically interacting with humans to better achieve their development objectives.[592] Neutral networks can allow humanoid robots to process and produce speech and facial expressions, responding seamlessly to humans or other stimuli.[593] The social robots market specifically is expected to grow from $5.64 billion in 2024 to $22.93 billion by 2029 at a CAGR of 32.4%.[594]

The average cost of an industrial robot has fallen 50% over the past 30 years

OPPORTUNITY

With growing applications and shrinking costs, robotics can become central to sustainable development.[595] Engineers can design affordable robots that automate a range of essential development stepping stones, from eliminating weeds in agriculture without pesticides[596] to more efficiently building and repairing infrastructure for housing and transportation,[597] providing humanitarian relief moments after a disaster,[598] and assisting in medicine delivery and rehabilitation programmes.[599]

Shifting the focus of robotics research, learning, and design in universities and research institutions to SDGs rather than merely automating tasks can bring many economic and societal benefits, influencing where investments are made. Instead of being seen as mechanisms for replacing or assisting humans in tasks like agriculture, construction, surgery, or medicine delivery, they contribute significantly to global development. Assembled with the ability to adapt to diverse contexts[600] and communicate in any language, next-generation robots can work alongside humans to accelerate sustainable development progress both locally and globally.

BENEFITS

Across various geographies, affordable robotic platforms offer scalable solutions that address SDGs previously considered daunting.

RISKS

Market incentives and investments do not do enough to make robots affordable for countries most in need of solutions for sustainable development, widening existing development gaps and inequalities and inhibiting sustainable development instead of enabling it.

OPPORTUNITY 26

SCOPE VISIONARY

UNCERTAINTIES

Systems, Collaboration

MEGATRENDS

Boundless Multidimensional Data

TRENDS

Artificial Intelligence
Cross-sectoral partnerships
Edge computing
FinTech
Government Agility

SECTORS IMPACTED

Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Financial Services & Investment
Government Services
Insurance & Reinsurance
Professional Services
Real Estate

What if we no longer needed monetary policy?

BALANCED BOOKS

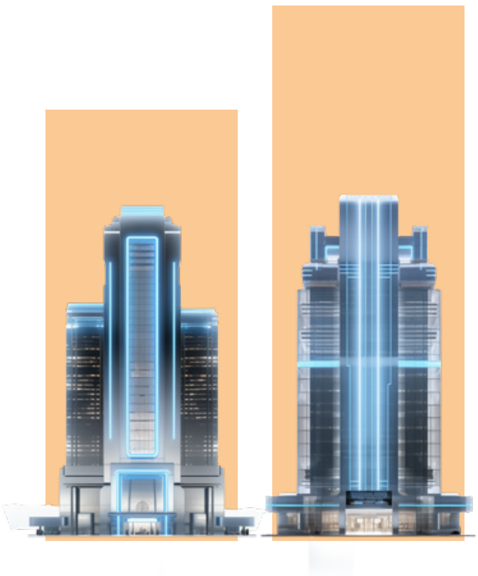
Advanced machine intelligence, edge computing, and the internet of things (IoT) make traditional methods like interest rate adjustments obsolete, enhancing financial stability and fostering sustainable growth.

WHY IT MATTERS TODAY

Monetary policy impacts on society. Lower interest rates can reduce savings returns, affecting retirees or those on a fixed income, while higher interest rates increase mortgage payments. Inflation raises the cost of living. Together with other shifts towards a new financial monetary system,[601] the previously independent roles of central banks and government fiscal policy are becoming increasingly interwoven.[602]

In the latest global financial stability report from the International Monetary Fund (IMF), global financial stability is fragile. Central banks may need to maintain tight monetary policies longer than expected because of high inflation, posing risks like asset repricing and banking vulnerabilities.[603] Global monetary policy synchronisation is decreasing as each nation faces unique economic conditions and opportunities for cooperation. In some cases, there is talk about shifting the stance on the global 2% inflation target to be higher in the short term.[604] Since at least the global economic crisis of 2008, lagging fiscal and monetary policy responses have resulted in heightened alerts and constant uncertainty, with calls to rethink approaches to monetary policy.[605]

Central banks are integrating artificial intelligence (AI) to support macroeconomic projections and forecasting[606] and are increasingly seeking to integrate new data sources, from real-time credit card data and social media data to Google Trends.[607] In 2019, more than 60% of central banks incorporated big data into their operational processes, and some 67% utilised big data in their policymaking decisions.[608]



In 2019, more than
60% of central banks
incorporated big data into their operational processes, and some
67%
utilised big data in their policymaking decisions

OPPORTUNITY

With advanced machine intelligence, edge computing, and the IoT, central banks become super-modellers continuously refining their approach, potentially making monetary policies, such as interest rate adjustments, obsolete. Addressing inflation, through various economic, social, and environmental inputs, allows central banks to accurately predict and automatically adjust to macroeconomic and national economic shifts.

This approach ensures real-time alignment of policy with economic realities, harmonising monetary and fiscal policies, strengthening financial stability, fostering sustainable growth, reducing the risk and costs of economic crises, and thus eliminating the usual tensions between those policies.[609]

BENEFITS

Mitigates risks to financial stability and promotes growth by monitoring shifts in real-time, fostering investment through interconnected national policies. Stable economies and price certainty enhance sustainable growth, benefiting all sectors and society.

RISKS

AI-guided monetary policy does not adequately address embedded bias or inaccurate information, leading to undesirable socio-economic outcomes.[610] AI-guided monetary policy may exacerbate global disparities favouring data-rich and technologically advanced nations. Exposure to cybersecurity threats and the potential for misuse leading to a financial shock that is challenging to resolve because of the AI black box.

Since at least the global economic crisis of 2008, lagging fiscal and monetary policy responses have resulted in

heightened alerts and constant uncertainty,

with calls to rethink approaches to monetary policy

OPPORTUNITY 27

SCOPE VISIONARY

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Boundless Multidimensional Data

TRENDS

Advanced Computing
Data Protection & Privacy
Edge Computing
Mobilising Innovation

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Communication Technologies & Systems
Cyber & Information Security
Data Science, AI & Machine Learning
Energy, Oil, Gas & Renewables
Government Services
Immersive Technologies
Logistics, Shipping & Freight
Art, Media & Entertainment
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if mobile edge computing (MEC) made data centres obsolete?

ZERO MARGIN

Mobile/multi-access edge computing (MEC) and the internet of things (IoT) merge to accelerate signal and data processing, enhancing real-time decision-making and enabling seamless, latency-free digital services across various sectors making centralised data centres obsolete.

WHY IT MATTERS TODAY

Introduced in 2014,[611] MEC decentralises cloud computing by placing computing and storage closer to the user or data source, at the 'edge' of the network.[612] This shift enhances the flexibility and reliability of data processing, offering faster real-time responses[613] and in some cases helping to meet data privacy and residency regulations that mandate storing certain data types closer to their origin.[614] The IoT generates vast amounts of data and MEC can efficiently process these data locally, reducing latency and improving decision-making.[615]

5G technology has already started to pave the way for diverse opportunities where it has been implemented, optimising service delivery and enhancing user experiences.[616] It is projected to contribute $13.2 trillion to the global economy by 2035 and create 22.3 million jobs.[617]

5G applications could add significant value across various sectors by 2030: $330 billion in global smart utilities, $15 billion in US industrial manufacturing, and $44 billion in Chinese healthcare.[618] Looking ahead, 6G will bring even higher speeds and bandwidth, fostering a fully integrated virtual metaverse and a wider range of smart devices.[619] It is expected that there will be an increase in internet-connected devices from 43 billion devices in 2020 to an estimated 51.9 billion devices in 2025.[620] Telecommunication companies can expect a 10% to 20% revenue increase from developing 5G-enabled connections and business-to-business use cases.[621]

OPPORTUNITY

A combination of MEC and the IoT, powered by advanced machine intelligence at the 'edge', significantly enhances data processing speeds. This transformation improves everyday life for both individuals and organisations by enabling immersive experiences and informing decisions in real time.[622] From transportation and agriculture to manufacturing, smart cities, environmental monitoring, and financial services, access to digital services becomes seamless and latency free.[623]

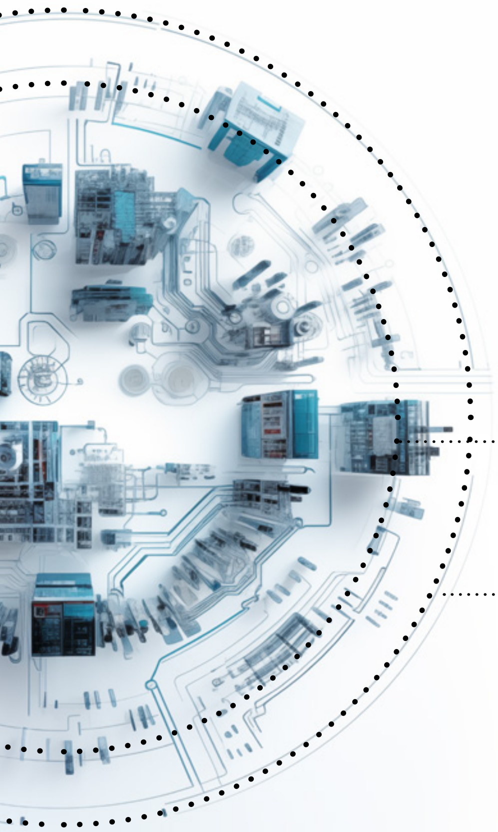
By shifting computing processes to the 'edge' and using device-to-device communication, multiple edge networks[624] connect and interact directly with each other to form an 'edge computing network'. This approach overcomes the need for hybrid clouds,[625] further reducing latency by bypassing the need for data centres entirely.

BENEFITS

Direct access to raw and processed data in real time increases opportunities for innovation in organisations and better day-to-day decision-making for individuals. Data privacy and security is improved.

RISKS

Edge networks may lack the robust physical security measures typically found in centralised data centres. This makes edge networks more susceptible to hacking and misuse.



Increase in internet-connected devices from

43 billion

devices in 2020 to an expected

51.9 billion

devices in 2025

5G applications could add significant value across various sectors by 2030

$330bn
in global smart utilities

$44bn
in Chinese healthcare

$15bn
in US industrial manufacturing

OPPORTUNITY 28

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Boundless Multidimensional Data

TRENDS

Advanced computing
Advanced connectivity
Air pollution
Automation
Urban Design

SECTORS IMPACTED

Agriculture & Food
Data Science, AI & Machine Learning
Energy, Oil, Gas & Renewables
Health & Healthcare
Infrastructure & Construction
Materials & Biotechnology

What if smart buildings evolved into smart urban ecosystems?

WALLS THAT TALK

Connected, eco-intelligent buildings form biomimicking ecosystems that optimise resources and minimise environmental impact to support sustainable, affordable, and healthier cities.

WHY IT MATTERS TODAY

Half of the world's population live in cities and 2.5 billion more people are expected to join them over the next 30 years.[626] Although they occupy only a fraction of the Earth's surface, cities account for some 67% of global energy consumption and more than 70% of greenhouse gas emissions.[627] Poorly designed or legacy urban areas are prone to pollution and associated health risks. Buildings contribute 30%–40% of emissions from cities[628] and building emissions must be reduced by 80%–90% to meet COP targets.[629]

In 2019, the Coalition for Urban Transitions highlighted the potential to reduce city emissions by 90% by 2050 using existing technologies.[630] Green buildings are energy-efficient, environmentally friendly, and often energy self-sufficient as they use data and analysis to enhance energy efficiency.[631] Powered by 5G and 6G, efficiencies can be further enhanced by managing the water–energy nexus with the internet of things (IoT).

At the same time, architects around the world are already looking at biomimicry to strengthen, cool, or heat buildings.[632] A design movement is underway that explores the integration of living organisms into building materials and services, with bioluminescent algae or microbial fuel cells that can generate energy and improve air quality as examples.[633] Progress in synthetic biology could also contribute to buildings that can adapt to environmental changes and self-repair,[634] while sustainable organic building materials can absorb carbon dioxide.[635]

As of January 2024, 28 cities have committed to the World Green Building Council's Net Zero Carbon Buildings Commitment, aiming for net-zero carbon by 2050 for all buildings.[636] Global smart city projects focusing on building innovation are limited[637] and less than 1% of buildings have so far reached net zero.[638]

Cities account for some

67% of global energy consumption

and more than

70% of greenhouse gas emissions

OPPORTUNITY

Advanced connectivity, advanced computing, and the IoT facilitate citywide biomimicry, making cities themselves, like forests, an ecosystem. Buildings would actively track and share data on energy, water, emissions, and people flows. With an aim for collective response and impact, advanced machine intelligence could make cities net positive, as opposed to buildings being net zero, by 2050. For instance, a building with net-positive energy from solar and thermal energy can automatically assist others across the city. Similarly, if a building's water usage hits a critical level, it can seek others with surplus harvested water for redistribution. A building can offset another building's increased emission levels.

To transform the city into a living ecosystem, every building must be equipped with new infrastructure, including sensors, actuators, and enhanced connectivity. This will also necessitate the redesign of current municipal, water, and energy systems.

BENEFITS

Accelerated achievement of city-level net-zero targets, reducing the city's total energy and resource consumption while also reducing and capturing emissions enhancing urban sustainability. Additionally, managing the interplay between water and energy in cities is likely to become more cost-effective.

RISKS

Implementing and maintaining connected and closed systems may be costly over time. Organic materials on buildings may deteriorate or become contaminated, posing potential environmental or health hazards. Allocating costs to individual buildings could disadvantage some. Cybersecurity threats in IoT systems may lead to inaccurate data, compromising intended objectives.

half of the world's population

live in cities

and

2.5 billion more people

are expected to join them over the next 30 years

OPPORTUNITY 29

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Borderless World - Fluid Economics

TRENDS

Artificial Intelligence
Human–Machine
International Collaboration
Legal Transformation
Mobilising Innovation

SECTORS IMPACTED

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

What if advanced machine intelligence enhanced global justice?

GLOBAL PRECEDENTS

Global working groups, using advanced machine intelligence, review the relevance and extract insights from existing global legal precedents[O] in anticipation of future scenarios in areas of transformative change such as climate, well-being, and digital realities enhancing global collaboration and adaptability and reducing legal uncertainty in an increasingly global and borderless world.

[O] In applicable jurisdictions.

WHY IT MATTERS TODAY

Currently, two-thirds of the world's population (some 5.1 billion people) lack meaningful access to justice.[639] Technology-based solutions play an important role in filling this gap.[640] Chatbots for example are increasingly being trained and deployed to provide free legal information and assistance.[641] For instance, the automated platform Do Not Pay has overturned more than 100,000 speeding tickets, saving low-income Americans millions of dollars.[642]

Lawyers are also increasingly using artificial intelligence (AI) for routine, labour-intensive tasks, such as contract drafting, legal memo writing, and document analysis.[643] A Goldman Sachs report estimated that generative AI could soon automate 44% of legal tasks in the United States.[644] In China, automated, online 'smart courts' built on big data, blockchain, and advisory and determinative AI systems have increased access to justice and enabled more efficient dispute resolution.[645] These developments bring about a new set of risks, such as digital data management, cybersecurity, and ethical and bias considerations.[646] However, many of these concerns can be addressed via concerted efforts to improve the algorithms, datasets, and regulatory frameworks underpinning AI legal proceedings.[647]

The rule of law is a robust system that includes laws, institutions, norms, and communities that are accountable, transparent, just, and accessible.[648] AI-powered legal services and simulated courtroom proceedings have the potential to democratise access to the law.[649] Developing and continuously improving equitable frameworks for the training and use of legal AI could ensure unbiased datasets and algorithmic accountability.[650]

Two-thirds of the world's population (some 5.1 billion people)

lack meaningful access to justice

OPPORTUNITY

Global working groups, whether under the International Bar Association[651] or other, are established to explore – using advanced machine intelligence – the entire body of legal precedents to evaluate their applicability in increasingly borderless areas of future transformation such as climate change, well-being,[652] and digital realities.

When legal precedents are part of a legal system, they promote efficiency and neutrality.[653] Particularly in complex global future scenarios that involve technological advances with unknown risks or with risks that emerge over time, applying advanced machine intelligence and legal precedents can improve every aspect of the rule of law. in the long run, it can create synergies across relevant laws and regulations, identifying opportunities for cooperation and optimisation across jurisdictions,[654] updated in real time.

BENEFITS

Besides operational efficiencies, facilitates collaboration and optimisation among relevant laws and regulations when it comes to climate change, well-being, and digital realities. Supports an increasingly borderless dispute settlement system.

RISKS

Efforts may sustain or even exacerbate existing inequalities and biases within existing legal precedents.[655] Lack of agreement on priority areas of future transformation and the need to collaborate or use advanced machine intelligence within judicial systems amongst public and corporate stakeholders.

Generative AI could soon automate 44% of legal tasks in the United States

OPPORTUNITY 30

SCOPE WITHIN REACH

UNCERTAINTIES

Systems, Values

MEGATRENDS

Future humanity

TRENDS

Cross-sectoral Partnerships
ESG & Beyond GDP
Generational diversity
Government Agility
Heritage & culture

SECTORS IMPACTED

Agriculture & Food
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Education
Energy, Oil, Gas & Renewables
Government Services
Health & Healthcare

What if every government appointed a chief sociologist?

SOCIOLOGIST-IN-CHIEF

Governments appoint a chief sociologist to advise on the impacts of policy on society and shape more effective and equitable policies to address the needs of communities and society in the future.

WHY IT MATTERS TODAY

Worldwide, countries are seeking to push policymaking beyond economic growth objectives to include sustainability and inclusivity.[656] Moreover, social change and uncertainty are constantly reshaping policy agendas.[657]

Two-thirds of Organisation for Economic Co-operation and Development (OECD) countries use a legal framework for policy evaluation, and half employ overarching policy frameworks to foster a culture of evaluation.[658] The frameworks vary, ranging from primary to secondary legislation, with countries like Germany, Mexico, Switzerland, and France making policy evaluation a constitutional duty.[659]

In some cases, however, it is not always evident how government spending improves people's lives. According to the United Kingdom's National Audit Office, in 2022 only 8% of major government projects were robustly evaluated, while 64% were not evaluated at all.[660] Besides evaluation, community engagement and imagination in policymaking can catalyse more proactive solutions to social challenges,[661] particularly in sustainable transitions.[662]

The UAE Government had previously created the post of Minister of State for Happiness in February 2016 and Minister of State for Government Development and the Future in July 2020.[663]

Two-thirds
of OECD countries use a legal framework for policy evaluation, while
half employ overarching policy frameworks
to foster a culture of evaluation

OPPORTUNITY

Chief sociologists can be appointed at national government level to play a key role in shaping policy at global, national, and regional levels with a focus on long-term social impact. This approach would prioritise proactive and future-oriented approaches that take social and behavioural aspects into consideration.

Policies that affect a substantial part of the population would be subjected to evaluation analysis, concentrating on social behaviours, cultural dynamics, and the needs of current and future communities. Aided by participatory methods, the chief sociologist can work with communities throughout the policymaking process.

BENEFITS

Government policies are optimised to be more effective and fair, benefiting society and future generations, ushering in a renaissance in the practice of sociology, and enhancing understanding of society and societal dynamics.

RISKS

Efforts prove to be resource-intensive, relying on inputs, processes, or data that may not be easily accessible. Despite significant efforts, evaluations that are perceived as subjective often fail to persuade others about the effectiveness of a particular approach to public policy.

According to the United Kingdom's National Audit Office, in 2022

only 8% of major government projects were robustly evaluated

OPPORTUNITY 31

SCOPE VISIONARY

UNCERTAINTIES

Systems, Technology

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Artificial Intelligence
Biotechnology
Government Agility
HealthTech
Real-time analytics

SECTORS IMPACTED

Chemicals & Petrochemicals
Government Services
Health & Healthcare
Materials & Biotechnology
Professional Services

What if advanced machine intelligence enhanced public trust in vaccine and drug development?

PHASTER PHARMA

Advanced machine intelligence enhances drug efficacy, discovers new applications for existing vaccines, and streamlines administrative tasks, aiding more efficient and more efficacious vaccines and drug development.

WHY IT MATTERS TODAY

Infectious diseases naturally occur frequently.[664] Some 60% of human infections originate from animals.[665] Fifty years ago, infectious disease deaths had decreased because of better health practices and innovations like vaccines and antibiotics.[666] The eradication of smallpox was announced in 1980 by the World Health Organization, but optimism waned with emerging threats like AIDS and antibiotic resistance, the resurfacing of old diseases like malaria and tuberculosis, and new outbreaks such as avian flu, SARS, Ebola, Zika, and COVID-19.[667]

New and improved drugs are key to healthcare but bringing them to market involves an exhaustive process that includes research, drug discovery, preclinical development, clinical trials, and regulatory approval. The entire process usually requires 10 to 15 years and hundreds of millions of dollars.[668] Once clinical trials are successfully completed and results are submitted for regulatory approval, it usually takes a year or more for a drug to be reviewed,[669] although this was challenged during the COVID-19 pandemic when the Pfizer and Sinopharm vaccines were launched in a record time of nine months[670] using mRNA vaccine technology.[671]

Artificial intelligence (AI) is rapidly transforming the pharmaceutical industry.[672] There is a growing deployment of AI in larger pharmaceutical companies for productivity, speed, and compliance.[673] It also holds promise for the future particularly when it comes to bioengineering.[674] Beyond that, from generative AI to scaling and machine learning operations that ramp up and standardise machine learning development within pharmaceutical settings,[675] future opportunities include natural language processing models that can quickly examine regulatory documents and allow pharmaceutical companies to find information and insights relevant to a given drug.[676] AI can also expedite data analysis within pharmaceutical clinical trials.[677]

OPPORTUNITY

Advanced machine intelligence can uncover new applications for existing vaccines and drugs that have been in use for years, enhance their effectiveness, and discover new vaccines and drugs that may not need to follow traditional clinical trials given extensive historical data. Advanced machine intelligence can also streamline administrative tasks undertaken by both pharmaceutical companies and regulators. Advanced systems can swiftly adapt or even inform the need for new regulations using the latest public health findings and cases that may uncover safety signals and patterns that are often challenging to detect, such as drug interactions and causes of lower efficacy.[678]

On the regulatory side, advanced machine intelligence means that regulatory bodies will transition from concentrating on administrative processes and clinical trials to regulating – and informing the public about – systems that underlie drug discovery, thus enhancing public trust.

BENEFITS

Improved pharmaceuticals align with the latest findings without waiting for new trials. Efficiency in administrative processes free up time and financial and material resources in both public and private sectors, allowing possible reallocation to healthcare initiatives and other priorities.

RISKS

Lack of algorithm transparency may inadvertently reintroduce issues that adversely affect public health and have a negative impact on public trust. The substantial amounts of data required may not be available or accessible. Regulating the AI underlying drug development requires regulators with knowledge and experience in AI.

Advanced machine intelligence can uncover new applications for existing vaccines and drugs that have been in use for years, enhance their effectiveness, and discover new ones

OPPORTUNITY 32

SCOPE VISIONARY

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Boundless Multidimensional Data

TRENDS

Advanced Computing
Bioinformatics
Biotechnology
Data Protection & Privacy
Nanotechnology

SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Insurance & Reinsurance
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Professional Services
Utilities

What if synthetic DNA met our need for indefinite and unlimited data storage?

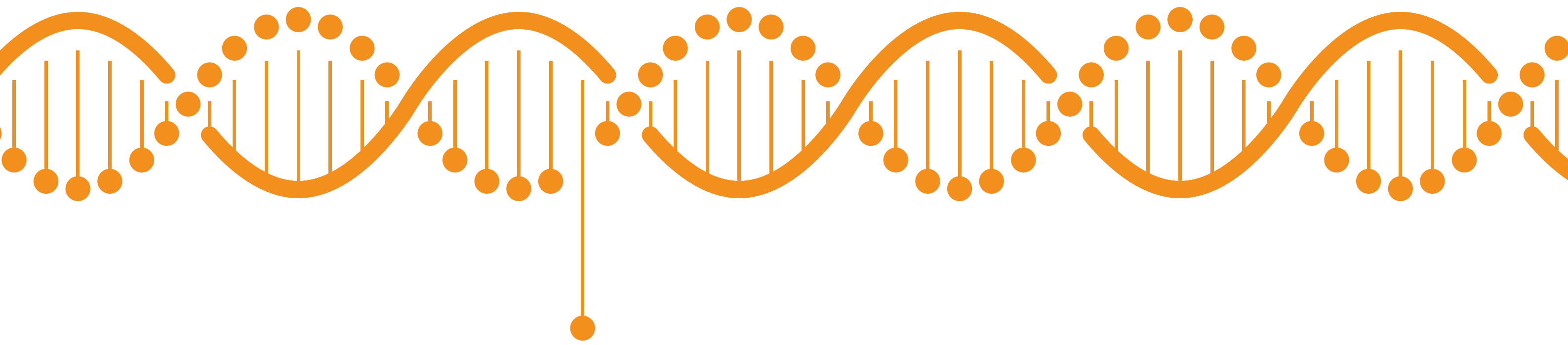
DATA HELIX

Synthetic DNA chips meet humanity's increasing need for durable, large-scale data storage, by offering a solution that can preserve information indefinitely while also reducing the environmental footprint of the digital world.

WHY IT MATTERS TODAY

The global datasphere (i.e. the total amount of data in the world) has increased dramatically from 2 zettabytes in 2010 to an estimated 97 zettabytes in 2022[679] and is forecast to increase by 300% by 2025.[680] However, current data storage media degrade over time, leading to data loss or corruption.[681] As data storage capacities continue to grow, managing and organising massive databases becomes complex – effectively retrieving and using such data can prove to be challenging.[682] Unstructured data represent up to 90% of all new enterprise data.[683] These combined factors put the global datasphere at risk of growing decay and inaccessibility. At present, data storage is a massive contributor to climate change: data centres are responsible for 2% of global greenhouse gas emissions.[684]

DNA is being researched as an alternative data storage mechanism. With a storage density of 2.2 petabytes per gram, a DNA hard drive the size of a teaspoon could store all the world's data.[685] These data can be translated into computer-readable files via DNA sequencing. In 2012, geneticists at Harvard University encoded a 52,000-word book in DNA.[686] Researchers at the Eindhoven University of Technology predict the first DNA data centre will be up and running in 5–10 years.[687] Cost decreases will be key to large-scale use – a 2 megabyte file currently costs $7,000 to synthesise and $2,000 to read.[688] Fluorescent labelling of DNA-stored data has been shown to facilitate better data sorting and retrieval.[689]



With a storage density of 2.2 petabytes per gram, a DNA hard drive the size of a teaspoon could store all the world's data

OPPORTUNITY

DNA can keep critical data needed for the functioning of society intact for millions of years[690] in contrast with current data servers, which require constant replacement.[691] Developments in DNA encoding and sequencing can enable speed increases and price decreases, making the technology viable as an everyday enterprise data storage solution. Scientists can develop alternative, less destructive read-write techniques for DNA storage, increasing data durability.

Beyond enhancing data longevity and storage volume, because of their compact footprint and low power demands after data sequencing, DNA data storage centres can have fail-safe measures and multiple backups at minimal economic and environmental cost,[692] reducing data decay and improving sustainability. Taking advantage of DNA's unique structural and biomolecular characteristics can enable next-generation approaches to cryptography and information security.[693]

BENEFITS

In theory, synthetic DNA provides indefinite, durable storage of an unlimited amount of data in less space and without interoperability issues.

RISKS

Accessing data is complex and limited. A lack of procedural and technical guard-rails risks saving massive amounts of erroneous data, leading to inefficiencies in access and use. There are interoperability issues related to historical data and global data sharing with nations where DNA storage is not used. DNA storage continues to be expensive, limiting implementation and potentially exacerbating global inequalities.

The global datasphere has increased dramatically from

2 zettabytes

in 2010 to an estimated

97 zettabytes

in 2022

OPPORTUNITY 33

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Collaboration

MEGATRENDS

Future humanity

TRENDS

Artificial Intelligence
Cross-sectoral Partnerships
Ideation, IP & Entrepreneurship
Mobilising Innovation
Open Data

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Data Science, AI & Machine Learning
Education
Health & Healthcare
Materials & Biotechnology

What if the future of innovation goes back to basic (research)?

RESEARCH 101

Advanced machine intelligence accelerates basic research and enhances its translation into applied research and tangible societal benefits, making nations around the world engines of innovation and productivity.

WHY IT MATTERS TODAY

Since 1981, gross domestic spending on research and development (R&D) in Organisation for Economic Co-operation and Development (OECD) member countries has hovered at just under 3% of gross domestic product (GDP).[694] In the 10 years prior to the COVID-19 pandemic, it was business R&D spending in the OECD that drove 75% of overall R&D growth.[695] In contrast, R&D spending in higher education – where basic research takes place – rose by only 1%.[696] The International Monetary Fund (IMF) estimates that a 10% increase in domestic research raises productivity by around 0.3%.[697]

From Einstein's Theory of Relativity underpinning GPS, to mRNA technology for vaccines, today's technologies descend from decades of basic scientific research.[698] Basic scientific research is a key driver of innovation and productivity.[699] Declining R&D investment in Australia, especially in basic research, hampers innovation, necessitating increased funding to match international levels.[700] In the United States, science agencies are approaching their lowest funding levels in 25 years.[701] Some 40% of projects funded by the European Research Council in 2007–2014 influenced European patents, with life sciences, physical sciences, and engineering influencing patents the most. While 50% of these patents are owned by private companies, universities and research organisations also hold significant shares, indicating a strong academia–industry linkage in innovation.[702]

Support for basic and creative research is a basis for innovation and thus a key driver of long-term prosperity.[703] The most innovative economies engage with key players from both private and public sectors, encompassing start-ups, research universities, and innovation clusters along with R&D spending.

Support for basic and creative research is a basis for innovation and thus a key driver of long-term prosperity

OPPORTUNITY

Advanced machine intelligence transforms basic research by enhancing efficiency and facilitating its transition into applied research that focuses on the key challenges that we face today and into the future.

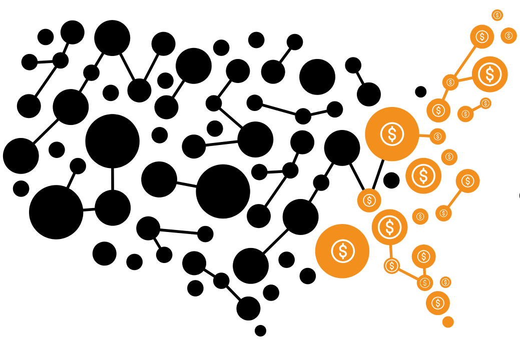
As advanced machine intelligence automates routine research tasks, funds can be redirected and employees reskilled to focus on basic research. Technological advances, for example in materials science are reducing the costs of research tools such as large particle colliders[704] and next-generation microscopes and telescopes[705] thereby enabling new research to be conducted in a non-traditional way. Combined with open science and an open mindset to integrate complex insights from diverse sources and collaboration across academia, industry, and government,[706] basic research can more rapidly produce scientific discoveries and translate them into applications for the benefit of society. Advanced machine intelligence can further assist discovery in fundamental science by helping design experiments, interpret data, and identify insights.[707]

BENEFITS

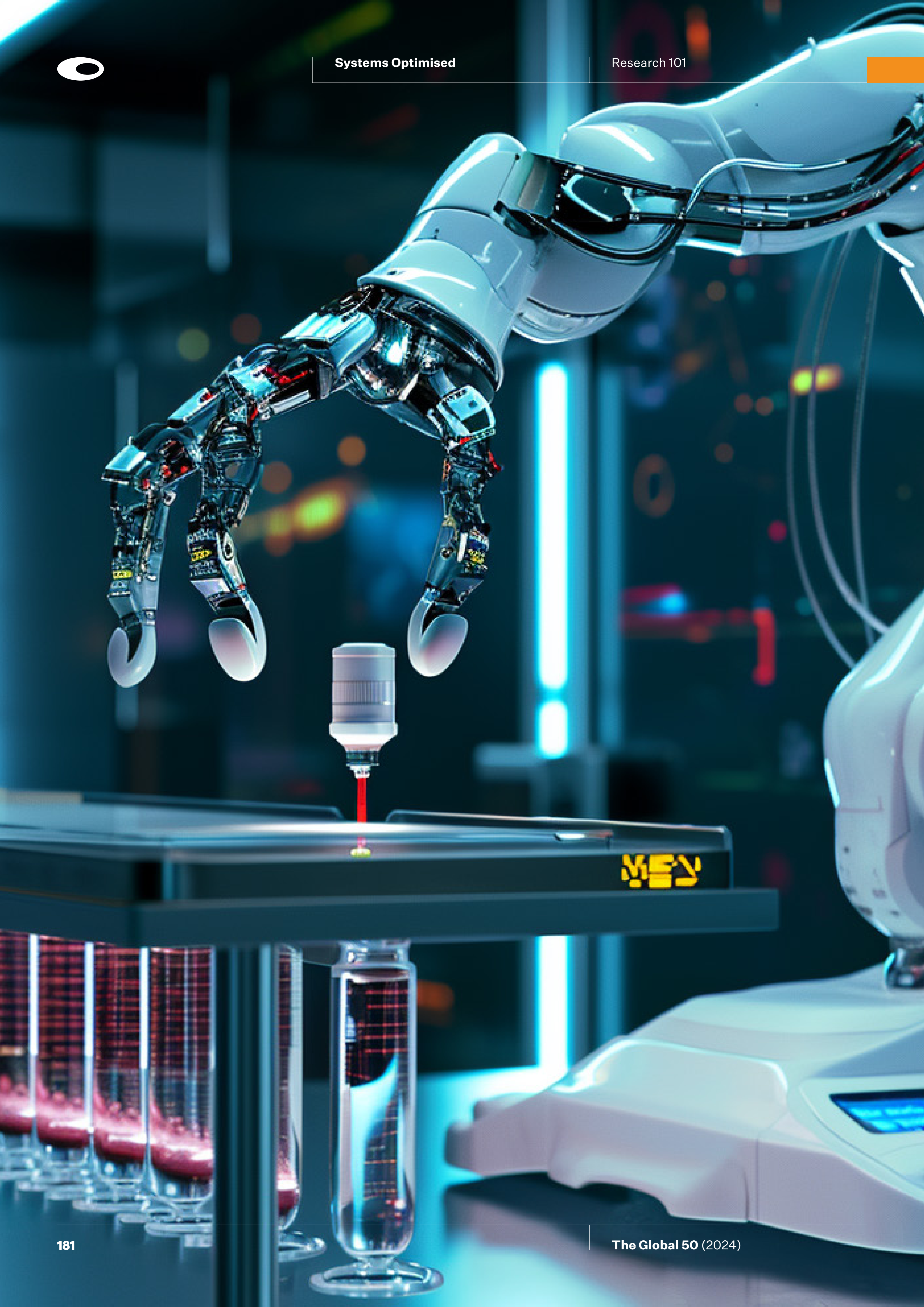
The basis for future breakthroughs is sustained, and long-term progress continues to advance in areas such as healthcare, renewable energy, transportation, infrastructure, and public policy. There is economic growth and educational advancement.

RISKS

International diffusion of basic research findings makes countries hesitate to increase, let alone approve, spending on basic research, limiting shared social progress. Data misuse and lack of transparency impact on individuals, organisations, and society, generating false outcomes and conclusions.



In the United States, science agencies are approaching their lowest funding levels in 25 years



OPPORTUNITY 34

SCOPE WITHIN REACH

UNCERTAINTIES

Collaboration, Technology

MEGATRENDS

Future Humanity

TRENDS

Artificial Intelligence
Cross-sectoral partnership
Future of purpose & work
Human–Human
Human–Machine

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Cyber & Information Security
Data Science, AI & Machine Learning
Education
Government Services
Health & Healthcare
Materials & Biotechnology

What if the future of advanced machine intelligence is interdisciplinary?

NO A'I' IN TEAM

An integrated, interdisciplinary, collaborative approach to AI education, research, development, and deployment leads to increased successful deployment of AI and associated public trust and tangible benefits.

WHY IT MATTERS TODAY

The World Economic Forum's Future of Jobs Report 2023 indicates that 75% of companies plan to adopt AI, leading to significant workforce changes.[708] By 2025, AI investment may reach $100 billion in the United States alone and $200 billion globally, with significant impacts on the global economy expected to start somewhere between 2025 and 2030.[709]

The success of AI depends on the underlying models, data, and training parameters. Despite advances, AI implementation failure rates are high, with up to 87% of projects never launched[710] and up to 80% facing challenges in data acquisition.[711] When deployed in healthcare, for example, a growing number of AI programmes are not being translated into better health outcomes, whether in terms of public health policy effectiveness, response to emergencies, or combating non-communicable diseases.[712] Many exhibit poor methodology and high risk of bias, hindering reproducibility and real-world clinical applications beyond the laboratory and testing results,[713] as seen in IBM's Watson Health and Google's DeepMind.[714] In addition, while AI is transforming healthcare and other areas, it faces challenges in sustainably integrating into society, whether because of challenges in interdisciplinary collaboration, transparency in decision-making or AI education and regulation.[715]

Despite advances, AI implementation failure rates are high, with up to

87% of projects never launched and up to 80% facing challenges in data acquisition

OPPORTUNITY

An interdisciplinary approach to AI development and deployment, considering ethical, environmental, and social impacts, from the requirements stage through to implementation, can produce beneficial outcomes,[716] positioning AI as a source of opportunities and fostering public trust in AI. Teams of experts or cross-disciplinary, global consortiums can enhance AI's adoption and demonstrate tangible benefits.[717] Broadening AI in higher education and research across all disciplines – beyond computer science and engineering – causes AI to become an interdisciplinary field that bridges the human–machine gap.[718]

BENEFITS

An interdisciplinary approach to AI means that the deployment of AI is improved and more likely to occur. With enhanced innovation, AI solutions will perform better, taking ethical and societal considerations into account. Advances in education and research support growth in the field and enhance public trust in AI.

RISKS

Interdisciplinary approaches to AI development and deployment may include excessive costs and slower turnaround times, resulting in the same quality outcomes and the deterrence of further investments, or resulting in a reaction to do things faster to recover costs.

OPPORTUNITY 35

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Materials revolution

TRENDS

Advanced computing
Advanced connectivity
Edge computing
Internet of Things (IoT)
New materials

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if new materials enabled internet of things (IoT) devices to run indefinitely?

LIMITLESS CONNECTION

Triboelectric nanogenerators (TENGs) enable an interconnected IoT across rural and urban contexts, powering digital twins, optimising policies without external power needs, and advancing the IoT towards energy autonomy.

WHY IT MATTERS TODAY

The IoT can make the unknown known through real-time data.[719] Valuable insights are extracted through a network of physical 'things' embedded with sensors, software, and other technologies to capture and exchange data.[720] Various IoT applications, such as smartphones, intelligent monitoring, home security systems, and wearable electronic devices, already facilitate aspects of human life.[721]

As advanced machine intelligence and connectivity continue to grow, the global IoT market is projected to grow to just over $12.6 trillion by 2025, [722]and spending on IoT ecosystems will exceed $1 trillion in 2026,[723] including, for example, 62% in manufacturing, retail, professional services, and utilities.[724] The number of IoT devices is expected to grow from 14.6 billion in 2021 to 30.2 billion in 2027.[725] However, wide implementation of the IoT calls for decentralised power supplies and wireless transmission technologies at scale[726] along with innovative ways of reducing network traffic and managing changing types of data.[727] The amount of unstructured data is expected to continue to grow by 20% every year to 144ZB in 2025[728] and 660ZB in 2030.[729]

Over the past decade, TENG development has progressed rapidly, covering a wide spectrum of voltage outputs that can be applied across devices.[730] Combining the effects of contact electrification and electrostatic induction, TENGs effectively convert mechanical energy from the living environment or materials – polymers, metals, and inorganic materials[731] – into electric power or signals.[732] TENG development is interdisciplinary, integrating materials science, chemistry, physics, electrical engineering, medicine, and more. Future TENG developments promise to push the IoT towards energy autonomy.[733]

The IoT can make **the unknown known** through real-time data

OPPORTUNITY

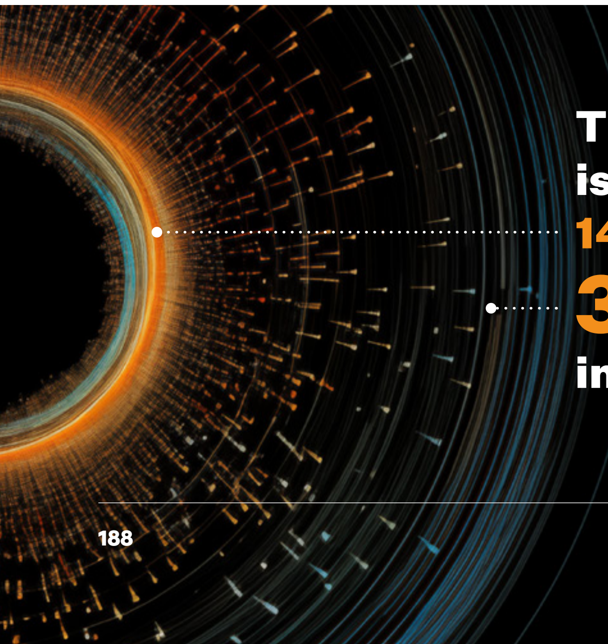
Devices powered by TENGs become part of an infinitely connected IoT capturing information from devices in vehicles, homes, telecommunication systems, and nature throughout rural areas, cities, and countries. With advanced machine intelligence, data from TENGs are used to power up digital twins and optimise policy and innovation outcomes without the need for an external power supply such as batteries or dependency on intermittent sources of power such as the wind and the sun.[734]

BENEFITS

Creative application of the IoT optimises efficiency and ushers in a new era of growth and well-being. Smart cities use the IoT to maximise environmental sustainability and efforts in environmental resilience and adaptation, and, as TENGs reveal detailed insights into supply chains, transportation, health monitoring, and weather patterns, among other areas, with advanced machine learning they also optimise goods and services delivery and offer innovative solutions to challenges.

RISKS

IoT applications expand at a pace that cybersecurity is unable to keep up with, creating new data and infrastructure security vulnerabilities. IoT networks, storage, and connectivity cannot handle high-velocity, big, and multidimensional data.



The number of IoT devices is expected to grow from 14.6 billion in 2021 to

30.2 billion

in 2027

OPPORTUNITY 36

SCOPE WITHIN REACH

UNCERTAINTIES

Collaboration, Systems

MEGATRENDS

Future humanity

TRENDS

Digital communities
Government Agility
International Collaboration

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Metals & Mining
Professional Services
Travel & Tourism
Utilities

What if foresight was a form of diplomacy?

AMBASSADOR OF SCENARIOS

Formal intergovernmental cooperation and mechanisms for scenario planning and foresight facilitate global cooperation to pre-emptively address global challenges by integrating futures and futures studies into global negotiation and diplomacy.

WHY IT MATTERS TODAY

Foresight is already part of the strategic planning and policymaking process of many governments around the world

UAE's Ministry of Cabinet Affairs

UAE's Government Development and the Future Office

Policy Horizons Canada

Centre for Strategic Futures in Singapore

Government Office for Science (GO-Science) in the United Kingdom

Foresight Network in the EU

National Research and Technology Foresight Project in South Africa

African Union's Agenda 2063

Global challenges such as climate change, sustainable energy, and pandemics require multipronged approaches involving both science and foreign policy, or science diplomacy.[735] This concept involves integrating scientific expertise into policymaking and has led to structural changes in governments which have adopted this approach.[736] By utilising science and innovation, anticipatory science diplomacy often engages with non-state actors (such as technology companies, civil society, and international organisations) to foster partnerships and attract investment.[737] However, recent trends have highlighted a gap between science and foreign policy, marked by cultural and professional divides between scientists and diplomats.[738]

The same could be said when it comes to futures. Global scientific and technology networks that increasingly address complex global future challenges need to better engage with national, international, and multilateral organisations that work on local and global challenges.[739] Likewise, in higher education programmes and research, the majority of political science and international relations research, particularly in the United States, remains anchored in studying the past, often overlooking the potential their research might have on shaping the future.[740] Academic publications in major journals predominantly focus on empirical evidence rather than addressing complex future-oriented questions.[741]

Nevertheless, there are already some examples of futures embedded in diplomacy and global action. The SDG Lab organises discussions with United Nations member states and international organisations that raise awareness of future science trends and build bridges between relevant actors and innovators in anticipation of predicted challenges.[742] Other examples include existing future-oriented multistakeholder consultation mechanisms that support global policymakers, such as the Intergovernmental Panel on Climate Change (IPCC) and the Global Partnership on Artificial Intelligence (GPAI).[743]

In addition, foresight is already part of the strategic planning and policymaking process of many governments around the world through horizon scanning of future threats and opportunities and navigating complex technology, science, and sustainable development landscapes. Examples include the UAE's Ministry of Cabinet Affairs[744] and the Government Development and Future Office,[745] Policy Horizons Canada,[746] the Centre for Strategic Futures in Singapore,[747] the technology horizon scanning service under the Government Office for Science (GO-Science) in the United Kingdom,[748] strategic foresight within the European Commission and the EU-wide Foresight Network,[749] the National Research and Technology Foresight Project in South Africa,[750] and the African Union's Agenda 2063.[751]

OPPORTUNITY

While foresight is already part of many governments' strategic planning and management, the practice of foresight more broadly implemented across nations could improve negotiation and coordination towards a common, long-term view.[752]

Countries could coordinate forward-looking bilateral and multilateral cooperation through a formal, intergovernmental mechanism to regularly evaluate drivers of change and imagine futures. Through the leveraging of varied backgrounds, countries could work together to develop anticipatory solutions and policies and advance coordination on solutions for complex challenges. This aids policy development and advances collaboration by promoting shared goals of growth, prosperity, and well-being before global challenges become acute,[753] and that is diplomacy.

BENEFITS

From climate change to evolving global supply chains, envision various potential futures with others around the world to prepare for significant, unforeseeable changes that countries might not otherwise anticipate on their own.[754] Futures diplomacy institutionalises evidence-based and proactive international cooperation, providing lasting solutions to current and future challenges that benefit countries.

RISKS

Improper use of foresight tools and models, together with country bias and preferred futures results in ineffective solutions, casting doubt on the effectiveness of foresight diplomacy.

OPPORTUNITY 37

SCOPE WITHIN REACH

UNCERTAINTIES

Systems, Technology

MEGATRENDS

Borderless World - Fluid Economics

TRENDS

Cross-sectoral partnerships
Future of purpose & work
Ideation, IP & Entrepreneurship
International Collaboration
Mobilising Innovation

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Metals & Mining
Professional Services

What if we had a global trade licence for small businesses and start-ups?

THE ‘GLOBAL’ PROTOCOL FOR SMALL BUSINESSES

An international treaty facilitates a global trade licence for small businesses and start-ups in multiple countries.

WHY IT MATTERS TODAY

Between 1950 and 2022, world trade volume grew 4,500% to over $24 trillion[755] and is expected to grow another 3.3% in 2024.[756] However, the rapid expansion of global trade has unfortunately not benefited everyone.[757] A $2 trillion trade finance gap[758] prevents smaller companies (particularly in the Global South) from maximising global trade opportunities.[759] The smaller the company, the more difficult it is for them to participate in international trade.[760] On top of this, the world is currently experiencing a widespread trade slump, with just 0.8% growth in 2023 due to a combination of inflation, high interest rates, and geopolitical tensions.[761]

For most exports, non-trade barriers (NTBs) are typically the biggest impediment to international trade and more than twice as significant as general tariffs for market access.[762] In proportion to value, the average cost of NTBs in the European Union is just over 13%, compared with under 2% for tariffs.[763] NTBs cost 1.6% of global gross domestic product (GDP), or $1.4 trillion annually.[764] Changes to the global trade architecture that benefits developing and emerging economies can reduce the need for humanitarian aid,[765] and mutual recognition of export standards could facilitate the elimination of NTBs.[766]

Some 99% of businesses in the United States are small businesses employing just over 45% of workers.[767] In the United States, one in five businesses fail in their first year, nearly half within five years, and nearly two-thirds by the 10-year mark.[768] In 37 of 49 economies surveyed in the Global Entrepreneurship Monitor (GEM) 2022/2023 Report, over 40% of potential entrepreneurs fear failure, with more than 60% in Saudi Arabia and just under 60% in China, which partly hinders the launch of business startups.[769] In contrast, just under 40% in the United Arab Emirates and just under 20% in the Republic of Korea share this fear.[770]

Some 99% of businesses in the United States are small businesses employing just over 45% of workers

OPPORTUNITY

An international treaty facilitates a global trade licence for small businesses and start-ups in multiple countries. With a single application, small businesses and start-ups can apply to set themselves up in multiple cities or countries. Limited to a few years, their registration adheres to common requirements across respective cities or countries, including, but not limited to, a minimum number of workers or business activities to prevent 'brass plate' companies.

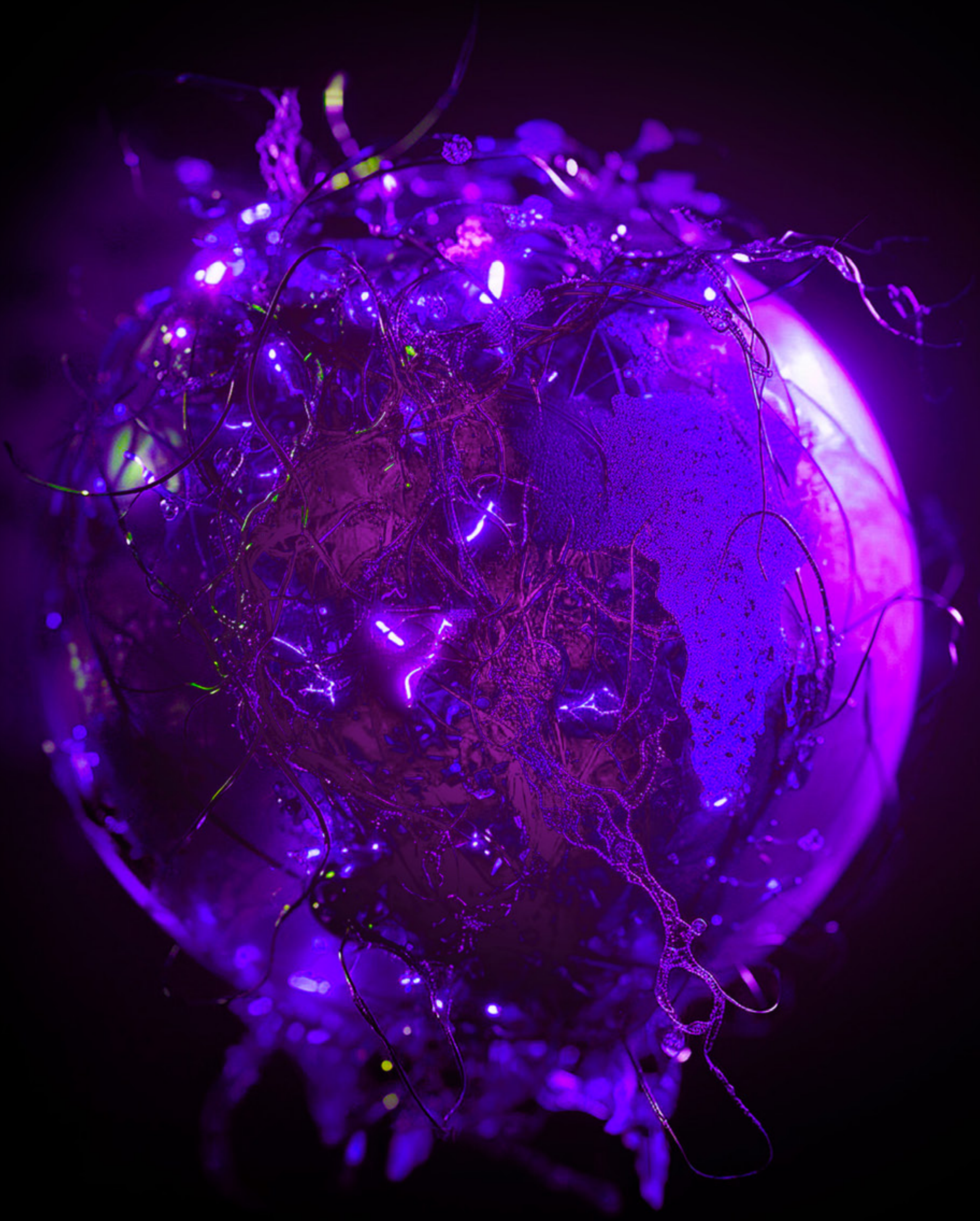
More than a company branch, this licence lowers barriers to setting up a business and enables borderless trade. Blockchain-powered supply chains would facilitate automated customs clearance and enhance transparency and trust, offering greater financial flexibility.[771] Complemented by the World Trade Organisation's (WTO) Trade Facilitation Agreement (TFA),[772] these efficiencies and reduced costs could significantly boost trade and employment. With more than a single regulator or authority, a legal issue in one country could prompt an alert in another, shortening the time to detect anomalies.

BENEFITS

Business corridors for small businesses and start-ups across countries and industries offer global market access, boosting entrepreneurial expansion, capital inflows, and supply chain resilience in an increasingly borderless world.

RISKS

Establishing a business remains expensive and complex because of diverse global regulations, risking the emergence of 'brass plate' companies that exist only in name, with no real presence or employment, potentially facilitating money laundering activities.



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 and aid the transformation of humanity to new digital and non-digital realities.

OPPORTUNITY 38

SCOPE TRANSITIONAL

UNCERTAINTIES

Systems, Values

MEGATRENDS

Future Humanity

TRENDS

Future of education
Future of purpose & work
Generational & cognitive diversity
Longevity & vitality
Mental health

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if young people were paid to explore careers and retirees never retired?

FLIPPING THE CAREER LADDER

Reversing career trajectories: ‘pensions’ for young people, a growth period, then ‘internships’ for retirees encourages dynamic, diverse hiring and societal engagement across generations.

WHY IT MATTERS TODAY

By 2050, more than 4 in 10 individuals in Organisation for Economic Co-operation and Development (OECD) economies are likely to be over 50 years old.[773] By 2050, the average life expectancy around the globe is expected to reach 77.2 years,[774] and the number of people aged 80 years or over is expected to triple, reaching 426 million.[775]

However, according to a 2023 Pew Research Centre survey, it is senior workers who most enjoy working.[776] A survey of 34 global markets showed that in 2023 there was a significant decline in the number of people who believed they would retire before the age of 65 – from 61% in 2022 to 51% in 2023.[777] Extending working lives could potentially boost gross domestic product (GDP) per capita by 19% by 2050 in OECD countries.[778]

In a survey on longevity conducted by the World Economic Forum and Mercer, a substantial portion of globally surveyed educated professionals reported feeling isolated (40%) and lonely (30%) even though 80% had a reliable circle of friends.[779] The World Economic Forum has highlighted loneliness as a public health crisis, equating its impact to smoking 15 cigarettes a day.[780]

Concerns about the future of work, particularly for young people, are rising in the face of technological advances and artificial intelligence.[781] Coupled with this is a loneliness epidemic affecting not only retirees but also the younger generation.[782]

By 2050,
more than 4 in 10
individuals in OECD economies are likely to be over 50 years old

OPPORTUNITY

With longer lifespans and the recognised positive impacts of societal engagement in later years,[783] reversing traditional career trajectories could be an opportunity. Young early career entrants start with a ‘pension’ phase, which is followed by a period of growth (as today), before culminating in ‘internships’ for retirees.

They would be provided with a basic income, aiding them as they explore various career options within a time-limited framework. Conversely, older individuals have the opportunity to embark on ‘internship’ roles, keeping them engaged if they so choose. This approach not only shapes future workforces but also ensures that older generations remain actively involved. Designing workplaces as such would enhance intergenerational knowledge transfer and increase both productivity and organisational resilience.[784]

BENEFITS

Early career entrants explore interests without income pressure, focusing on achievements. Retirees remain engaged, leading fulfilling lives. UBI investment yields diverse returns and even aids charity hiring, which often struggles to attract early career entrants.

RISKS

Experience gaps for early career entrants and challenges in securing full-time roles later on. Challenges in securing suitable ‘internship’ roles for retirees. Reduced career motivation and less self-reliance.[785]

Concerns about the future of work, particularly for young people, are rising in the face of technological advances and artificial intelligence

OPPORTUNITY 39

SCOPE VISIONARY

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Living with Autonomous Robots
and Automation

TRENDS

Artificial Intelligence
Automation
ESG & Beyond GDP
Future of Purpose & Work
Human–Machine

SECTORS IMPACTED

Automotive, Aerospace & Aviation
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Financial Services & Investment
Health & Healthcare
Materials & Biotechnology
Art, Media & Entertainment
Real Estate
Travel & Tourism

What if the future knowledge economy was shaped by the welfare of societies?

THE GOOD ECONOMY

In a distant future that will pivot on advanced machine intelligence and major technological breakthroughs, the future of the knowledge economy will revolve around the sustained well-being of societies where education and innovation thrives. This era will be shaped by globally aligned societal values about technology, harmonisation of related laws and regulations, and technological progress that enhance quality of life and access to services towards the common good.

WHY IT MATTERS TODAY

As technology advances, from advanced connectivity, edge and quantum computing to more AI applications being transformed into general purpose technologies,[786] people will need to become upskilled in using machines for increased productivity.[787] AI challenges fundamental aspects of how humans have traditionally gained and used knowledge. Most people can, should they choose, use AI tools to communicate and for creativity.[788] AI tools have the potential to take over roles traditionally held by humans, from answering customer service enquiries to assembling legal documents.[789] In the United States, nearly 30% of professionals say they have already used ChatGPT or other AI tools for a work-related task.[790] In the future, people are more likely to use AI-powered chatbots than search engines[791] and education will most likely be transformed.[792] Between 2013 and 2021, annual scholarly publications on AI more than doubled[793] and corporate investment increased 30-fold.[794]

In today's knowledge economy, work processes are linked to how the human mind develops ideas, making knowledge growth central to economic activity.[795] Throughout economic history, the most advanced production practices have not always initially been the most efficient or accurate, but have inspired widespread change across sectors.[796]

As the knowledge economy has challenged the concept of diminishing marginal returns through continuous innovation expanding both supply and demand potential,[797] so will technological breakthroughs and advanced machine intelligence.

In the United States, nearly 30% of professionals say they have already used ChatGPT or other AI tools for a work-related task

OPPORTUNITY

The future of the knowledge economy is a system of production and consumption that focuses on the sustained well-being of societies, blending equity, resilience, and and sustainability. Competitiveness will be based on who best protects the future interests and welfare of future societies. Emphasising human–machine collaboration, people will be encouraged to spend more time developing unique perspectives on, and solutions to, challenges beyond those the machine can find.[798]

In an increasingly automated workplace, job roles will evolve to include managing and supervising intelligent systems, ensuring compliance, quality, and effective governance and reporting on performance with transparency and accountability. Analytical skills and creative thinking will stand out as the most important skills for workers.[799] The future knowledge economy emphasises creativity, imagination, experimentation, and a dynamic human–machine interaction and technological advances[800] that will drive global models of education and life long learning.

BENEFITS

Merging human–machine creativity leads to new solutions to global challenges and a creativity revival. This maximises productivity, ensuring sustainability and prosperity for today's and future generations. People will experience a life of growth, prosperity, and well-being at its best.

RISKS

The reliance on advanced machine intelligence may result in people having a diminished set of practical skills and knowledge, particularly on the rare occasion when access to advanced machine intelligence is disrupted. Those without access to advanced machine intelligence may fall behind both economically and socially. Not all individuals and nations will prefer globalised economies for growth, prosperity, and well-being.

A future knowledge economy is a system of production and consumption that is focused on safeguarding societies' long-term welfare, blending equity, resilience, and sustainability

OPPORTUNITY 40

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Values

MEGATRENDS

Digital Realities

TRENDS

Advanced Computing
Advanced Connectivity
Artificial Intelligence
Extended Reality (XR)
Human–Machine

SECTORS IMPACTED

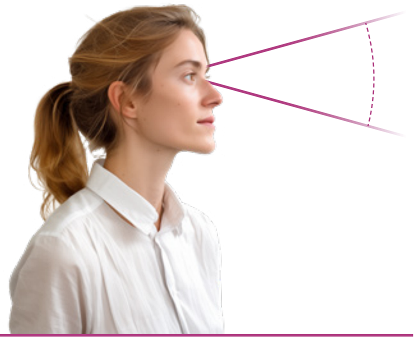
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Travel & Tourism

What if contactless haptics transformed gaming and healthcare?

SEEING IS FEELING

GenAI

Contactless haptic technology enhance gaming, digital realities, healthcare, and everyday life, offering immersive, wearable-free experiences for both sighted and visually impaired individuals.



Over
2.2 billion people
have near or distance sight impairment

WHY IT MATTERS TODAY

Over 2.2 billion people have near or distance sight impairment.[801] This represents a significant global economic burden, with annual productivity losses estimated at over $410 billion.[802] Over 75% of blind and partially sighted individuals of working age are unemployed.[803] As populations age globally, eye care needs will grow rapidly.[804] By 2050, up to 895 million people could have severe distance vision impairment, of whom 61 million will be blind.[805]

Skin tactile receptors are crucial for sensing and movement[806] and to replicate them various artificial tactile sensors – for example, capacitive, piezoresistive, and magnetic – are used in wearables, prosthetics, and robotics, enhancing dexterity and monitoring.[807] A variety of wearable devices (e.g. gloves, shirts, hats) ultrasonically transmit mid-air haptics to the wearer's skin, instantly 'reading' close and distant visual information (e.g. text, lines, shapes) as Braille.[808]

However, besides wear and tear and reliance on wireless communication, wearables today are not complete for tactile sensing in all parts of the hands like the palm and fingertips.[809] Skin devices face longevity issues from skin renewal and external factors. Wearables disrupt the tactile experience, and bulky gloves strain muscles.[810] Haptic technology in the case of vibrotactile technologies uses over 200 unique vibrations or motions to provide people with an artificial sense of touch.[811] Although minimally invasive surgery, such as laparoscopic procedures, has increased more than four and half times since its introduction in 1980,[812] with some 310 million major surgeries occurring worldwide annually,[813] no tactile sensing product has yet achieved commercial success.[814] This lack of tactile feedback risks tissue damage[815] resulting from more force in tissue handling and less sensitivity.[816]

Haptic technology consists of systems and devices that simulate touch, providing tactile feedback in various forms like vibrations, pressure, or temperature changes.[817] Haptic technology is crucial in gaming, virtual reality, healthcare,[818] and automotive industries. The haptic technology market, valued at $16.8 billion in 2022, is expected to reach $47 billion by 2030, growing at a CAGR of 13.7%.[819]

OPPORTUNITY

Advanced machine intelligence and advances in contactless haptic technologies transform experiences from gaming, digital realities, and amusement rides to surgeries, engineering, manufacturing, education, and everyday life for the visually impaired. Without the need for wearables, this could make interacting with our real and virtual surroundings more engaging and seamless.[820]

Advanced haptic technologies, also called mid-air haptics, use ultrasound, electrostatic forces, light-induced heat, or electric plasma, and even all four, for touch sensations without direct contact. They are contactless as the technology can project feedback onto the user's body, adapting to their movements without physical contact.[821] Like contact-based haptics such as vibrotactile devices, contactless haptics have more complex challenges including varying intensity, rapid updates, and the need to align patterns with moving body parts.[822] Algorithms are improved for optimised user perception and integration of multimodal inputs, identifying effective patterns beyond trial and error.[823]

Over 75%

of blind and partially sighted individuals of working age are unemployed

BENEFITS

Enables people with vision impairment or blindness to fully engage with their surroundings, ensuring their independence, quality of life, and productivity. Navigating public transport, watching television, and other everyday tasks involving visual information become much more accessible. Public space hygiene[824] and surgical precision avoiding inadvertent tissue damage[825] also improves.

RISKS

Data privacy, ethics, and potential misuse leading to false user perceptions. Connectivity disruptions could severely impact on services using contactless haptics, increasing the risk of causing inadvertent harm.

The haptic technology market, valued at $16.8 billion in 2022, is expected to reach $47 billion by 2030

OPPORTUNITY **41**

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Values

MEGATRENDS

Future Humanity

TRENDS

Artificial Intelligence
Digital Communities
Future of Purpose & Work
Human–Machine
Transforming Education

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
Immersive Technologies
Art, Media & Entertainment
Professional Services

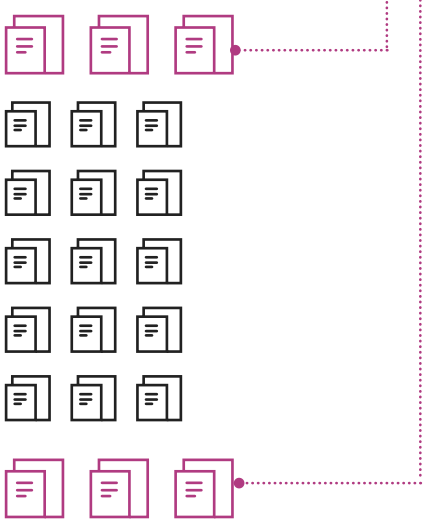
What if we had a Turing declaration for human intelligence?

THE POST-TURING ERA

A declaration of original thought and the extent of human–machine intelligence ushers in a new era of innovation and creative thinking, encouraging greater accountability and integrity.

In less than three years, while GPT-3 performed in the bottom 10% across 30 academic/professional exams,

GPT-4 scored in the top 10%



WHY IT MATTERS TODAY

The Generative Pre-trained Transformer 3 (GPT-3) language model was developed by OpenAI in 2020, since then, the progress has been rapid. With less than three years between the relaease of GPT-3 and GPT-4,[826] while GPT-3 performed in the bottom 10% across 30 academic/professional exams, GPT-4 scored in the top 10%.[827] GPT-4 handles image and text inputs, processing 25,000 words compared with GPT-3.5's 4,000 and is both 40% more accurate than GPT-3[828] and up to 60% less likely to make things up than GPT-3.5.[829]

GPT-3 was used to train OpenAI's ChatGPT, a form of generative AI (GenAI), a type of algorithm that can produce content based on user prompts.[830] Launched in late 2022, ChatGPT gained over 1 million users in just five days, reaching more than 100 million users in late 2023.[831] Handling multiple modes for inputs and outputs, such large-language-model-based tools can now write poems or letters in seconds[832] and generate images[833] and are expected to generate video and audio content in the future.

GenAI will transform industries, from consumer-packaged goods, financial services, and healthcare services, to media, telecommunications,[834] and academia.[835] In the near term, GenAI could contribute $4.4 trillion in economic value, boosting productivity and industry growth. Some 80% of current AI research is focused on GenAI.[836]

A variety of challenges are emerging because of the difficulty of distinguishing human-content from machine-generated content. The rise of GenAI brings legal issues of copyright violation, ownership of AI-generated content, and the use of unlicenced content in training data.[837] GenAI can be used to clone human voices and create hyper-realistic images and videos, resulting in serious implications for misinformation.[838]

The Turing test – created by Alan Turing in 1950 – asserts that if a machine can engage in a conversation with a human without being detected as a machine, it has demonstrated human intelligence.[839] Recently, there have been claims that some AI tools, including Google's LaMDA (Language Model for Dialogue Applications)[840] and OpenAI's ChatGPT,[841] have passed the Turing test.

OPPORTUNITY

As technology increasingly blurs human and machine intelligence making the Turing test obsolete, a declaration – or formal statement or assurance – about the originality of thought and extent of human–machine intelligence promotes accountability and integrity[842] and indirectly ushers in a new era of innovation and creative thinking,

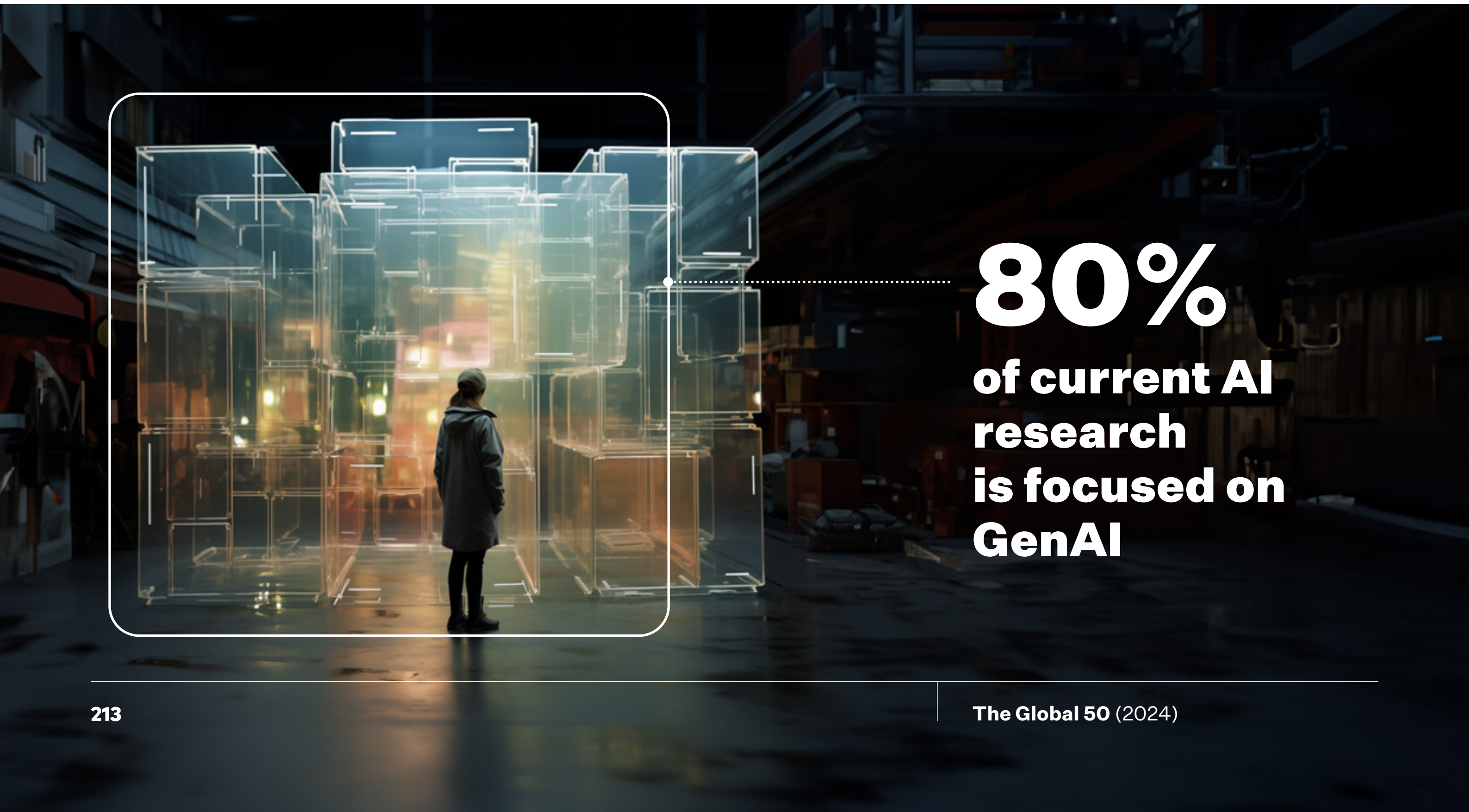
Although expanding the Turing test to encompass broader aspects such as content ownership, authorship, contextual understanding, and AI manipulation is important, the rapid pace of technological advances makes this approach extensively challenging.

BENEFITS

Human intelligence becomes more valuable, and education and research increasingly shift focus to critical thinking and community engagement. Humans make the best use of technology boosting productivity through transparency.

RISKS

People increasingly prefer machine-generated content, leaving original thinkers and content creators with limited impact and return. The human voice is lost among the machines.



80%

of current AI research is focused on GenAI

OPPORTUNITY 42

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Pushing the Boundaries on Energy

TRENDS

3D Printing
Artificial intelligence
Net Zero
Transforming Energy
New Materials

SECTORS IMPACTED

Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Energy, Oil, Gas & Renewables
Health & Healthcare
Immersive Technologies
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Metals & Mining
Real Estate
Utilities

What if the future of batteries is internal?

PERPETUAL POWER

Innovative battery energy storage redesign using non-lithium or minimal lithium materials and advanced machine learning offers opportunities for flexibility, reliability, and sustainable applications in various sectors.

WHY IT MATTERS TODAY

Between net-zero commitments by companies[843] and nations[844] around the world, along with the global push for affordable, reliable, decarbonised electrical systems,[845] the need for energy storage solutions will continue to grow at a CAGR of 8.5%, reaching nearly $360 billion by 2028.[846] Soaring demand for electric vehicles,[847] coupled with growth in solar and wind energy installations – as well as the need to address intermittent output – will further increase demand.[848]

Batteries, especially lithium-ion (Li-ion) batteries, remain the most common energy storage method.[849] Energy storage through batteries is key to decarbonising the transport and mobility sectors and supporting off-grid energy.[850] Australia, Chile, and China are the largest producers of lithium,[851] and Li-ion battery demand is expected to grow by 27% annually to 2030 to reach 4,700GWh of energy.[852] Over 80% of this growth is driven by demands in mobility, and nearly 40% of that demand comes from China.[853] However, besides degrading over time,[854] overheating, and limited storage capacity,[855] Li-ion batteries – with nickel and cobalt – are considered rare Earth metals[856] or critical minerals[857] which require extreme forms of mining and extraction with environmental and social impacts.[858]

Batteries, especially lithium-ion (Li-ion) batteries, remain the most common energy storage method

OPPORTUNITY

Beyond new rare raw materials, superior, cost-effective batteries may be possible through innovative battery redesign using non-lithium, easily available materials.[859] Enabled by advanced machine intelligence,[860] batteries are redesigned internally to optimise energy generation and storage combining materials and leading to improved performance whether in decarbonised transport and electric vehicles,[861] electric aeroplanes,[862] or grid-connected or off-grid energy powering remote education, work, and health services.[863]

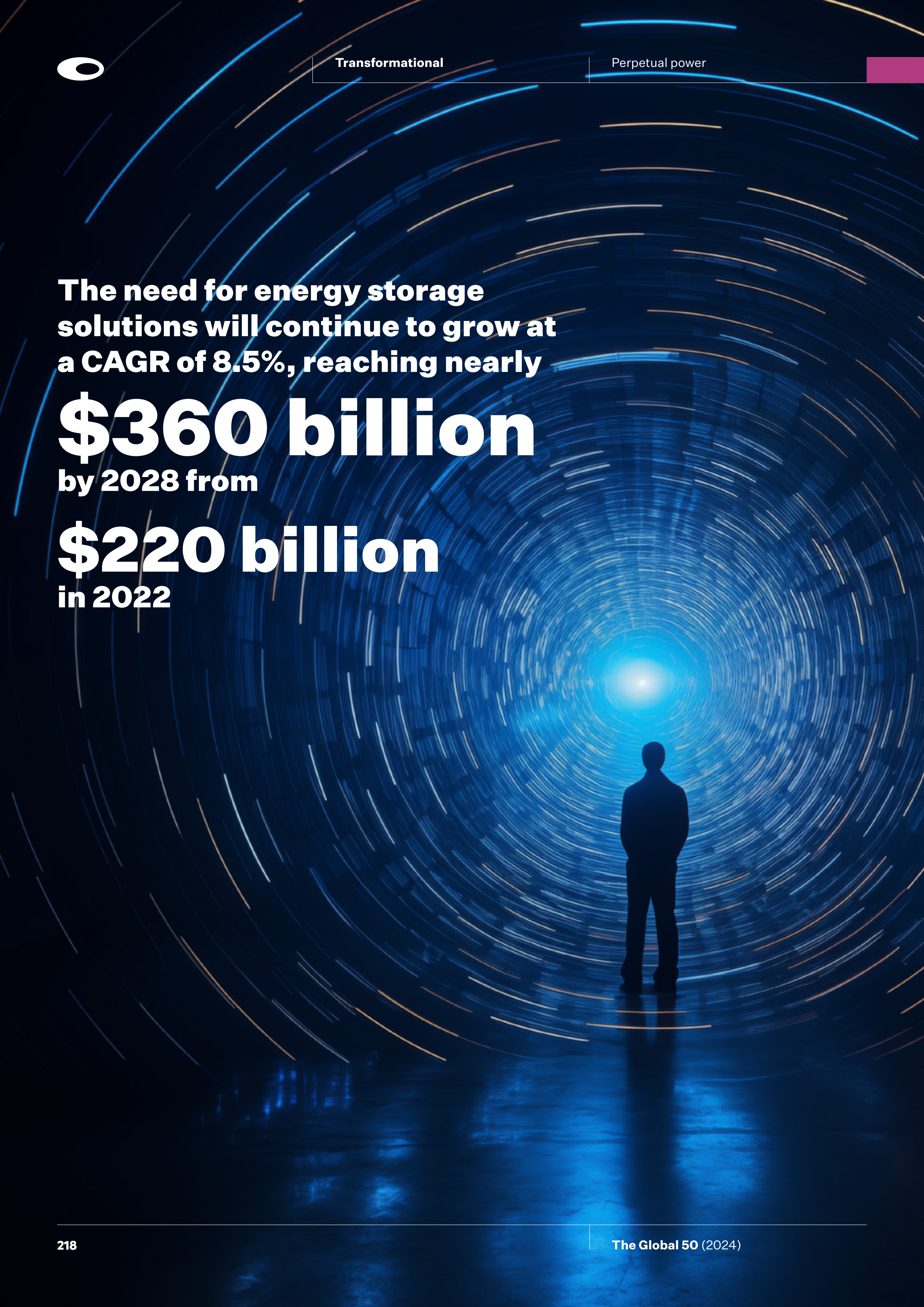
Future lithium alternatives include sodium-ion batteries and lithium–sulphur batteries,[864] along with zinc–air[865] and safer, solid-state batteries that continue to evolve through new high-conductivity materials.[866] Graphene batteries also have potential,[867] and, between solid-state and liquid-based battery technologies, magnesium-ion batteries may offer a safe, low-cost, high-energy alternative.[868]

BENEFITS

Innovative battery technologies improve eco-friendly mobility, connecting remote areas sustainably and advancing decarbonised transport, including electric aeroplanes.

RISKS

The diverse range of available battery technologies prevents any one battery innovation from scaling up, achieving cost reductions, and reaching its full potential within society. Redesigns face supply chain challenges, potential issues with new materials and increased battery waste.



The need for energy storage solutions will continue to grow at a CAGR of 8.5%, reaching nearly

$360 billion

by 2028 from

$220 billion

in 2022

OPPORTUNITY 43

SCOPE VISIONARY

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Pushing the Boundaries on Energy

TRENDS

Advanced mobility
Mobilising Innovation
Net zero
New Materials
Transforming Energy

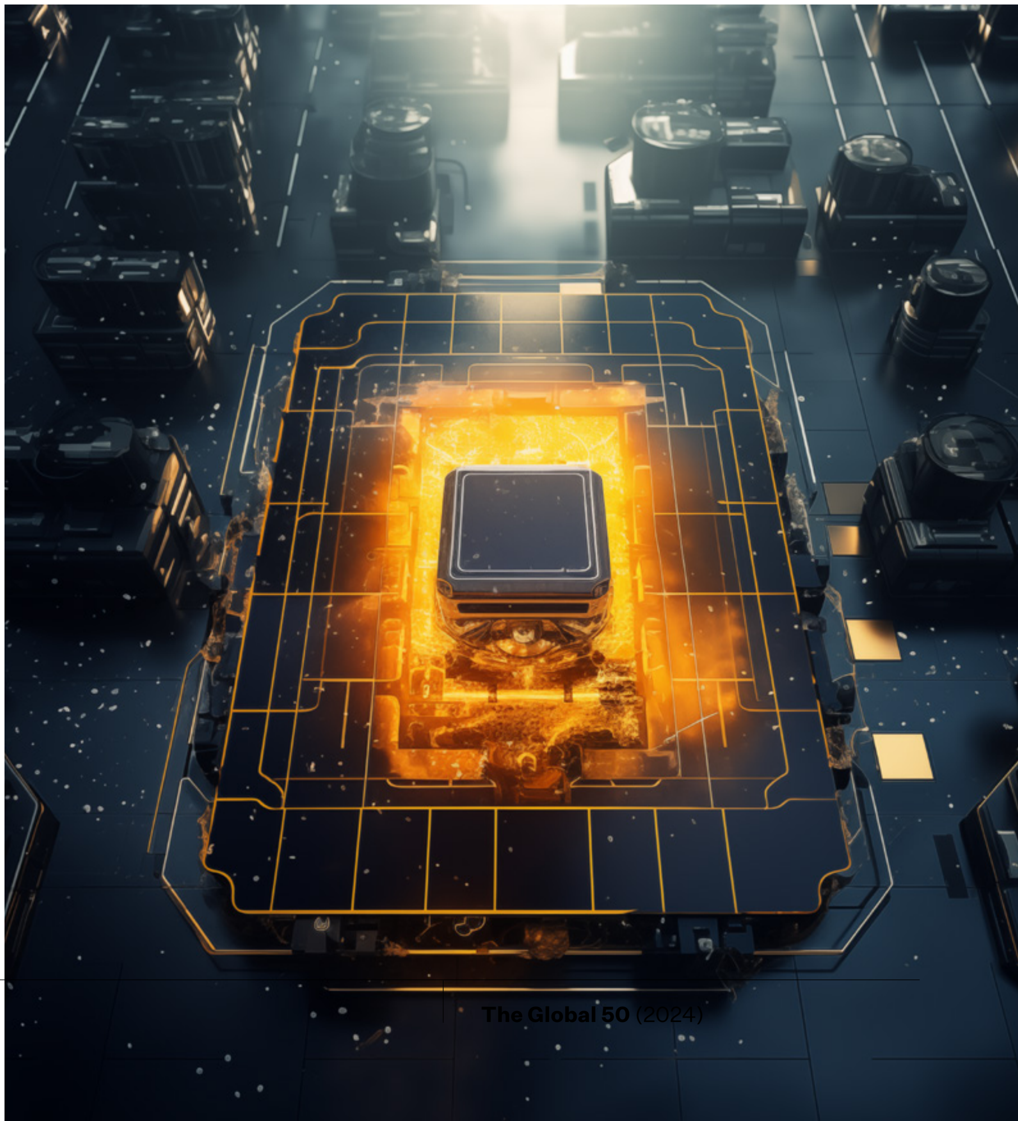
SECTORS IMPACTED

Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Energy, Oil, Gas & Renewables
Logistics, Shipping & Freight
Materials & Biotechnology
Travel & Tourism

What if fully solar-powered vehicles were everywhere?

SUNSHINE STEERING

Advanced machine intelligence – for novel materials and solar technology design – and nanotechnology enhance solar photovoltaic (PV) cells and storage and enable weather-resilient solar vehicles that rival electric ones.



WHY IT MATTERS TODAY

Despite four decades of research trying to develop a viable solar-powered car, the challenge remains.[869] Students around the world compete to try to meet the challenge (e.g. in the World Solar Challenge[870] and the American Solar Challenge[871]), while companies like Sono,[872] Lightyear,[873] and Aptera[874] face uncertainties in their attempts. Even with the current limited solar technologies, the market for solar-powered cars is expected to reach $46.11 billion by 2031. [875]

Electric cars comprised 18% of 2023's total car sales[876] and by 2030 could represent 35% of sales globally, avoiding around 700Mt carbon dioxide equivalents.[877] This growth will increase pressure on existing grid capacity and rely on the roll-out of charging infrastructure to keep up with demand.[878] Some estimates suggest that the total investment needed for worldwide charging infrastructure could be as much as $210 billion to 2030.[879]

In addition, current electric vehicles have a limited range, making them unsuitable for long-distance private and commercial transport, and manufacturers are working to improve overall system flexibility by providing extra capacity through solar panels; the panels of the hybrid Hyundai Sonata and Toyota Prius models, for example, enable nearly 1,250 sun-powered kilometres a year.[880]

Besides reducing the weight of the cars, researchers are already working on ultra-thin and ultra-strong PV weighing 100 times less than current cells but generating 18 times more power per kilogram.[881] PV paint (integrating nanoscale semiconductors known as quantum dots[882]) at an industrial scale that can be nanoprinted onto specialised surfaces, for example ultra-strong fabric known as Dyneema®, reduces the need for heavy solar panels.[883]

Total investment needed for worldwide electrical car charging infrastructure could be as much as

$210 billion

to 2030

OPPORTUNITY

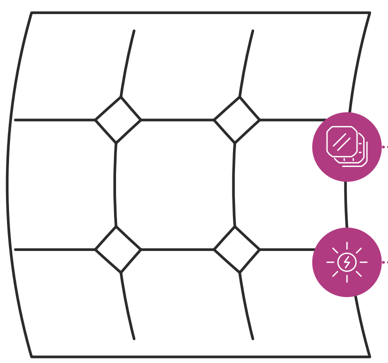
Beyond new rare raw materials and autonomous energy efficient route prediction in vehicles,[884] advanced machine intelligence enables innovative installation designs of solar PV cells through simulations, nanotechnology for energy harvesting,[885] creation of novel materials such as perovskite (a combination of titanium oxide minerals[886]), or synthetic biology[887] which lead to solar-powered vehicles that can compete with regular electric vehicles, overcoming any weather conditions, without the need for an external battery for storage. This leads to a breakthrough in decarbonised transport, reducing reliance on both grid-connected power and off-grid energy and eliminating the need for charging.

BENEFITS

Innovative solar technology enables sustainable solar-powered vehicles, advancing decarbonisation without grid reliance and offering emission-free, self-sustainable energy mobility for millions, especially in areas with limited access to electricity.

RISKS

The wide variety of solar technologies prevents any single innovation from scaling up effectively. Redesigns, including installation combinations, face supply chain challenges. Despite novel materials, solar-powered vehicles may not operate effectively in all weather conditions. Managing maintenance, recycling, and disposal of nanoparticles in these vehicles poses additional challenges.



Researchers are already working on ultra-thin and ultra-strong PV cells weighing 100 times less than current cells but generating 18 times more power per kilogram

OPPORTUNITY 44

SCOPE VISIONARY

UNCERTAINTIES

Technology, Values

MEGATRENDS

Advanced Health and Nutrition

TRENDS

Brain–Computer interfaces (BCI)
Neuroscience
Transforming Education

SECTORS IMPACTED

Communication Technologies & Systems
Cyber & Information Security
Data Science, AI & Machine Learning
Education
Health & Healthcare
Immersive Technologies
Materials & Biotechnology

What if we could learn new skills while we sleep?

RESTFUL RETENTION

Advanced sleep studies, neuroscience, and brain–computer interfaces, augmented by advanced machine intelligence, deepen our understanding of of learning during sleep enabling our ability to retrieve learning when awake.

WHY IT MATTERS TODAY

The ability to deepen knowledge or enhance cognitive functions during sleep and to retrieve sensory connections and retained knowledge when awake hold out hope for enhancing cognitive rehabilitation for people after a stroke,[888] with brain trauma[889] or moderate dementia,[890] and for skills development more generally.

Related to health, stroke is the second leading cause of death worldwide, with 6.6 million deaths in 2020, 86% of which were in low- and middle-income countries,[891] and stroke mortality is projected to increase by 50% to 9.7 million between 2020 and 2050.[892] Traumatic brain injury affected 55 million people in 2022 and costs over $400 billion annually.[893] Besides the burden of care, it increases the risk of other neurodegenerative diseases later in life.[894] Over 55 million people globally have dementia, with 60% in low- and middle-income countries and 10 million new cases annually.[895] Dementia is the seventh leading cause of death globally and a major cause of disability, with a global economic impact of $1.3 trillion in 2019.[896]

Given the expected impact of technology on the future of work, cultivating new skills is essential. Employers surveyed within the World Economic Forum's Future of Jobs report expect that 44% of employees' skills will shift, in some way, in the next five years.[897] Accelerated education and upskilling could add $8.3 trillion to global gross domestic product (GDP) by 2030.[898]

OPPORTUNITY

Learning new skills during sleep has been an area of neuroscientific research for nearly six decades,[899] although results have been inconsistent.[900] Besides rest and improving memory retention by up to 40%,[901] the processing of memories from waking hours occurs during sleep.[902] What is not typically linked to sleep is the encoding of new memories or, in other words, learning.[903] Techniques like transcranial alternating current stimulation can induce lucid[P] dreaming[904] and thus enable interactive learning and communication.[905]

A combination of advanced sleep studies, neuroscience, and brain–computer interfaces enhanced by advanced machine intelligence enhances our understanding of how rapid eye movement (REM) and non-REM (NREM) stages of sleep are tied to learning[906] and enables our ability to retrieve learning when awake.[907] This would also guide the design of a feedback system during sleep to reinforce learning. So far, the approaches used for learning have mostly revolved around using sound and odour as stimuli, with reflex responses or electroencephalogram reactions,[908] during sleep to confirm learning,[909] but the success of these methods can be subjective.

BENEFITS

Enhancing, recovering, and gaining cognitive functions[910] particularly after a stroke,[911] brain trauma,[912] or moderate dementia.[913] More time and opportunities for learning that can meet changing societal and economic demands for diverse skills and expertise.

RISKS

Advanced technologies that are designed to stimulate learning during sleep could impact on neurological health or be misused through thought manipulation. Rising expectations about learning might create further inequalities for those who do not have access to such technologies.

[P] Lucid dreaming is the state of consciousness during sleep.

OPPORTUNITY 45

SCOPE VISIONARY

UNCERTAINTIES

Technology, Collaboration

MEGATRENDS

Living with Autonomous Robots and Automation

TRENDS

Advanced computing
Artificial intelligence
Automation
Cross-sectoral partnerships
New Materials

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Energy, Oil, Gas & Renewables
Health & Healthcare
Infrastructure & Construction
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Metals & Mining
Real Estate
Utilities

What if machines could self-repair?

FOREVER MACHINES

Self-repairing machines, integrating preventive maintenance, smart materials, and advanced sensors enable downtime-free manufacturing and sustainable, long-lasting consumer products and robotics.

WHY IT MATTERS TODAY

Many machines and structures, such as telescopes, deep-sea cables, satellites, and drilling equipment in certain sites, are hard to reach in case of malfunction. Some take significant amounts of money and months, even years, to repair.[914] In some cases, repairs can also be dangerous, leading to workplace injuries.[915]

The economic and environmental impact of a lack of repairability is a growing issue.[916] The premature disposal of repairable consumer goods generates 261 million tons of greenhouse gas emissions, uses 30 million tons of resources, and results in 35 million tons of waste in the European Union (EU) every year.[917] Some 77% of EU consumers prefer to repair goods[918] instead of discarding them, and the upcoming 'right to repair' directive in the EU is expected to generate $5.3 billion[Q] in growth[919]. More than 40 states in the United States have initiated efforts to develop distinct legislative proposals regarding the right to repair.[920]

Driven by artificial intelligence, 3D printing, and materials informatics, the field of materials science has been rapidly evolving and its impact is significant. In the chemicals industry, the use of materials that are more sustainable can help to reduce emissions, increase recycled inputs, and create safer chemicals.[921] Advanced materials, such as carbon-fibre composites, could enhance the efficiency and durability of wind turbine blades, with a 5%–13% lower energy and carbon payback period than current models.[922] The global self-healing materials market size was valued at $1.68 billion in 2022 and is estimated to grow at a compound annual growth rate of 24.8% from 2023 to 2030.[923]

The global self-healing materials market size was valued at

$1.68 billion

in 2022 and is estimated to grow at a CAGR of

24.8%

from 2023 to 2030

[Q] Based on EURUSD exchange rate on 30 December 2023.

OPPORTUNITY

Self-repairing machines combine preventive maintenance, design for repairability, stretchable electronics,[924] novel smart materials (such as metals,[925] elastomers, and polymers[926]), and alternative next-generation batteries[927] into one system.

Powered by advanced machine intelligence and advanced sensor technologies,[928] self-repairing machines operate in an optimum way to avoid damage by combining sensory functions, opening up new frontiers for discovery and development in remote environments, such as extraterrestrial exploration and mining.

Manufacturing is downtime free as preventive and routine maintenance are no longer needed. The risk of defects due to machine failure is reduced to zero. Domestic appliances that repair themselves allow consumers to invest in new (or upcycled) products without infringing intellectual property (IP) rights. Even electronic devices can recover from almost any damage, prompting a market pivot towards device component upgrades instead of new device purchases. From vehicles and ships, to aeroplanes and rockets, self-repairing machines usher in a sustainable supply chain, with near-perfect circularity.

BENEFITS

Enhanced safety, reduced downtime, and extended machine and robot lifespans, reducing maintenance costs and improving the quality of products and service automation. Opens up opportunities for remote exploration and a near-perfect supply chain. IP-protected aspects of machines remain intact.

RISKS

Malfunctioning self-repair mechanisms could inadvertently harm users and the surrounding environment. Autonomous machines are susceptible to cyber threats, and their complex design and autonomous decision-making processes can result in increased costs, effort, and diminished benefits.

OPPORTUNITY 46

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Materials Revolution

TRENDS

Artificial intelligence
Immersive technologies & wearables
New Materials
Nanomaterials
Transforming energy

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if graphene were mass produced?

FINALLY GRAPHENE

By unlocking solutions for mass production, graphene could transform energy storage, hydrogen fuel efficiency, air filtration, water desalination, sensor technologies, and healthcare, particularly in drug delivery and personalised medicine.

WHY IT MATTERS TODAY

Graphene is useful for everything from healthcare and energy to supercomputers and building materials, including batteries, solar cells, and sensors

The thinnest material known, graphene is a layer of carbon atoms arranged in a hexagonal matrix. It is also a superconductor,[929] lightweight,[930] strong (200 times stronger than steel),[931] flexible, and nearly transparent.[932] These invaluable properties mean graphene is useful for everything from healthcare and energy to supercomputers and building materials,[933] including batteries, solar cells, and sensors.[934]

Even though it was discovered 20 years ago,[935] it has yet to be adopted in mass manufacturing as it remains expensive to produce graphene that, beyond small flakes,[936] is both defect free and in single layers.[937] Nevertheless, some companies assert their ability to mass produce good quality graphene layer, e.g. 2DCarbon in China,[938] and graphene flakes, e.g. Avadain in the United States.[939]

In 2013, the European Union launched a decade-long, $1.1 billion[R] Graphene Flagship project that has led to 83 patents, over 5,000 publications, and 17 spin-off companies.[940] Abu Dhabi's Khalifa University of Science and Technology and the University of Manchester (where graphene was first produced) have partnered to jointly explore areas where graphene can make an impact, including water filtration and energy storage.[941]

The global graphene market was valued at $175 million in 2022 and is expected to grow at a CAGR of 46.6% from 2023 to 2030.[942] Graphene's global market potential is projected to reach $190 billion by 2030.[943]

Graphene membranes have also been shown to boost the efficiency of air filtration by 55%–65%, and the efficiency of graphene-enhanced solar desalination increases by 70%–90%.[944] Graphene also has the potential to make desalination a more sustainable solution for usable water and, as the need for more sensitive sensors grows, graphene, which has been shown to have increased the sensitivity of a fibre-optic sensor by 50%,[945] could replace silicon and, for example, boost the efficiency of solar cells and conductivity in semiconductors.

From drug delivery to cancer treatment, as one of the most adaptable nanocarriers potentially available and with its ability to directly engage with the immune system,[946] graphene may transform the way we approach healthcare and personalised medicine.

[R] Based on EURUSD exchange rate on 30 December 2023.

OPPORTUNITY

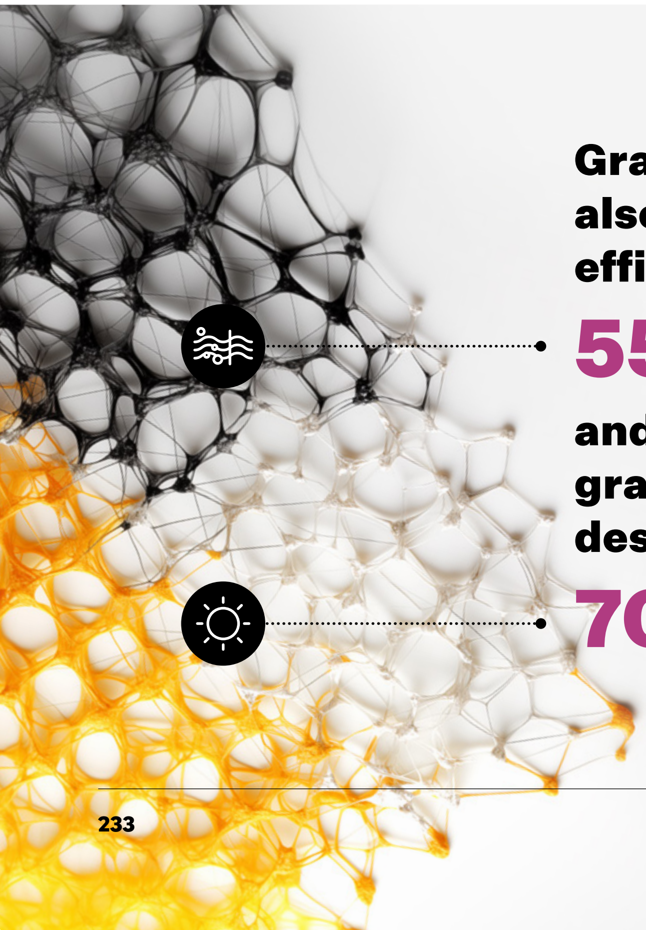
With advanced machine intelligence, the mass production and application of graphene may become a reality with many applications owing to graphene's flexibility, conductivity, and high surface area[947] – from water treatment[948] and wearable sensors[949] to e-skins[950] and energy storage technologies, enhancing batteries, supercapacitors, and solar cells.[951] As graphene has also been shown to boost hydrogen fuel cell efficiency,[952] its application could accelerate the future potential of hydrogen in aviation[953] such that 40% of European flights could be powered by hydrogen before 2050,[954] earlier than currently expected.

BENEFITS

Thanks to its strong, stretchy, conductive, and atom-thin properties, graphene disrupts entire value chains, transforming everything from batteries to water and air purification, healthcare, wearables, and electronics.[955]

RISKS

Graphene's disruptive impact may affect jobs, with its toxicity posing health risks[956] and creating new challenges in environmental sustainability.[957]



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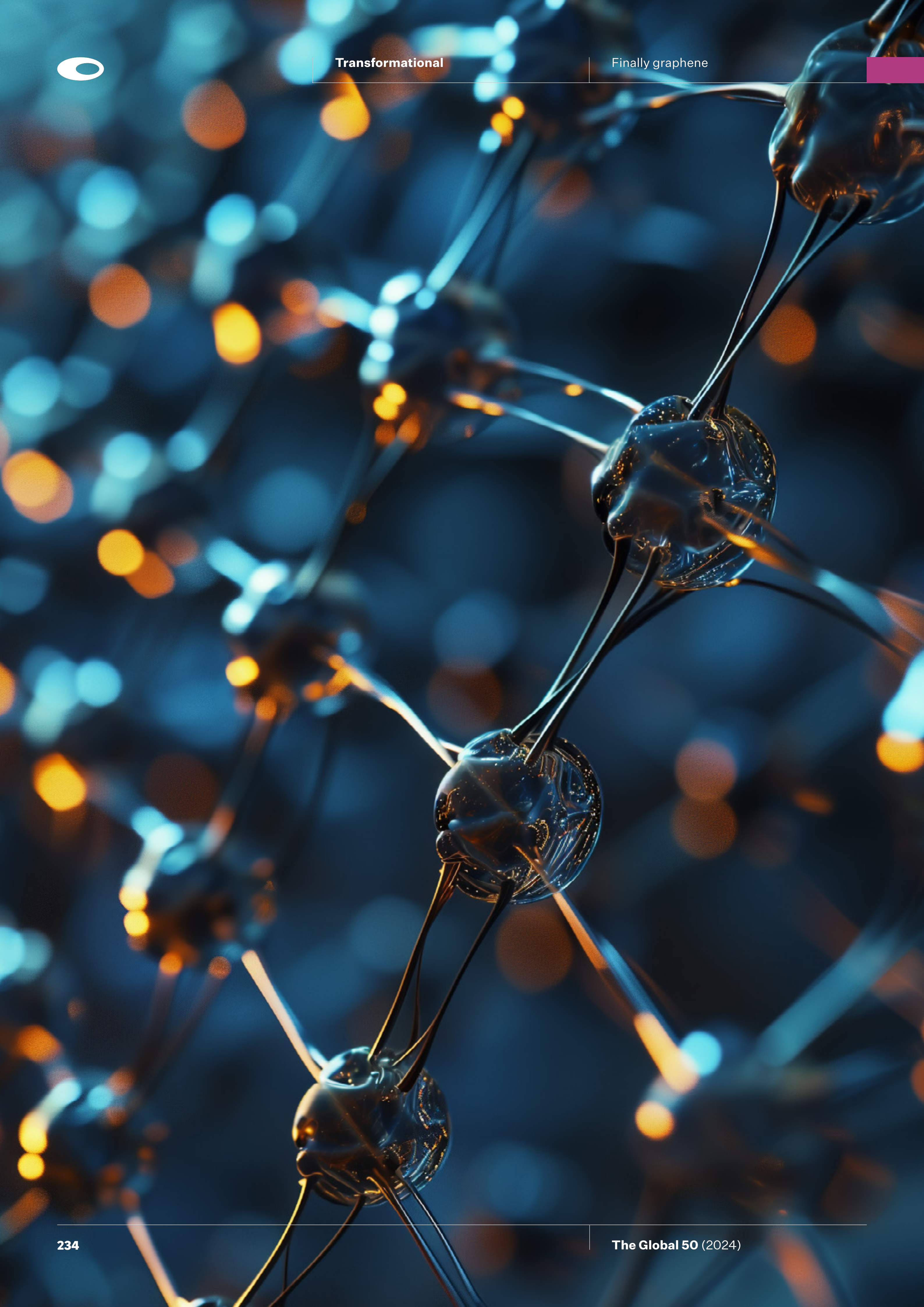


OPPORTUNITY 47

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Values

MEGATRENDS

Future Humanity

TRENDS

Artificial Intelligence
Ideation, IP & Entrepreneurship
International Collaboration
Open Data
Transforming Education

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if multimodal large language models (LLMs) allow disruptive science once again?

OPEN-SOURCE SCIENCE

A global scientific task force trains LLMs on scientific theories and data prioritising concerns related to bias, privacy, and reliability to accelerate research, enhance science communication, and inform policy.

WHY IT MATTERS TODAY

LLMs – open or proprietary – are costly. It has been estimated that running ChatGPT costs OpenAI nearly

$700,000

per day

Science is critical to society, informing decisions that impact on society, such as those related to climate change and biotechnology.[958] It is critical for effective policymaking and leadership,[959] particularly in terms of solutions to improve the quality of life.[960] Even though it is widely understood that accumulated knowledge enables future scientific and technological progress, and despite exponential growth in the number of papers and patents in recent decades, science and technology have become less disruptive, i.e. they push less often in new directions.[961]

Generative artificial intelligence (GenAI) and foundational LLMs are speeding up application development and empowering non-technical users. Even though they are expected to contribute $4.4 trillion in economic value, the full potential of AI can be more profoundly realised by combining GenAI with emerging AI technology to process unstructured data and enhance existing solutions.[962]

LLMs – open or proprietary[963] – are costly. While it has not been publicly disclosed by OpenAI, it has been estimated that running ChatGPT costs nearly $700,000 per day.[964] Customised models can be purpose-built or fine-tuned versions of public models, such as BloombergGPT and smaller LLMs by NVIDIA, or they can combine public, private, and open-source LLMs to leverage their benefits while maintaining control over AI initiatives and avoiding vendor lock-in.[965] In 2023, the UAE launched Falcon 180B, an open-source LLM free of royalties with 180 billion parameters,[966] close to OpenAI's GPT-4, which is thought to have around 220 billion parameters.[967]

AI can offer real-time support to scientists, innovators,[968] and publishers. Frontiers' Artificial Intelligence (peer) Review Assistant (AIRA) reads papers, makes quick recommendations (up to 20 recommendations in seconds) on language, integrity, plagiarism, and conflicts of interest.[969] LLMs can specifically enhance research visibility, transparency, and reputation and connect scientists with diverse audiences,[970] particularly on scientific topics that concern, or can impact on, societies.

OPPORTUNITY

A global task force of research and higher education institutions train multimodal LLMs on scientific theories and open data, prioritising concerns related to bias, accuracy,[971] privacy, reliability, and intellectual property. From abstracts and expert evaluation, LLMs accelerate research, enhance science communication and education, and foster interdisciplinary insights focused on a specific socio-scientific angle, feeding into policy decision-making. Continuous data collection through authorised access enables learning from successes and failures, uncovering new scientific principles and applications, while ensuring that quality is maintained. This opens the doors for ideation and entrepreneurship in fields that otherwise seem inaccessible or not possible to others.

Connecting LLMs with other forms of GenAI can involve producing multimodal outputs, including audio and images, enhancing understanding and providing greater opportunities for creativity and ideation.

BENEFITS

Accessible science accelerates the scientific process and makes it open-source – throughout society, people are constantly ideating, testing, and revising innovations.

RISKS

Over-reliance on accessible science causes scientific educational systems and thinking skills to degrade, like a muscle atrophying, resulting in fewer foundational scientific discoveries. With scientific theories operating as axioms that guide people’s daily lives, inaccurate scientific theories could steer people towards harm. Operating the LLMs may be costly.

In 2023, the UAE launched Falcon 180B, an open-source LLM free of royalties with

180 billion parameters

OPPORTUNITY 48

SCOPE TRANSITIONAL

UNCERTAINTIES

Technology, Nature

MEGATRENDS

Materials Revolution

TRENDS

Artificial intelligence
Biomaterials
Immersive technologies & wearables
New Materials
Sustainable Waste Management

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Digital Goods & Services
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Metals & Mining
Professional Services
Sports

What if food waste was the key to sustainable flexible electronics?

GREEN PLASTICS

Advanced machine intelligence with sustainable agriculture bioengineer starch from food waste transforming it into fully biodegradable plastics for electronics, wearables, and packaging, supporting a fully circular bioeconomy.

WHY IT MATTERS TODAY

The equivalent of 2,000 trucks full of plastic enter the world's oceans, rivers, and lakes daily,[972] taking hundreds of years to degrade, with negative impacts on land and marine ecosystems.[973] Recent studies indicate that some 77% of people have plastic particles in their blood.[974] E-waste, which includes plastic, is expected to increase from 50 million to 110 million tons by 2050.[975] Only some 20% of e-waste is recycled.[976] Soft, flexible and stretchable electronic devices are particularly difficult to recycle.[977]

With rising plastic waste and plastic bans, researchers are developing biodegradable, starch-based, plastic substitutes with low toxicity for humans and ecosystems as they degrade.[978] Starch is inexpensive and less environmentally harmful than conventional plastics.[979] Researchers are working to improve on current starch-based plastics, which have poor flexibility and high water vapor permeability.[980]

Flexible electronics (also known as flexible circuits) are capable of bending, folding, and stretching without losing their functionality. They are thin, lightweight, and can be designed for recyclability.[981] Manufacturing processes for flexible electronics are more material- and energy-efficient, generating less waste.[982] By 2030, it is estimated that the flexible electronics market will surpass $61 billion.[983]

Only some

20% of e-waste is recycled

OPPORTUNITY

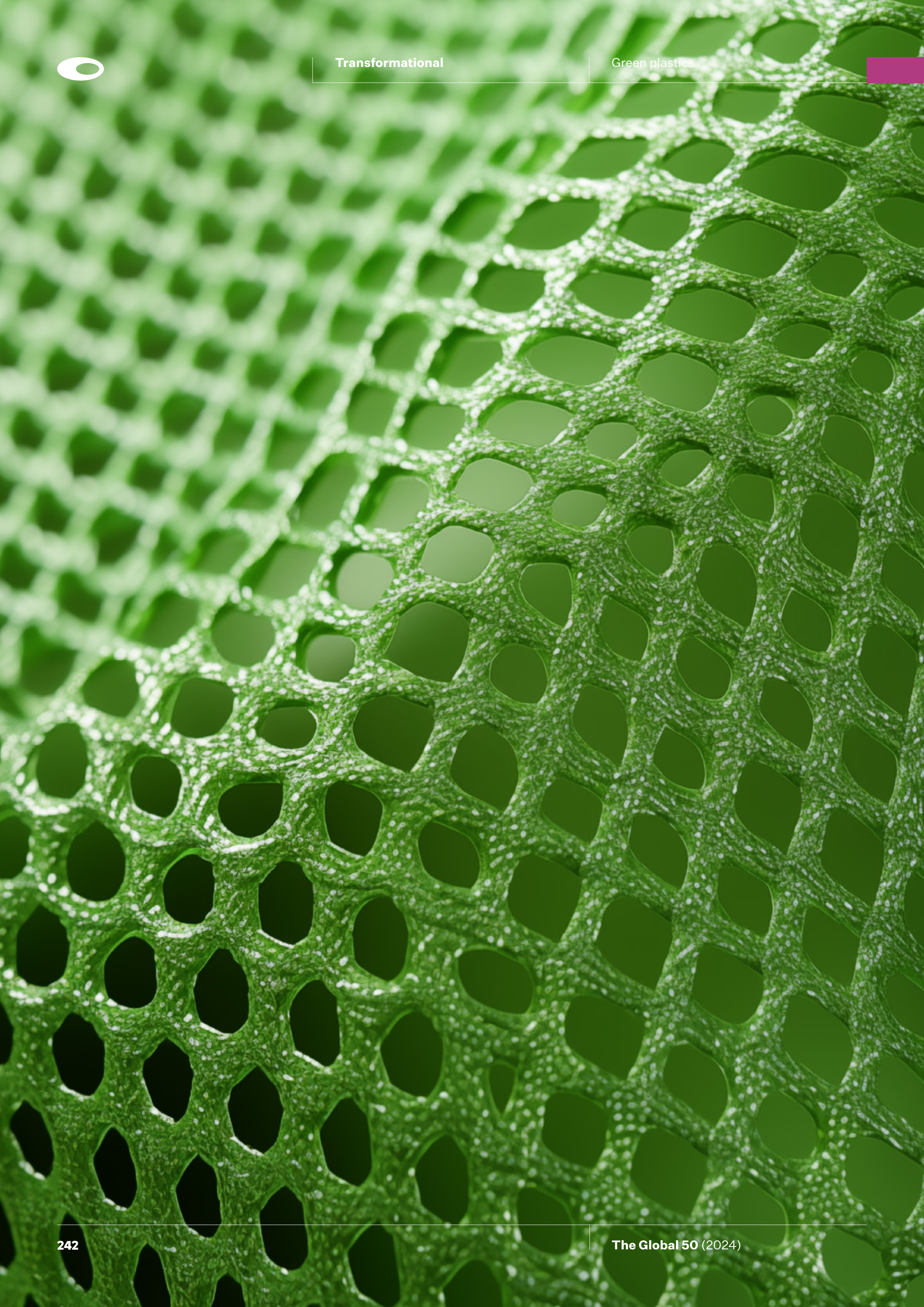
Even though starch, as a biopolymer, has been an area of high potential for at least 20 years, it is brittle, sensitive to moisture, and has poor thermal properties and mechanical resistance.[984] Advanced machine intelligence enables the bioengineering of starch into 100% biodegradable plastics that can subsequently be used as external and internal components for all types of electronics, wearables, and consumer packaging. Avoiding the need to blend with other polymers to enhance performance[985] and derived from organic waste – such as pineapple stems[986] – starch-based plastics can boost sustainable agriculture as production for green plastics expands into a growing market supporting agricultural livelihoods and moves towards a circular bioeconomy.

BENEFITS

Using starch as a biodegradable form of plastics reduces the harmful effects of plastic e-waste on people and nature, while also opening up new possibilities with stretchable electronics and soft robotics.

RISKS

Starch-based biodegradable plastics may not be as durable as expected, leading to higher maintenance and repair costs. Using food waste for bioplastic production could inadvertently result in more food waste and less sustainable agriculture to meet increased demand.



OPPORTUNITY 49

SCOPE WITHIN REACH

UNCERTAINTIES

Technology, Systems

MEGATRENDS

Increasing Technological and Biological Vulnerabilities

TRENDS

Advanced computing
Cross-sectoral partnerships
Data protection & privacy
Interoperability
Quantum technology

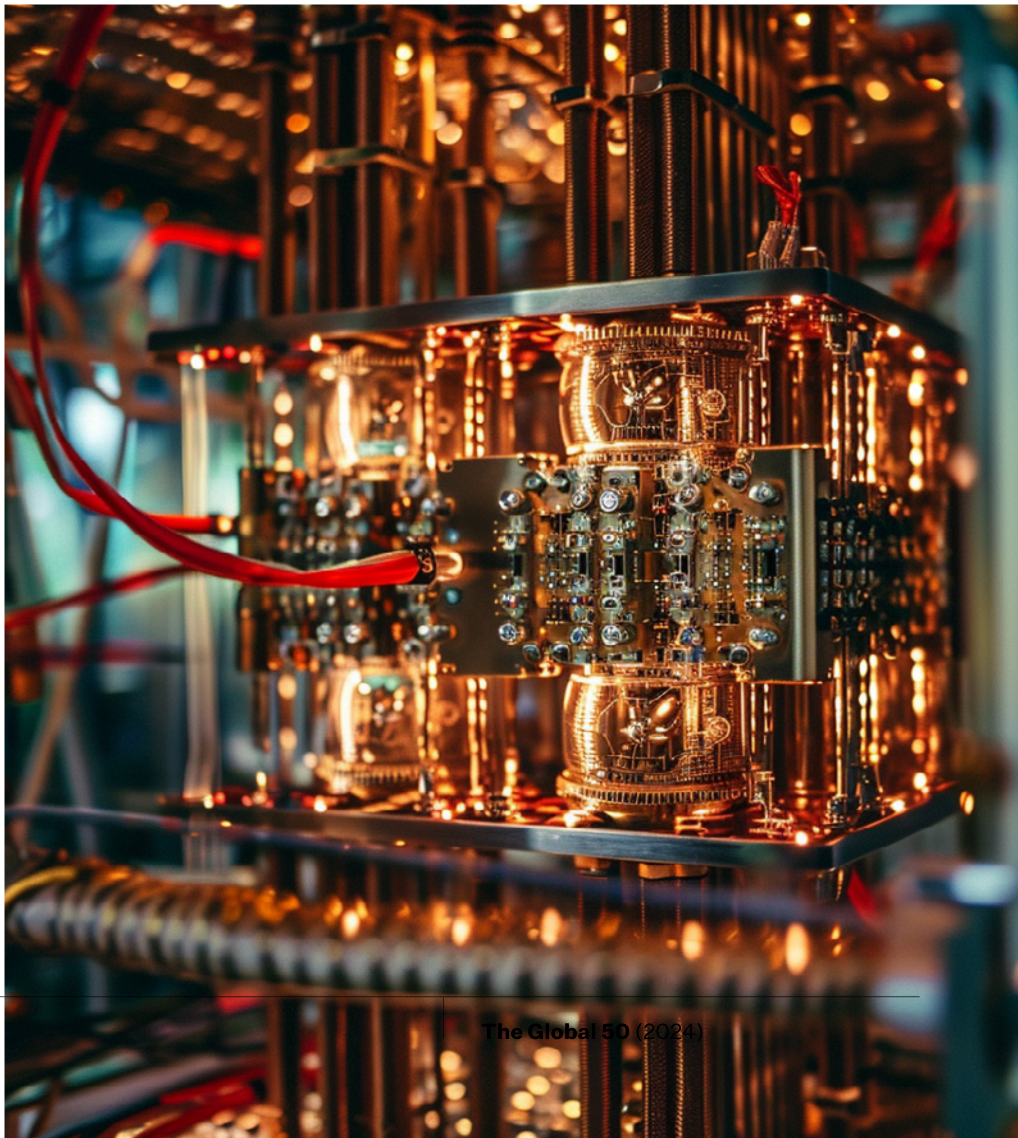
SECTORS IMPACTED

Communication Technologies & Systems
Data Science, AI & Machine Learning
Digital Goods & Services
Government Services
Health & Healthcare
Insurance & Reinsurance
Professional Services

What if we seamlessly transitioned into quantum computing?

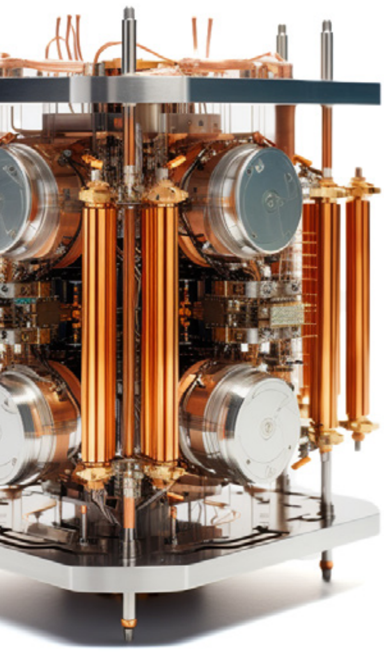
THE QUANTUM JUMP

A data interoperability bridge that enables a secure and seamless data transition between quantum and classical computers.



WHY IT MATTERS TODAY

While quantum computing seems far away, some industry leaders expect it to make an impact as early as 2025



Quantum technologies have the potential to accelerate scientific discovery and innovation, radically transforming medicine, materials development, finance, and how we live, work and consume.[987] While quantum computing seems far away, some industry leaders expect it to make an impact as early as 2025.[988] The automotive, chemical, financial services, and life sciences sectors, which are expected to be among the first to benefit economically from quantum computing, could see a potential increase in value of up to $1.3 trillion by 2035.[989] The global quantum computing market was expected to reach $866 million in 2023 and is forecasted to reach $4.4 billion by 2028, growing at a CAGR of 38.3% from 2023 to 2028.[990]

Quantum computing is powerful, with computing speeds 158 million times faster than some of today's most sophisticated supercomputers.[991] Within a span of merely three years, quantum computing progressed from 24 qubits on a chip to over 400,[992] and in December 2023 IBM unveiled a new quantum computing chip of just over 1,000 qubits, laying the foundation for quantum computers reliable enough to consistently outperform conventional computers in real-world applications by 2033.[993] With this speed comes challenges and IBM have already announced that they will focus on technologies to ensure error-free operation of quantum computing given its high speed and as a result more frequent and varied errors.[994]

Perhaps the greatest impact will be when it is combined with other technologies that are themselves expected to advance. For example, combined with artificial intelligence (AI), quantum computing could, in 10 years, lead to computing power 100 times greater than today's and, in 20 years, 10,000 times greater.[995] Once available at scale, quantum computers can simulate complex chemical reactions that are difficult or impossible for classical computers, accelerating discovery of innovative materials[996] with lower computational cost while maintaining high accuracy.[997] Supply chains and logistics could be optimised, starting from better modelling in the short term to optimising logistics and analysing data in real time with edge computing.[998]

In preparation for this shift, the Open Quantum Institute (OQI) was launched at CERN and designed by the Geneva Science and Diplomacy Anticipator (GESDA) to ensure that quantum computing remains accessible to all around the world to avoid another digital divide.[999] The UAE's Technology Innovation Institute has also been working on Qibo, an open-source algorithm to enable deployment of quantum applications.[1000]

OPPORTUNITY

Quantum computing is powerful, with computing speeds
158 million
times faster than some of today's most sophisticated supercomputers

A data interoperability bridge encompassing middleware[1001] solutions, amongst others, that provides unified and secure data exchange between quantum and classical computers allowing seamless connection and translation between both ensuring that specified outgoing data from classical computers are encrypted and error-free at the receiving end of a quantum computer. This is supported by a roadmap towards quantum transitions starting in areas that would have the greatest impact on society and a review of laws and regulations that would look at implications of the transition.[1002]

The shift to quantum computing will pose several challenges, including one which will be the integration with today's computers, with their different architectures, ensuring that we do not lose data or other critical information and that we achieve seamless quantum–classical communication.[1003] Otherwise, significant errors that will impact on society will occur and the expected advantages of quantum computing will fall short. Sensitive information will need to be secured through quantum-safe encryption techniques.[1004]

BENEFITS

The shift to quantum computing is seamless and data are safeguarded with minimal errors. Fast computing speeds transform medicine, materials development, finance, and other areas.

RISKS

The expensive and slow mobilisation of resources to build a data interoperability bridge could deepen the digital divide and lead to flawed quantum computing outputs and exposure of sensitive data, adversely affecting society.

OPPORTUNITY 50

SCOPE TRANSITIONAL

UNCERTAINTIES

Collaboration, Technology

MEGATRENDS

Borderless World - Fluid Economics

TRENDS

Advanced Connectivity
Artificial intelligence
International Collaboration
Mobilising Innovation
Space economy

SECTORS IMPACTED

Agriculture & Food
Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Energy, Oil, Gas & Renewables
Financial Services & Investment
Government Services
Health & Healthcare
Immersive Technologies
Infrastructure & Construction
Insurance & Reinsurance
Logistics, Shipping & Freight
Manufacturing
Materials & Biotechnology
Art, Media & Entertainment
Metals & Mining
Professional Services
Real Estate
Sports
Travel & Tourism
Utilities

What if we had a global, seamless internet?

THE NETWORK OF NETWORKS

Advances in satellites and advanced machine intelligence enable seamless, global internet access, supporting the internet of things (IoT) and reducing network disruptions through intelligent transitions between cellular and satellite networks.

WHY IT MATTERS TODAY

Today, 95% of the world's population has access to mobile broadband of 3G or above, but geographic disparities underlie this figure; for example, while 88% of the global population have 4G coverage, only 50% of the population on the African continent have access to 4G.[1005] Moreover, as the world transitions to 5G, legacy networks like 3G are often switched off to free-up space for 5G.[1006] While standards have not yet been set for 6G, speeds are expected to be 10 to 1,000 times faster than current 5G.[1007] While 5G networks theoretically offer speeds up to 10 gigabits per second (Gbps), real-world tests show it could be 1.4 to 14 times faster than 4G, up to 20 Gbps.[1008] Doubling the broadband speed for an economy increases gross domestic product (GDP) by 0.3%.[1009] By 2029, 5G will account for 76% of mobile data traffic, i.e. triple the 2023 levels.[1010]

While satellite internet speeds have, historically, been slow, connection speeds have jumped from 0.08 megabits per second (Mbps) in 1997[1011] to upwards of 200 Mbps today.[1012] While altitude limits may vary, satellites in low Earth orbit (600–1200 km above the Earth)[1013] have been the most popular, those in very low Earth orbit (some 350 km above the Earth) can provide 6G access and bring real-time, more reliable, more cost-effective internet.[1014] At 530 km above the Earth, the TeraByte InfraRed Delivery system of NASA and Massachusetts Institute of Technology (MIT) (and others) recorded laser transmission at 200 Gbps per second, i.e. over 2 terabytes in 5 minutes, or 1,000 high-definition movies.[1015]

Satellite internet continues to gain traction worldwide, with the global satellite industry expected to be worth over $500 billion in 2024.[1016] SpaceX's Starlink is the world's largest satellite internet provider[1017] with just over 4,500 active Starlink satellites,[1018] with lifespans of around five years each.[1019]

6G speeds are expected to be

10 to 1,000

times faster than current 5G

OPPORTUNITY

Advances in satellite technology and communications result in higher data speeds, lower costs, and lower latencies.[1020] The integration of 5G and 6G cellular networks with satellite internet would provide unrestricted internet access, facilitating unprecedented levels of collaboration in work, life, and digital realities around the world and accommodating the growing needs of both users who increasingly rely on autonomous vehicles and other devices and technological advances, including the IoT, edge computing, quantum computing (QC), and others. Regardless of on-the-ground connectivity, network disruptions could become a thing of the past as, through advanced machine intelligence and automation, one network seamlessly takes over when the other fails.[1021]

BENEFITS

Communications are both universal and optimised for sustainability and connectivity. As connectivity becomes borderless, new lifestyle and problem-solving opportunities emerge. Digital realities, autonomous mobility, energy, smart cities, and remote surgeries (telesurgery) become highly reliable as the risk of disconnection is extremely low.

RISKS

Implementing and maintaining satellite internet is expensive, both in terms of hardware and functioning speed. The complexity of allocating costs per user could lead to access restrictions due to intricate user charging mechanisms that may or may not be monopolised by specific operators. An increasing number of satellites limit further launches as space debris becomes a significant issue.

METHODOLOGY AND ON USING GENAI

REVIEW PUBLISHED TREND AND FUTURES

- List reputable global and influential institutions that publish trends- or future-oriented reports, seeking a balance across international governmental organisations, academia, and government and private sources.
- Gather reports published.
- Analyse the content and extract key messages.

THIS YEAR: We conducted a detailed review of 54 reports (out of an initial total of 93) published by 53 reputable organisations between June 2022 and August 2023. Through them, we uncovered key trends, megatrends, and uncertainties across geographies.

CONDUCT EXPERT INTERVIEWS

- Identify experts to approach for roundtables, ensuring that there is coverage across geographies, areas of expertise, and sectors.
- Select experts who did not participate in roundtables or interviews the previous year.
- Conduct virtual roundtables under the Chatham House Rule. These focus on growth, prosperity, and well-being and seek answers to 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?’

THIS YEAR: Roundtables were conducted between 28 September and 19 October 2023. While the majority of the roundtables took place virtually, DFF also hosted a high-level invitation-only workshop at the Geneva Science and Diplomacy Anticipator on 12 October 2023 in Geneva, Switzerland.

CONCEPTUALISE AND GENERATE OPPORTUNITIES FOR THE FUTURE

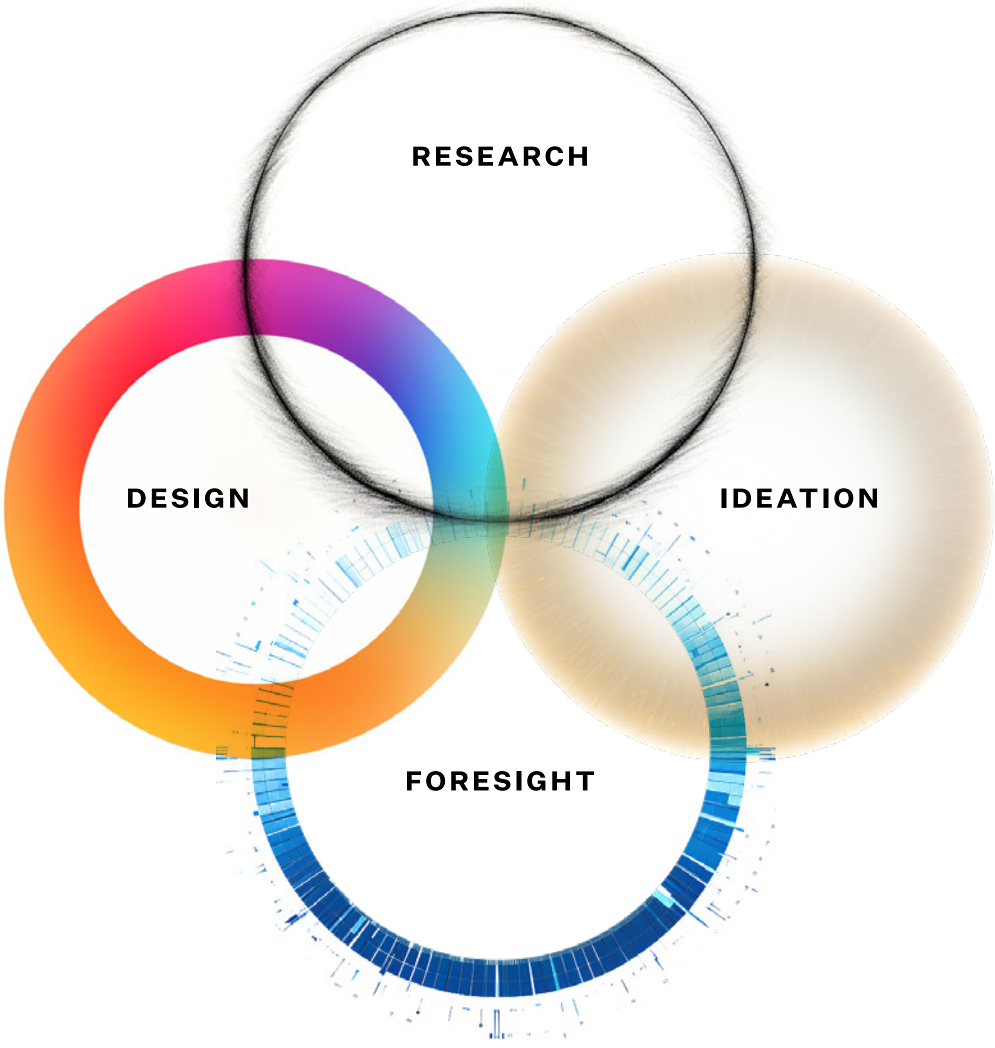
- Use the results of our metareview and analysis of the roundtables to validate a set of uncertainties, assumptions, and megatrends that form our view of the future.
- Draft a list of opportunities and questions about the future and then use ‘What if?’ analysis to finalise the list.
- Select 50 opportunities to feature in this year’s report and group them into categories.

THIS YEAR: An initial brainstorm generated a total of 197 opportunities. We then provided ChatGPT and Bard with prompts specific to 'The Global 50' and the Dubai Future Foundation’s view of the future, which generated 317 opportunities. Five of the opportunities featured in this report were inspired by those suggested by generative AI.

ON USING GENERATIVE ARTIFICIAL INTELLIGENCE (GENAI)

Under the guidance of Sheikh Hamdan bin Mohammed, the Dubai Future Foundation (DFF) aims to shape the future through three main strategies: envisioning, designing, and implementing. DFF focuses on developing programmes and initiatives, both nationally and globally, formulating future-oriented strategies, producing foresight reports, and backing innovative projects. This effort positions Dubai as a global hub for innovative solutions and practices to benefit humanity.

Along these lines, and as a significant piece of original research, the DFF explored the use of GenAI across 'The Global 50' in content, ideation, foresight, and design.



What we tried:

From a **content perspective**, GenAI was used to aid in reviewing and extracting insights from expert meeting notes (while adhering to the Chatham House Rule) and in analysing research undertaken to review global trend reports. Additionally, GenAI was used to identify grammatical errors and suggest linguistic improvements. It was also used to assist in finding the latest data (at country, city, or other levels) on relevant signals and trends.

For **ideation,** GenAI was primed with our our view of the future and research insights and asked to generate future opportunities. Through further prompting, we guided GenAI in generating additional ideas.

From a **foresight perspective**, and as a form of sensemaking, GenAI was used to extract key patterns and make connections between various inputs as a form of systems mapping for the opportunities. GenAI was also used to create rough scenario analyses to uncover related benefits and risks.

Finally, GenAI was used to improve the **report's design** by generating images that visually represented the opportunities by using keywords representative of the content.

What we found:

'The Global 50' was written by people. From a **content** perspective, GenAI did well in swiftly combining topics and carrying out grammatical editing. Editors were crucial for quality, consistency, and managing complexity especially as GenAI struggled with narrative cohesion and often overlooked key aspects given the comprehensiveness sought. For data, GenAI performed better with more specific guidance, achievable only after analysis, irrespective if it was assisted by AI. As a result, good quality results and data can be obtained by reverse engineering searches with GenAI once original thinking is done highlighting GenAI's current limitations despite its apparent intelligence. This may change in the future. While GenAI was useful in some aspects of trend analysis, its effectiveness was limited, as without prior knowledge, reliance on GenAI often led to overlooking key research findings. Overall, when it comes to research, although GenAI had a positive impact on several aspects, it risks digressing away from the intended purpose of original research if not used appropriately and transparently.

In respect to **ideation**, five out of fifty opportunities were inspired, rather than generated, by GenAI. This was because most of the ideas were either more representative of current trends or, upon further research and reflection, would not have a positive impact on future growth, prosperity, and well-being. Reviewers, not knowing which opportunities were generated by GenAI, predominantly selected for inclusion those that inspired opportunities included in the report.

From a **foresight** perspective, GenAI was good at extracting insights and guiding thinking about system linkages and impacts of respective opportunities. However, it sometimes missed key insights and impacts were generic at times.

Lastly, when it comes to **image generation**, despite GenAI's phenomenal ability to combine ideas into good quality images with designer oversight, it sometimes overlooks basic quality aspects such as incomplete human extremities or illogically merging objects and representations. Human oversight was crucial. Overall, when it comes to using GenAI for images, although transformational, it risks leading teams to decision and perfection paralysis due to the abundance of design choices available.

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/

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GLOSSARY

A

ADVANCED MACHINE INTELLIGENCE

A future form of artificial intelligence, advanced machine intelligence (in the context of 'The Global 50') is 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. Advanced machine intelligence is referred to in the opportunities.

AGRITECH

Agritech covers a range of technologies contributing to increased agricultural yields and efficiency. It spans genetic modification, chemical and biochemical pesticides, herbicides and fertilisers, technologies for water and effluent management, harvesting, animal husbandry, and storage.

ANTIMICROBIAL RESISTANCE (AMR)

Antimicrobial resistance occurs when bacteria, viruses, fungi, or parasites no longer respond to medicines, making infections harder to treat and increasing the risk of disease spread, illness, and sepsis leading to death.

AUGMENTED REALITY (AR)

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.

AUTONOMOUS MACHINES

Autonomous machines are machines programmed to operate on their own and that can perform a variety of complex tasks without the need for external controls or commands.

B

BASIC RESEARCH (NEW)

Basic research is research aimed at understanding fundamental aspects of scientific phenomena irrespective of application, use, or concern. Basic research is the opposite of applied research, which aims to undertake research to come up with solutions to problems.

BIODOME (NEW)

A biodome is a self-contained ecosystem that can be used for scientific research, education, protection, and tourism.

BIOLUMINESCENCE (NEW)

Bioluminescence is the production and emission of light by a living organism released from chemical reactions occurring inside the organism or released by it.

BIOMARKER (NEW)

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.

BIOMATERIALS

Biomaterials are 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

Biomimicry is the imitation of natural biological forms, properties, or processes in engineering and design approaches to develop better products and processes.

BIOPRINTING (NEW)

Bioprinting is a technology where bioinks and biomaterials are 3D printed to construct natural tissue-like 3D structures.

BIOTECHNOLOGY

Biotechnology uses and engineers living organisms and biological matter (genetically or at the molecular level) to develop processes and products for healthcare, pharmaceuticals, materials, fuels, and agriculture and food systems.

BLUE ECONOMY (NEW)

The blue economy refers to the sustainable use of ocean resources for livelihoods and revenue generation.

BRAIN–COMPUTER INTERFACES (BCI)

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

CARBON-BASED NANOMATERIALS (CBM) (NEW)

Carbon-based nanomaterials are engineered at the scale of 1 to 100 nanometres and can include nanotubes, graphene, and carbon quantum dots.

CENTRAL BANK (NEW)

A central bank is a public institution that manages the currency and financial stability by – most commonly – setting interest rates. This is also referred to as the monetary policy of a nation.

CIRCULAR ECONOMY (NEW)

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 of production of goods or services.

COBOTS (NEW)

A collaborative robot, or a cobot, is an industrial robot that can safely operate alongside humans in a shared workspace.

COMPOUND ANNUAL GROWTH RATE (CAGR)

The CAGR is the average annual growth rate over a specific period of time greater than one year.

CRYPTOCURRENCY

A cryptocurrency is a digital currency that relies on encryption for transactions and to produce new units (or coins). Cryptocurrencies are verified and traced using distributed ledger technology (DLT).

CULTURAL HERITAGE (NEW)

Cultural heritage includes the sites, artefacts, and traditions a society considers worthy of preservation. They can be symbolic, historic, artistic, aesthetic, ethnological/anthropological, or scientific.

D

DECENTRALISED AUTONOMOUS ORGANISATION (DAO)

A decentralised autonomous organisation is 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.

DRIVER (FORESIGHT) (NEW)

Drivers include phenomena, events, policies, strategies, or scientific and technological advances that create the conditions for a trend to manifest itself and/or accelerate its impact. They can be deliberate or spontaneous and create shifts in demand, behaviour, and policies.

E

ECOSYSTEM

An ecosystem consists of all living matter and organisms in a space, their physical environment, and the interactions between them.

EXTENDED REALITY (XR) (NEW)

A general term that refers to augmented, mixed, and virtual reality.

F

FORESIGHT PROFESSIONAL (NEW)

A multidisciplinary professional and – in some cases – a social scientist, with or without clear subject-matter boundaries. Foresight professionals work with global experts who have a future orientation in their own areas of expertise or verticals. Foresight professionals are entrepreneurial in their approach in carrying out future-focused activities, using appropriate tools for foresight and related communications.

G

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 (GAI, GENAI, OR GENERATIVE AI)

Generative artificial intelligence is a machine-learning model that can learn from a large amount of content to create other content. It includes code, images, data, music, and videos (for now).

GENE THERAPY

Gene therapy involves modifying an individual's genes to cure or treat a disease. Therapies include replacing a disease-causing gene with a healthy copy, deactivating a disease-causing gene, or introducing a new or modified gene to treat a disease. Gene therapies are in the research stage for cancer, genetic diseases, and infectious diseases.

GEOENGINEERING

Geoengineering covers a set of technologies designed to manipulate the environment to mitigate or partially prevent climate change effects. Geoengineering approaches include solar radiation management, cloud seeding, and carbon dioxide removal.

GRAPHENE (NEW)

Graphene is a single layer of carbon atoms with exceptional electric, mechanical, and chemical strengths that holds promise in many industries.

GREENHOUSE GASES (GHGs)

Greenhouse gases are gases that trap heat in the Earth's atmosphere, causing the Earth's temperature to rise either immediately or over many years. This process is known as the greenhouse effect. The accumulation of GHGs is the main cause of climate change. Gases are emitted from industrial processes, agriculture, and some modes of transportation, and can also be emitted from natural sources such as volcanoes and as a result of deforestation and melting ice sheets.

GIGAWATT (GW)

A gigawatt is a unit of energy, equal to one billion watts.

GIGAWATT HOUR (GWh)

A gigawatt hour is a unit of energy representing one billion watt hours and equivalent to one million kilowatt hours (KWh).

GUT MICROBIOTA (NEW)

The gut microbiota consists of a healthy balanced level of both good and bad bacteria in the gut.

H

HAPTIC TECHNOLOGY (NEW)

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.

HUMAN GENOME

The human genome consists of three billion base pairs of the human DNA (deoxyribonucleic acid). Thousands of genes have been decoded so far.

I

INTERNET OF THINGS (IOT)

The internet of things (IoT) is 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.

INTEROPERABILITY

Interoperability is 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

LARGE LANGUAGE MODEL (LLM) (NEW)

A large language model (LLM) is a deep learning algorithm that can recognise, translate, and generate text from other text.

LIVE BACTERIAL THERAPEUTICS (LBTS) (NEW)

Live bacterial therapeutics is the repurposing of individual microbes for therapeutic applications.

M

MACHINES

Machines (in the context of 'The Global 50') are computers or robots with intelligent processing capacity. See also advanced machine intelligence.

MIXED REALITY (MR) (NEW)

Mixed reality refers to the general use of a mix of augmented (AR) and virtual (VR) reality.

MOBILE EDGE COMPUTING (MEC) (NEW)

Mobile edge computing is a form of computing (processing and storage) that occurs at the location where a transaction takes place, where data is generated, or where it is needed by the user thus avoiding the need for a centralised cloud or servers .

MICROPLASTICS

Microplastics are minuscule plastic particles (under 5 mm in size) that emerge from various sources and processes, including friction of wheels on roads, clothing manufacturing, 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 who ingest them whether on land or in water.

N

NANOBOT (NEW)

Nanobots are autonomous robots that are of atomic size.

NANOMETRES

A nanometre is a standard unit of size: 1 metre is equivalent to 1 billion nanometres.

NANOPARTICLES

A nanoparticle is a particle that is under 100 nanometres in size.

NANOSCALE

Nanoscale is a scale used to measure lengths under 100 nanometres.

NANOTECHNOLOGY

Nanotechnology is research, science, and technology conducted at nanoscale.

NATURAL LANGUAGE PROCESSING (NLP) (NEW)

Natural language processing is a branch of AI focused on how computers process language.

NEUROTRANSMITTERS

Neurotransmitters are chemical messengers that transmit signals between neurons across synapses. Neurotransmitters govern a range of functions and include serotonin and melatonin, which play a role in, respectively, mood and sleep.

NET POSITIVE

With reference to the atmosphere, net positive refers to the state in which the amount of greenhouse gases (GHGs) removed from the atmosphere is greater than the amount of GHGs emitted into the atmosphere. It can also refer to the general position of achieving a more positive than negative impact on the environment on society and beyond.

NET ZERO

Net zero refers to the state in which the amount of greenhouse gases (GHGs) emitted into the atmosphere is equal to and balanced by the amount of GHGs removed from the atmosphere. It can also refer to the general position of balancing positive and negative impacts on the environment, society, and beyond.

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 qubits) and thus enhances potential computational power.

QUANTUM DOTS (NEW)

Quantum dots are semiconductor nanoparticles that form part of quantum technologies and are used in numerous electronic and biomedical applications and have the potential to advance quantum computing in the future.

R

RANSOMWARE

Ransomware is malicious software that is designed to carry out cyberattacks to restrict victims' access to their system or information in return for payment.

S

SELF-HEALING MATERIAL

Self-healing materials are polymers, metals, ceramics, and their composites that, when damaged by an operational use, can fully or partially recover.

SIGNAL (FORESIGHT) (NEW)

Events, hypes, new technologies, products and services, local and regional data and disruptions that have the potential to grow to become drivers or trends.

SOCIAL CAPITAL

Social capital allows individuals to work together based on the ability to obtain resources, support, favours, or information from one's personal connections.

SPACE DEBRIS

Space debris encompasses both natural (e.g. meteoroids) and artificial waste that is in orbit around the Earth.

SUPERCOMPUTER

A supercomputer is a computer that performs at a significantly faster rate than general computers, as measured in floating-point operations per second (FLOPS).

SYNTHETIC BIOLOGY

Synthetic biology involves the redesign or re-engineering of organisms and molecules to give them new properties – for example, synthetic enzymes capable of digesting plastic.

T

TELESURGERY

Telesurgery is surgery where the patient and the surgeon are in different physical locations.

TERAWATT HOUR (TWH)

A terawatt hour is a standard unit of energy equivalent to 1,000 gigawatt hours (GWh).

TIDAL ENERGY (NEW)

Tidal energy is a form of hydropower that converts energy from the tides into electricity.

TRANSCRANIAL ALTERNATING CURRENT STIMULATION (tACS) (NEW)

Transcranial alternating current stimulation is a form of non-invasive brain stimulation in which alternating electric currents are delivered to the scalp to modulate brain function.

TRANSCRANIAL MAGNETIC STIMULATION (TMS) (NEW)

Transcranial magnetic stimulation is a non-invasive procedure that uses magnetic fields to stimulate nerve cells in the brain to improve symptoms of major depression.

TREND (FORESIGHT) (NEW)

A sustained socio-economic, environmental, or technological change that has a measurably rising influence, such as a physical or financial impact.

TRIBOELECTRIC NANOGENERATOR (TENG) (NEW)

Triboelectric nanogenerators harvest electrical energy from mechanical energy generated from movement between sensors or distinct materials.

TURING TEST (NEW)

The Turing Test posits that, if a machine can engage in a conversation with a human without being detected as a machine, it has demonstrated human intelligence.

U

UPSKILLING (NEW)

Upskilling is the process of learning new and enhanced skills in a current role.

V

VALUE CHAIN (NEW)

A value chain consists of the steps that go into the creation of a finished product or service, from design to purchase.

VIRTUAL REALITY (VR)

Virtual realities are computer-generated environments 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 in fictitious environments.

W

WEB 3.0

Web 3.0, or Web3, is the third generation of the internet. It is characterised by greater reliance on AI for enhanced searchability and interaction.

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, start-ups 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.

DISCLAIMER

This report was prepared for informational, educational, and guidance purposes. It includes several future directions based on studies and research that should not necessarily be adopted or implemented. The findings, interpretations, and conclusions expressed in this report do not necessarily reflect the views of DFF.

The information presented in this report is based on studies, research, and data available up to the date of publication.

The report aims to provide information and stimulate critical thinking and informed decision-making in the areas of future foresight. DFF disclaims all liability related to the content and use of the report (or any reliance placed on it, in particular, for any interpretation, decisions, or actions based on the information in this report). DFF does not recommend or endorse any specific actions, strategies, or viewpoints discussed in this report.

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This report is provided in English as the authoritative and operative version. Any Arabic translation included herein 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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