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The future of sustainability

Navigating trends and innovations for a sustainable tomorrow

beyond the obvious

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The future of sustainability:

Navigating trends and innovations for a sustainable tomorrow

0/ Executive summary

The **Future of sustainability report** provides a comprehensive analysis of the evolving landscape of sustainability. The study aims to forecast key trends and innovations that will shape the future, offering actionable insights and strategic recommendations for businesses, policymakers, and researchers.

Methodology & approach

Trend analysis: The report identifies 87 sustainability trends across four dimensions: societal (16), technological (26), environmental (21), and economic (24). These trends are examined over three timeframes: short- (now–2030), mid- (2030–2040), and long-term (2040 and beyond).

Methodology: A multi-faceted approach was employed, including literature reviews, expert interviews, and the use of advanced Large Language Models (LLMs).

Trend Radar: The development of a trend radar maps out key trends, providing a visual and analytical guide for stakeholders to navigate the future of sustainability.

The perfect storm

Companies are facing a **perfect storm of sustainability trends**, driven by rapid technological advancements, shifting regulatory landscapes, evolving consumer expectations, and intensifying environmental challenges. From the rise of circular economy models and the integration of renewable energy to the transformative impacts of AI governance, quantum computing, and advanced recycling technologies, the sheer breadth and pace of change are unprecedented.

Navigating this storm requires businesses to not only understand the **evolving sustainability landscape** but also to critically assess which trends are most **relevant and existential** to their operations, stakeholders, and long-term goals. Given the reality of **limited resources**, companies must prioritise efforts that align with their core values and offer the greatest strategic impact. By proactively identifying and addressing these critical trends, businesses can turn challenges into opportunities, securing resilience and competitive advantage in an increasingly sustainability-driven market.

Key findings & strategic recommendations

Key findings	Strategic recommendations
Climate change adaptation and resilience Organisations must prioritise adaptation and resilience strategies to mitigate risks associated with climate-related events.	**Enhance climate resilience** Invest in resilient infrastructure and develop comprehensive risk management plans to protect operations and ensure continuity in the face of climate disruptions. This includes adopting adaptive practices in agriculture and urban planning.
Decarbonisation and green finance The transition to a low-carbon economy is accelerating, driven by regulatory pressures, technological advancements, and investor demand for sustainable finance.	**Accelerate decarbonisation efforts** Prioritise investments in renewable energy, energy efficiency, and carbon capture technologies. Leverage green finance opportunities to fund these initiatives and make sustainability a key factor in attracting investment.
Biodiversity and ecosystem preservation Biodiversity loss continues at an alarming rate, highlighting the need for urgent conservation efforts.	**Integrate biodiversity preservation** Incorporate biodiversity preservation into sustainability strategies by focusing on sustainable land use, reducing habitat destruction, and supporting conservation projects. This will help maintain ecosystem services and ensure the sustainability of natural resources.
Technological integration Technological advancements, particularly in artificial intelligence and data analytics, are pivotal in enhancing sustainability efforts.	**Leverage technological advancements** Invest in AI and data analytics to enhance sustainability efforts and improve operational efficiency. Implement new technologies to reduce environmental impacts and enhance transparency.
Regulatory and policy influence Geopolitical events and regulatory changes significantly influence sustainability practices.	**Proactively engage with policymakers** Stay ahead of regulatory changes and engage with policymakers to drive innovation and maintain a competitive advantage. Proactive engagement will be crucial for influencing and adapting to regulatory developments.

The **future of sustainability** report offers a detailed, forward-looking analysis that equips stakeholders with the knowledge and tools needed to navigate the complexities of the modern world. By proactively embracing these trends and recommendations, organisations can drive positive change and ensure long-term success in a rapidly evolving sustainability landscape.

Note of caution: It is important to recognise that forward-looking predictions can be uncertain and are based on our current best understanding. As such, these predictions should be interpreted with caution and flexibility to adapt to new information and changing circumstances.

1/ Introduction

Purpose and scope

The primary purpose of this study is to empower decision-makers with actionable insights into the evolving sustainability landscape, equipping them to address critical challenges and seize emerging opportunities. By identifying and analysing key trends and innovations, this report aims to serve as a strategic tool for policymakers, business leaders, and researchers. Our objective is to inspire meaningful action, encourage informed decision-making, and provide clear pathways for integrating sustainability into strategies, operations, and policies.

To achieve this, the study employs a comprehensive trend radar, which highlights the most pressing and influential trends across four dimensions of sustainability: societal (including political, regulatory, and social aspects), technological, environmental, and economic. Each dimension is analysed across three distinct timeframes: short-term (now–2030), mid-term (2030–2040), and long-term (2040 and beyond). This structure allows stakeholders to understand both immediate priorities and long-term strategies.

Recognising the European perspective that shapes much of this analysis, the study focuses on insights relevant to regions with advanced economies and established regulatory frameworks. While global trends are acknowledged, the emphasis is on actionable insights within contexts familiar to the authors and their intended audience. This targeted approach ensures the content remains focused, relevant, and impactful.

In response to the complexity and urgency of sustainability challenges, this study does not aim to provide an exhaustive catalogue of trends. Instead, it prioritises key areas with the greatest potential for driving transformation and creating value. For instance, technological trends emphasise pivotal innovations like artificial intelligence and clean technologies, while economic trends focus on models that integrate long-term value creation with environmental stewardship. By honing in on such high-impact areas, the report offers a sharper, more actionable perspective.

To maximise clarity and usability, the report is structured to begin with the megatrends driving sustainability action. These overarching trends provide a contextual framework, underscoring the urgency of change and highlighting the interconnectedness of societal, technological, environmental, and economic factors. Supporting sections delve deeper into specific dimensions, offering detailed insights and strategic recommendations tailored to the needs of the target audience.

Ultimately, this study is designed as a practical guide to navigating the future of sustainability. By emphasising the critical importance of proactive adaptation and collaboration, it seeks to inspire leaders to reimagine value creation, protect and restore vital resources, and foster a more equitable and resilient future for all.

Methodology

The methodology for the study of the future of sustainability involves a **multi-faceted approach** to ensure a comprehensive and well-rounded analysis. We began with a **selective literature review**, examining academic papers, industry reports, policy documents, and other relevant publications. This review provided a broad understanding of current trends, challenges, and innovations in sustainability.

Next, we leveraged the **expertise of specialists from VTT**, Finland's largest research and technology organisation, dedicated to providing applied research and innovation services to domestic and international partners, and striving to create meaningful impact on the world's biggest challenges. These experts contributed valuable insights from their research and development work in various sustainability-related fields. Their input helped to deepen our understanding and to validate our findings.

In addition to academic and research inputs, we verified trends and developments **with industry experts**, including Chief Strategy Officers and Chief Sustainability Officers. These (unstructured) conversations offered practical insights and forward-looking perspectives from leading companies and organisations, enriching our analysis with real-world experiences and strategic viewpoints.

To further enhance our analysis, we utilised **advanced Large Language Models (LLMs)**. These models assisted in processing and interpreting vast amounts of data, identifying patterns, and generating insights. The use of LLMs ensured that our analysis is both comprehensive and data driven.[1]

We then integrated the findings from the literature review, expert inputs, and LLM analysis to identify key trends and innovations in sustainability. This involved both **qualitative and quantitative analysis** to ensure a robust and evidence-based understanding of the future sustainability landscape.

The development of the **trend radar** is a crucial part of our methodology. The tool maps out the identified trends across four dimensions: **societal** (including political, regulatory, and social aspects), **technological**, **environmental**, and **economic**, and three timeframes: **short-term (now–2030)**, mid-term (2030–2040), and **long-term (2040–2050)**. The trend radar serves as a visual and analytical guide for stakeholders to navigate the future of sustainability.

Finally, we **validated our findings** and the trend radar through peer reviews. This step ensured the accuracy, relevance, and practical applicability of our conclusions and recommendations.

[1]See Appendix 1 for a detailed description of the methodology.

Structure of the report

The report is designed to guide readers through the key forces shaping the future of sustainability, from broad global developments to specific trends and megatrends. It begins with the **executive summary**, which provides a concise and accessible overview of the report's main findings. This section highlights the most critical trends and megatrends influencing sustainability, offering decision-makers, policymakers, and other stakeholders a quick snapshot of the report's key insights and takeaways.

Following this, the **introduction** establishes the purpose and scope of the report, explaining why understanding sustainability trends is critical for businesses, governments, and society. It also outlines the methodology used, emphasising the analytical rigour applied to identify emerging trends and ensure credible, actionable insights.

The **big picture: Tehe future of sustainability** sets the scene by framing sustainability within a broader context. It highlights the overarching forces, challenges, and opportunities that are redefining economies, societies, and ecosystems. This section provides a foundation for understanding the broader landscape, ensuring readers see the urgency and interconnected nature of sustainability transformations.

The **sustainability megatrends** section explores five transformative forces driving systemic change on a global scale. The first, **decarbonisation of the global economy**, discusses the transition to low-carbon systems, emissions reduction strategies, and policies supporting net-zero goals. Next, **the rise of circular economies** highlights strategies to optimise resource usage, close resource loops, and extend product lifecycles. **Sustainable urbanisation and resilient infrastructure** examines the development of climate-resilient cities, smart infrastructure, and sustainable urban planning to meet growing population needs. **The emergence of a sustainability-centric economic model** explores the shift toward economic systems that prioritise long-term environmental and societal value. Lastly, **sustainable food systems and consumption** focuses on transforming food production and consumption to ensure equity, nutrition, and resource efficiency in a rapidly changing world.

The **trend radar** forms the analytical core of the report and the basis for the megatrends, diving into emerging and evolving trends across four key dimensions: economic, environmental, technological, and societal. It begins with an **overview**, explaining the trend radar concept and the process used to identify these trends. The report then explores **economic trends in sustainability**, including the role of green financing, SG-driven investments, and the shift towards circular economic models. Environmental trends focuses on climate resilience, biodiversity preservation, and resource efficiency, highlighting efforts to mitigate pollution and promote nature-positive strategies. In parallel, **technological trends** examine the enabling role of innovation, from renewable energy and digital transformation to AI and sustainable material development. Finally, **societal trends** address shifts in behaviours, values, and consumption patterns, emphasising the role of equity, education, and generational change in advancing sustainability.

The **conclusion** synthesizes the report's findings, highlighting the interconnected nature of trends and megatrends while offering forward-looking perspectives for businesses, policymakers, and organisations. It underscores the need for collaboration, innovation, and systemic change to address sustainability challenges and seize new opportunities.

Finally, the **appendices** provide supporting information, including the methodology used to identify emerging trends with the help of Large Language Models (LLMs). References and data sources are also included to enable further exploration of the topics discussed in the report.

2/ The big picture: The future of sustainability

As environmental and social challenges escalate, several key strategic sustainability trends are emerging that will shape the business and societal landscape. These trends are critical for organisations aiming to navigate the complexities of the modern world while ensuring long-term resilience and success. The following explains why these seven key strategic sustainability trends are essential and how they are driving meaningful change across industries.

- **Climate change adaptation and resilience:** As climate-related events become more frequent and severe, organisations must prioritise both mitigation and adaptation to address the dual challenge of reducing greenhouse gas (GHG) emissions and preparing for rising temperatures. While the first priority must remain reducing GHG emissions to combat the root cause of climate change, the rising frequency and severity of extreme weather events necessitate proactive adaptation measures. Companies and public organisations should invest in resilient infrastructure, develop comprehensive risk management plans, and adopt adaptive practices in areas like agriculture and urban planning. This balanced approach will help mitigate risks, enhance recovery capabilities, and ensure continuity in the face of climate disruptions.[2]

- **Decarbonisation and green finance:** The transition to a low-carbon economy is accelerating, driven by regulatory pressures, technological advancements, and investor demand for sustainable finance. Long-term projections suggest significant growth in green bonds and sustainability-linked loans, providing essential funding for decarbonisation initiatives. Businesses must prioritise reducing greenhouse gas emissions through investments in renewable energy, energy efficiency, and carbon capture technologies. In addition, phasing out fossil fuels and transitioning to alternative raw materials are critical components of this shift. This includes adopting bio-based, recycled, or renewable materials across industries to reduce dependency on fossil-based resources. Access to green finance will be crucial for funding these initiatives, making sustainability a key factor in attracting investment.[3]

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[2] IPCC (2023); EEA (2023)

[3] IDFC (2023); CPI (2023)

- **Biodiversity and ecosystem preservation:** Biodiversity loss continues at an alarming rate, highlighting the need for urgent conservation efforts and changes in production and consumption habits. Long-term projections emphasise the importance of protecting ecosystems and restoring natural habitats. Companies and public organisations must integrate biodiversity preservation into their sustainability strategies, focusing on sustainable land use, reducing habitat destruction, and supporting conservation projects. Additionally, they should prioritise sustainable and responsible sourcing practices, paying close attention to the origins and production methods of their purchased goods and services, as these often have the largest biodiversity impacts. These efforts, while potentially introducing short-term costs and restrictions on resource availability, will help maintain ecosystem services and ensure the sustainability of natural resources in the long term.[4]

- **Technological integration:** Technological advancements, particularly in artificial intelligence and data analytics, are essential for enabling more sustainable decision-making by gathering critical data from the value chain and stakeholders. These technologies play a pivotal role in environmental monitoring, resource management, and sustainability reporting. However, for driving tangible improvements in sustainability, other technologies – such as those related to manufacturing processes, renewable energy, and energy efficiency – must also be emphasised. Organisations should critically evaluate how they can utilise new technologies and for what purpose, ensuring alignment with their sustainability goals. Robust governance frameworks will be essential to manage the risks and opportunities associated with technological integration, ensuring ethical and effective use.[5]

- **Regulatory and policy influence:** Geopolitical events and regulatory changes significantly influence sustainability practices. Long-term projections suggest stricter environmental regulations and policies to address climate change, pollution, and resource depletion. Companies and public organisations must stay ahead of regulatory changes, ensuring compliance and leveraging new policies to drive innovation and competitive advantage. Proactive engagement with policymakers and stakeholders will be crucial for influencing and adapting to regulatory developments.[6]

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[4] BCG Henderson Institute (2023); Agliardi, E., Agliardi, R. & Spanjers, W. (2024)

[5] Alotaibi, E., Nassif, N. (2024); UNEP (2022)

[6] Oliver Yébenes, M. (2024); Morgan Lewis (2024).

[7] Quattrone, P. (2022); Kim, W. (2023); Hyytinen A., Maliranta M., Rouvinen P., Tahvanainen A-J (eds.) (2024)

- **Corporate transparency and accountability:** Corporate transparency in sustainability is now a critical expectation, with intensified reporting requirements driving organisations to disclose their environmental and social impacts comprehensively. Standardised frameworks and metrics ensure comparability and build trust, enhancing reputation and fostering continuous improvement. However, transparency may also lead to conflicts, as environmental deterioration and resource competition can fuel disagreements among stakeholders. Navigating these perspectives effectively is essential for maintaining trust and operational stability. Moreover, transparent sustainability practices are increasingly a key competitiveness factor in job markets. Employees now prioritise organisations committed to sustainability, making transparency vital not only for financiers and markets but also for attracting and retaining talent. This underscores the multifaceted value of accountability in today's business landscape.[7]

- **Societal well-being and equity:** Addressing societal aspects of sustainability is becoming increasingly important. Long-term projections highlight the need for greater focus on social equity, community well-being, and inclusive growth. Companies and public organisations must prioritise initiatives that promote social justice, reduce inequalities, and enhance the quality of life for all individuals. This responsibility extends beyond direct operations and tier-1 suppliers to encompass the entire value chain, including local communities in distant regions where raw materials, components, and products are sourced or manufactured. Regulations increasingly mandate transparency and accountability across these supply chains, requiring organisations to know where and how their materials and products are produced. Advanced tools like artificial intelligence can play a pivotal role in managing the vast amount of data and information required to ensure responsible practices across extensive supplier networks. Additionally, fostering societal well-being involves investing in education, healthcare, and affordable housing, as well as ensuring fair labour practices, community engagement, and adherence to principles like providing a living wage. By addressing these areas comprehensively, organisations can build stronger, more resilient communities and contribute to a more equitable and sustainable future.[8]

Understanding and leveraging long-term projections for these key strategic sustainability trends is essential for effective strategic decision-making. By proactively embracing these trends, companies and public organisations can navigate the complexities of the modern world, drive positive change, and ensure long-term success. Building a resilient, sustainable, and prosperous future depends on our ability to anticipate and adapt to these evolving challenges and opportunities.[9]

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[8] OECD (2022).

[9] EEA (2024); Matti, C., Jensen, K., Bontoux, L., Goran, P., Pistocchi, A. and Salvi, M. (2023).

3/ The perfect storm

The ”Future of sustainability” study has identified 87 sustainability trends, all unfolding within a highly condensed timeframe, primarily from today to 2040. These trends span a wide range of environmental, technological, social, and economic dimensions, creating a complex web of challenges and opportunities for businesses. The interconnectedness of these trends further amplifies their complexity, as developments in one area often trigger cascading effects across others. Many of these trends are happening in parallel, forcing companies to make difficult decisions about which to prioritise as they navigate limited resources and competing demands. This unprecedented convergence of sustainability developments is reshaping industries, markets, and stakeholder expectations, demanding immediate and strategic responses.

The convergence of forces

The perfect storm of sustainability trends is driven by the intersection of environmental, societal, technological, and regulatory forces, each amplifying the challenges businesses face today. Environmental challenges from biodiversity loss and resource scarcity to extreme weather events are imposing immediate operational and strategic risks. These realities underscore the need for resilience and adaptation. Companies that embrace sustainability as a core principle are better positioned to mitigate risks and capitalise on emerging opportunities.

Societal expectations further compound these challenges. Today’s consumers are increasingly informed and value-driven, demanding transparency, ethical practices, and environmentally friendly products. Studies show that a majority of consumers are willing to pay a premium for sustainable goods, and loyalty often hinges on a company’s demonstrated commitment to social and environmental responsibility. Businesses that fail to adapt risk losing their competitive edge and alienating key stakeholders.

Technological advancements add another layer of complexity and opportunity. Innovations such as quantum computing, artificial intelligence (AI), and the Internet of Things (IoT) are opening new possibilities for resource efficiency, predictive analytics, and emissions reduction. For example, AI-powered tools are optimising energy grids, enabling smarter supply chains, and driving innovations in sustainable agriculture. Meanwhile, quantum computing promises breakthroughs in climate modelling and material science, potentially revolutionising industries reliant on complex problem-solving.

Parallel to these technological innovations, regulatory landscapes are evolving at a pace that few businesses can afford to ignore. Governments and international bodies are implementing ambitious policies to combat climate change, promote circular economies, and regulate carbon-intensive activities. Frameworks such as the European Green Deal and the United Nations Sustainable Development Goals (SDGs) are becoming benchmarks for corporate accountability. Non-compliance is no longer an option, as regulatory penalties and reputational risks grow more severe.

The interplay among these forces creates a highly dynamic and interconnected landscape. Businesses must navigate these complexities with foresight and agility, recognising that progress in one area often influences or demands action in others.

Navigating the storm

Navigating this perfect storm requires businesses to develop a deep understanding of the evolving sustainability landscape. It is not enough to react to trends as they emerge; companies must anticipate and prepare for the challenges and opportunities that lie ahead. This entails a strategic approach to identifying which trends are most relevant and existential to their operations and long-term goals.

First and foremost, businesses must undertake a comprehensive materiality assessment to prioritise sustainability issues that have the greatest impact on their stakeholders and bottom line. By focusing on material issues, whether it be carbon reduction, water management, or supply chain transparency, companies can allocate their limited resources to areas that drive the most value and resilience.

Moreover, cross-functional collaboration is essential. Sustainability cannot be siloed within corporate social responsibility (CSR) departments, it must permeate the organisation's culture and strategy. Cross-disciplinary teams that integrate expertise from operations, finance, marketing, and technology can ensure a holistic approach to tackling sustainability challenges. For instance, integrating IoT devices across manufacturing plants can lead to immediate gains in energy efficiency and waste reduction.

Turning challenges into opportunities

The perfect storm of sustainability trends also presents unparalleled opportunities for innovation and leadership. Companies that proactively embrace these trends can position themselves as industry leaders and secure a competitive advantage. Investing in circular economy practices, for example, not only reduces waste but also unlocks new revenue streams through resource recovery and product-as-a-service models. Similarly, leveraging AI for predictive maintenance can extend the lifespan of equipment, reducing costs and environmental impact.

To seize these opportunities, businesses must foster a culture of agility and continuous learning. This involves staying informed about emerging trends, engaging with stakeholders, and investing in research and development. Companies should also collaborate with industry peers, NGOs, and policymakers to shape the future of sustainability and establish standards that benefit society as a whole.

Preparing for the future

Looking ahead, the challenges posed by the sustainability storm will only intensify. As we approach 2040 and beyond, transformative technologies such as quantum computing and advanced recycling will redefine what is possible in sustainability. Simultaneously, societal expectations will continue to evolve, demanding even greater transparency, equity, and accountability from businesses.

To prepare for this future, companies must embed foresight into their strategic planning. Scenario planning and horizon scanning can help organisations anticipate shifts in the regulatory, technological, and social landscapes. By proactively identifying potential risks and opportunities, businesses can build resilience and adaptability into their operations.

While the political climate is currently shifting, it is important to recognise that these pressures are larger than short-term political and opinion fluctuations. Companies and individuals may feel compelled to interpret this as the end of sustainability efforts, but the driving forces behind these trends will continue independent of the "flavour of the day."

4/ Sustainability megatrends

Building upon the individual trends identified in this study and outlined in the trend radar, we have identified a set of powerful sustainability megatrends that emerge from the convergence of these individual trends. These megatrends represent transformative forces with the potential to reshape the global economy, society, and environment, as businesses, governments, and communities respond to the urgent and interconnected challenges of sustainability. Unlike isolated trends, these megatrends reflect systemic shifts driven by the intersection of technological advancements, economic restructuring, regulatory evolution, and changing societal expectations. They highlight how innovation, resource efficiency, and stakeholder collaboration are no longer optional but essential elements of a sustainable future.

The sustainability megatrends presented in this chapter transcend geographic, sectoral, and disciplinary boundaries, offering a holistic view of the transitions required to address critical global challenges such as climate change, resource scarcity, and social equity. Each megatrend demonstrates how individual trends, such as decarbonisation, the rise of circular economies, and sustainable finance, interact with and amplify one another, creating a powerful momentum for change. These shifts are not only reshaping industries and business models but also redefining how success is measured, prioritising long-term resilience, environmental stewardship, and societal well-being over short-term economic gains.

As we explore these megatrends, we aim to provide a comprehensive analysis of their underlying drivers, key implications, and the opportunities they present for innovation and growth. From the transition to decarbonised energy systems and circular economic practices to the development of resilient infrastructure and sustainable food systems, these megatrends offer a roadmap for navigating the complexities of global sustainability challenges. Moreover, they underscore the urgency of collective action, as the interplay between government policies, corporate strategies, and consumer behaviours will determine the speed and scale of this transformation.

Ultimately, these megatrends serve as a framework for understanding the interconnected nature of sustainability and the profound changes required to achieve a more equitable, regenerative, and prosperous future. In the pages ahead, we delve into the details of each megatrend, illustrating how they are reshaping our world and offering actionable insights for stakeholders across sectors. Whether through leveraging cutting-edge technologies, rethinking supply chains, or fostering cross-sector collaborations, the path forward will require bold and innovative approaches to ensure the well-being of both people and the planet.

Decarbonisation of the global economy

The drive to drastically reduce greenhouse gas emissions across all sectors is transforming industries, energy systems, housing, food production and transportation. This trend encompasses the shift from fossil fuels to renewable energy sources, coupled with innovations in clean technology, carbon capture, and sustainable finance. By 2040 and beyond, a decarbonised economy will be key to global sustainability efforts.[10]

Megatrend description

The decarbonisation of the global economy is one of the most transformative and urgent sustainability megatrends of our time. It refers to the systematic reduction of greenhouse gas emissions across all sectors, including energy, transportation, industry, and agriculture, with the ultimate goal of achieving a low-carbon or net-zero economy.[11] As nations commit to ambitious climate targets under international agreements such as the Paris Accord, businesses, governments, and investors are increasingly aligning their strategies and investments with decarbonisation pathways.[12]

The decarbonisation megatrend encompasses a range of individual trends that collectively drive the transition away from fossil fuels and towards cleaner, renewable energy sources. Key individual trends such as **corporate sustainability** and **sustainable finance** (1.1.1, 1.1.4) are pushing companies to take greater responsibility for their environmental impact, with ESG (Environmental, Social, Governance) criteria now influencing investment decisions.[13] The shift towards **renewable energy** (3.1.2) and **energy efficiency** (1.1.2) is already underway, with rapid advancements in solar, wind, and energy storage technologies providing cost-effective and scalable solutions for reducing reliance on fossil fuels.[14]

Further contributing to this megatrend are technological innovations such as **carbon capture and storage (CCS)** and **carbon capture and utilisation (CCU)** (3.2.2), which play a critical role in mitigating emissions from hard-to-decarbonise sectors.[15] By the mid-term horizon (2030–2040), advancements in **clean technologies** (1.2.3), such as electric vehicles and green hydrogen, will become even more economically viable, accelerating the global transition to a decarbonised economy.[16] By 2040 and beyond, the **decarbonised economy** (1.3.1) is expected to be largely realised, with renewable energy sources becoming the dominant means of energy production, accompanied by dramatic reductions in fossil fuel use across sectors.[17]

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[10] IPCC (2018); IEA (2021).
[11] UNFCCC (2016); World Bank (2015).
[12] World Economic Forum (2021).
[13] Global Sustainable Investment Alliance (2023).
[14] IRENA (2024).
[15] Global CCS Institute (2024).
[16] IEA (2022); IRENA (2024).
[17] IRENA (2024).

Trend implications

The decarbonisation megatrend has wide-reaching implications for economies, industries, and societies:

- **Energy transition:** The global shift away from fossil fuels will drive massive investments in renewable energy infrastructure. Solar, wind, and hydropower will form the backbone of this energy transition, supported by **energy storage** (3.1.5) innovations to ensure grid reliability. **Smart grids** (3.1.4) will play a key role in efficiently managing energy distribution, enabling the integration of decentralised renewable energy sources into the grid.[18]

- **Transportation:** The decarbonisation of transportation is already accelerating, with the rise of **eMobility** (1.1.5) driving the adoption of electric vehicles (EVs). Governments around the world are implementing policies to incentivise the development of EV charging infrastructure, while automakers are scaling up production of electric models. This trend is expected to grow further in the mid-term, with EVs becoming mainstream and playing a significant role in reducing emissions from the transportation sector. [19]

- **Industrial transformation:** Hard-to-abate industries such as cement, steel, and chemicals will increasingly turn to clean technologies (1.2.3) and carbon capture (3.2.2) solutions to mitigate their carbon footprints. Resource efficiency (1.2.6) innovations will reduce energy consumption and emissions in manufacturing processes. The rise of green hydrogen (3.3.5) as a clean energy carrier will offer an alternative to fossil fuels for industrial processes that are currently challenging to decarbonise. These advancements will require clean electricity and robust infrastructure, including smart grids, to support the integration of carbon capture solutions and the widespread adoption of green hydrogen.[20]

- **Finance and investment:** The growth of sustainable finance (1.1.4) is channelling capital into low-carbon technologies and businesses. The rapid expansion of green bonds and sustainable investment funds is driving companies to adopt more sustainable practices, creating new markets and investment opportunities. By the mid-term, green finance (1.2.1) products, such as green loans and impact investing, will continue to evolve, providing further financial incentives for companies to decarbonise.[21]

- **Global competitiveness:** Nations and companies that lead in the decarbonisation race will gain competitive advantages. Countries with well-developed renewable energy integration (1.2.8) and smart city (3.2.3) infrastructures will attract investment and talent, while businesses that adopt low-carbon strategies early will enjoy reputational and financial benefits. Conversely, those that lag behind may face regulatory penalties and stranded assets as the global economy shifts.[22]

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[18] IRENA (2024).

[19] IEA (2024).

[20] WEF (2024:2); Material Economics (2019).

[21] United Nations (2024:3); Pertseva, S., Vityazeva, A. (2024).

[22] OECD (2023); Deloitte. Insights (2019).

Quantitative indicator

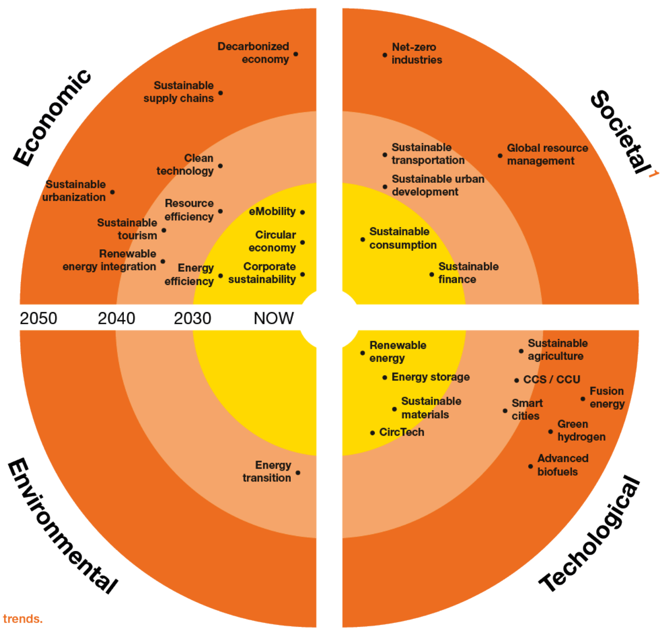
A key quantitative indicator for tracking the progress of global decarbonisation is **global carbon emissions**, measured in gigatonnes (Gt) of CO_2 equivalent per year. The following targets and milestones provide a clear indicator of the megatrend's trajectory:

- **2030:** Global carbon emissions must decrease by approximately 45% from 2010 levels to limit global warming to 1.5°C, according to the IPCC.[23]
- **2040:** By this time, most developed economies are expected to have fully decarbonised their energy sectors, with renewable energy providing the majority of electricity. Global emissions should be on track to approach net-zero by mid-century.[24]
- **2050:** Net-zero emissions globally are required to achieve the Paris Agreement goals. Major shifts in industry, energy, and transportation will have occurred, largely completing the decarbonisation of the global economy. [25]

Individual trends covered

The decarbonisation of the global economy is a cornerstone of the sustainability transition, driven by a confluence of trends that span corporate responsibility, technological innovation, financial instruments, and government policies. As this megatrend accelerates in the coming decades, it will reshape industries, redefine energy systems, and create new opportunities for growth and innovation while addressing the urgent need to combat climate change.

Decarbonization of the global economy



1) Societal dimension includes political, social and regulatory trends.

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[23] IPCC (2018).

[24] IEA (2021).

[25] IPCC (2018); IEA (2021); UNFCCC (2016).

The rise of circular economies

Circular economies, which emphasise the reuse, recycling, and regeneration of resources, are becoming a fundamental principle for businesses, technologies, and policies. This shift is transforming supply chains, production processes, and product life cycles, with a focus on reducing waste and maximising resource efficiency.

Megatrend description

The rise of circular economies represents a fundamental shift in how resources are managed, produced, and consumed. Unlike the traditional linear economic model, where products are made, used, and discarded, a circular economy seeks to keep resources in use for as long as possible by maximising reuse, recycling, and regeneration. This model aims to minimise waste, reduce environmental impact, and promote long-term sustainability by designing out waste and pollution, keeping materials in circulation, and regenerating natural systems.[26] As companies, governments, and consumers increasingly recognise the need to decouple economic growth from resource consumption, the circular economy is emerging as a critical pathway for building a more sustainable future.[27]

Several individual trends within the economic, technological, and environmental dimensions are contributing to this megatrend. The **circular economy** (1.1.3) trend has gained momentum in recent years, with businesses adopting circular business models that prioritise resource efficiency and waste reduction. Technological innovations, such as **CircTech** (3.1.6) and **advanced recycling technologies** (1.3.8), are enabling more efficient recovery of materials and are making it easier to close the loop on waste. Similarly, the emphasis on **sustainable supply chains** (1.3.2) and **resource efficiency** (1.2.6) reflects how industries are rethinking their production processes to ensure the continuous circulation of materials.[28] In the mid- and long-term, advances in **biodegradable materials** (3.3.10) and **synthetic biology** (3.3.8) will further drive the development of circular systems, offering new solutions for creating sustainable, regenerative products.[29]

Achieving a truly circular economy will require transforming current products & production systems to overcome systemic bottlenecks, technical, organisational, and behavioural. Recycling, while essential, represents only one part of the broader strategy. Other approaches, such as designing products for durability and repairability, fostering sharing and service-based business models, and implementing strategies for material reduction and substitution, must also be emphasised to create a holistic and effective circular economy.

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[26] Webster, K., MacArthur, E. (2013).

[27] UNEP (2011); Thomsen, T.P., Lybæk, R., Christensen, T.B. (2022).

[28] WEF (2024:2); Circle Economy Foundation / Deloitte. (2024); Bajuk, M. and Linder, M. (2024).

[29] Rajvanshi, J., Sogani, M., Kumar, A., & Arora, S. (2023); Oliver-Cuenca, V., Salaris, V., Muñoz-Gimena, P. F., Agüero, Á., Peltzer, M. A., Montero, V. A., Arrieta, M. P., Sempere-Torregrosa, J., Pavon, C., Samper, M. D., Crespo, G. R., Kenny, J. M., López, D., & Peponi, L. (2024).

Trend implications

The rise of circular economies has far-reaching implications across sectors, from manufacturing and technology to agriculture and waste management. This megatrend influences everything from product design to the way industries handle end-of-life materials and extends to new business models that prioritise durability, repairability, and remanufacturing.

1. **Resource efficiency and waste reduction:** One of the primary drivers of the circular economy is the need to use resources more efficiently and reduce waste. Companies are rethinking their production processes, adopting practices that minimise material input and energy consumption, while finding ways to recycle waste materials back into their supply chains. The **resource efficiency** (1.2.6) trend in manufacturing is central to this shift, with innovations such as lightweight, durable materials and more efficient production techniques helping to reduce the environmental footprint of industry.[30]

2. **Circular business models:** As businesses seek to reduce waste and extend the lifecycle of products, new circular business models are emerging. These include product-as-a-service models, where consumers lease or rent goods instead of purchasing them, and reverse logistics systems that enable the return and refurbishment of used products. The expansion of **circular economy** (1.1.3) principles is reshaping industries from fashion and electronics to packaging and construction. Companies are developing products that are designed for easy disassembly and recycling, while also exploring ways to incentivise consumers to return products at the end of their useful life.[31]

3. **Advanced recycling and waste-to-resource systems:** The development of **advanced recycling technologies** (1.3.8) is key to making circular economies viable on a large scale. Innovations in chemical recycling, bioplastics, and waste-to-resource technologies are enabling the efficient recovery of materials that would otherwise be lost. This is particularly important for industries like electronics, textiles, and plastics, where waste streams have traditionally been difficult to manage. By mid-century, **biodegradable electronics** (3.3.10) and **synthetic biology** (3.3.8) may offer new solutions to long-standing waste management challenges.[32]

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[30] OECD (2024:5); WBCSD (2021).

[31] Markkula A., Pihkola H., Arnold M, Heikkilä P., Hradil P., Kivikytö-Reponen P. (2024).

[32] Peng Z., Simons T. J., Wallach J., Youngman A. (2022); Babaremu, K., Adediji, A., Olumba, N., Okoya, S., Akinlabi, E., & Oyinlola, M. (2024).

4. **Sustainable supply chains:** Circular economies require fully transparent and sustainable supply chains. Companies are increasingly investing in traceability technologies, such as **blockchain** (3.2.5), to ensure that materials are sourced sustainably and remain in circulation. This trend is particularly relevant for industries like fashion and food, where the environmental and social impacts of raw material sourcing have come under greater scrutiny. By the long-term horizon (2040 and beyond), **sustainable supply chains** (1.3.2) will be the norm, with industries collaborating across sectors and regions to achieve circularity goals.[33]

5. **Consumer engagement and behaviour change:** The success of the circular economy depends not only on innovations in production and waste management but also on changes in consumer behaviour. The **sustainable consumption** (4.1.1) trend highlights how consumers are becoming more conscious of their environmental impact and are demanding products that align with circular economy principles. Brands that embrace durability, repairability, and recyclability are likely to win customer loyalty in the coming years. Additionally, as consumers shift towards buying fewer, higher-quality products, businesses will need to adapt their marketing strategies and product offerings to meet this new demand.[34]

Quantitative indicator

A key indicator for tracking the progress of the circular economy is the **global circularity rate**, which measures the percentage of materials recovered and cycled back into the economy. This indicator is used to assess how effectively a country or industry is transitioning from a linear to a circular model.

- **Current circularity rate:** According to the Circularity Gap Report, only about 8.6% of the global economy is currently circular, meaning that the vast majority of materials extracted are not returned to the economy.[35]

- **Target for 2030:** To align with global sustainability goals and address resource efficiency, it is projected that significant advancements in recycling, resource utilisation, and circular business models will be necessary to increase the circularity rate, with ambitious regions like the EU targeting rates near 23-30%.[36]

- **Target for 2050:** By 2050, it is hoped that at least 50% of the global economy will operate on circular principles, with industries fully embracing advanced recycling technologies and biodegradable materials.[37]

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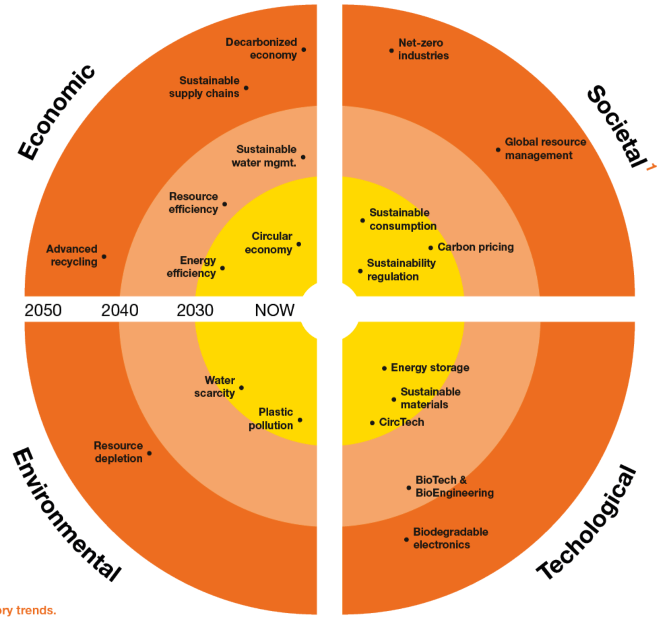
[33] Ellen MacArthur Foundation (2023); Difrancesco, R.M., Meena, P. & Kumar, G. (2023).
[34] Rohsig Lopez NS, Legardeur J. (2024); Bączyk M., Tunn V., Worrell E., Corona B. (2024); Hyytinen A., Maliranta M., Rouvinen P., Tahvanainen A-J (eds.) (2024).
[35] Circle Economy Foundation / Deloitte. (2024).
[36] EEA (2023); CEIC (2022).
[37] European Commission (2020); Schröder P., Barrie J. (2024).

Individual trends covered

The rise of circular economies is transforming the way resources are used, products are designed, and waste is managed. By integrating circular economy principles into every stage of production and consumption, businesses and governments are creating systems that prioritise resource efficiency, waste reduction, and sustainability. As individual trends such as **advanced recycling** (1.3.8), **sustainable supply chains** (1.3.2), and **resource efficiency** (1.2.6) continue to evolve, the circular economy will play a central role in shaping a more sustainable global economy, reducing environmental impact, and fostering long-term resilience.

The rise of circular economies



1) Societal dimension includes political, social and regulatory trends.

Sustainable urbanisation and resilient infrastructure

As the world grapples with climate change, urbanisation, and resource challenges, the development of resilient infrastructure and sustainable cities will be crucial. This trend involves creating smart, climate-resilient, and eco-friendly infrastructure to ensure cities are adaptable to environmental changes while supporting sustainable growth.

Megatrend description

Sustainable urbanisation refers to the transformation of cities and urban spaces to address the challenges of rapid urban growth while ensuring environmental sustainability, social equity, and economic resilience. As more than half of the world's population now lives in urban areas, a figure expected to rise to 68% by 2050, the pressure on cities to become more sustainable is intensifying.[38] The concept of sustainable cities goes beyond reducing carbon footprints; it involves redesigning urban environments to improve the quality of life for residents, enhance resource efficiency, and create resilient infrastructure that can withstand the impacts of climate change.[39]

This megatrend incorporates several individual trends that are reshaping the way cities are designed and function. **Green infrastructure** (1.2.5) and **smart cities** (3.2.3) are key pillars of sustainable urbanisation, focusing on the integration of technology, green spaces, and energy-efficient systems to create cities that are both livable and environmentally friendly. The shift towards **sustainable urban development** (4.2.4), coupled with the adoption of **sustainable transportation** (4.2.5) solutions, is paving the way for cleaner, more efficient urban mobility. In the long term, the planning and development of **sustainable urbanisation** (1.3.7) will shape cities that prioritise renewable energy, climate resilience, and social inclusion.[40]

Trend implications

The transition to sustainable urbanisation has wide-reaching implications for city planning, infrastructure, and social equity. As cities grow, they must innovate to balance environmental stewardship with economic vitality and social well-being.

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[38] United Nations (2018).

[39] Mukim M., Roberts M. [editors] (2023).

[40] UN Habitat (2020); IEA (2021:2).

1. **Green infrastructure and urban resilience:** Cities of the future will increasingly rely on **green infrastructure** (1.2.5) to mitigate the effects of urbanisation and climate change. Green spaces such as parks, urban forests, and green roofs not only reduce the urban heat island effect but also improve air quality and support biodiversity. Additionally, these spaces provide stormwater management solutions, helping cities to cope with extreme weather events such as floods and heavy rainfall. In parallel, **climate-resilient infrastructure** (3.2.8) will be essential for safeguarding cities against rising sea levels, droughts, and other climate-related risks.[41]

2. **Smart cities and digital innovation:** The development of **smart cities** (3.2.3) will play a critical role in making urban environments more efficient and sustainable. Smart grids, sensor networks, and data-driven urban management systems will allow cities to optimise energy use, manage resources more effectively, and reduce pollution. For example, cities equipped with **IoT** (3.1.3) technologies can monitor real-time data on energy consumption, transportation patterns, and waste management, enabling more responsive and efficient city operations.[42]

3. **Sustainable mobility:** Urban transportation is one of the largest contributors to greenhouse gas emissions, and cities are increasingly turning to **sustainable transportation** (4.2.5) solutions to address this challenge. Electric vehicles, shared mobility services, and expanded public transportation networks are key components of this shift. As **eMobility** (1.1.5) becomes more widespread, cities will need to invest in charging infrastructure and incentivise the adoption of clean, electric transportation options. Furthermore, pedestrian-friendly urban designs and cycling infrastructure will reduce dependence on cars and promote healthier lifestyles.[43]

4. **Energy efficiency and renewable integration:** As cities seek to reduce their carbon footprints, **energy efficiency** (1.1.2) and the integration of **renewable energy** (3.1.2) into urban infrastructure will become increasingly important. Buildings, which account for a significant share of urban energy use, will need to adopt energy-efficient technologies, improved insulation, and smart energy management systems to minimise energy consumption. Cities will also invest in renewable energy systems such as solar panels, district heating, and **smart grids** (3.1.4) to reduce their reliance on fossil fuels.[44]

5. **Social equity and inclusive growth:** A critical component of sustainable urbanisation is ensuring that urban development is inclusive and equitable. Cities must address disparities in access to clean air, green spaces, affordable housing, and public services to create healthier, more livable environments for all residents. The trend of **community engagement** (4.1.2) and the growing focus on **sustainable consumption** (4.1.1) are reshaping urban living by empowering residents to take part in local sustainability initiatives and make choices that reduce their environmental impact. In the long-term, **sustainable urbanisation** (1.3.7) will involve planning cities that are socially just and provide opportunities for all inhabitants to thrive.[45]

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[41] Pamukcu-Albers, P., Ugolini, F., La Rosa, D. et al. (2021); Kumareswaran, K., Jayasinghe, G.Y. (2023).
[42] McKinsey (2018); Bibri S. E., Visvizi A., Troisi O. [Editors] (2024).
[43] Khurshid A., Khan K., Saleem S. F., Cifuentes-Faura J., Calin A. C. (2023); ITF (2023).
[44] IEA (2024:2); IRENA (2020).
[45] OECD (2024:6); White, K., Habib, R., & Hardisty, D. J. (2019).

Quantitative indicator

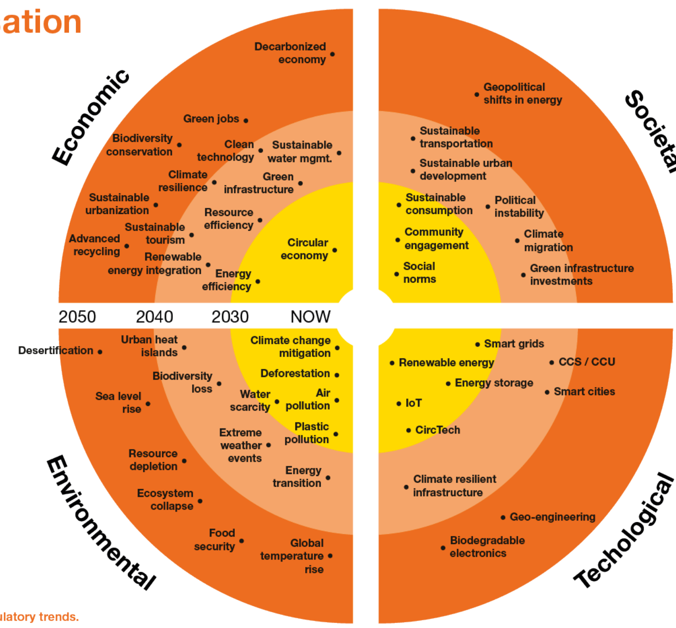
A key quantitative indicator for tracking progress in sustainable urbanisation is the **percentage of urban population with access to green spaces**, a measure that reflects both environmental quality and social equity in urban areas.

- **Current access:** Rapid urbanisation with **over 55% of the global population living in cities**, leading to increased pressure on infrastructure and services.[46]
- **Target for 2030:** Enhance inclusive and sustainable urbanisation with participatory, integrated planning and management to ensure equitable development, aiming for **90% of urban areas to have inclusive planning processes.**[47]
- **Target for 2050:** Develop resilient infrastructure to support the anticipated urban population growth, ensuring sustainability and adaptability to climate change, with a goal of **100% of new urban infrastructure being climate-resilient.**[48]

Individual trends covered

The sustainable urbanisation megatrend underscores the critical need for cities to evolve into resilient, resource-efficient, and socially inclusive spaces. By integrating **green infrastructure** (1.2.5), **smart city technologies** (3.2.3), and **sustainable mobility** (4.2.5) solutions, cities can reduce their environmental impact while enhancing the well-being of their residents. As urban populations continue to grow, the shift towards **sustainable urbanisation** (1.3.7) will become essential for meeting global sustainability goals and building cities that are fit for the future.

Sustainable urbanisation and resilient infrastructure



1) Societal dimension includes political, social and regulatory trends.

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[46] UN-Habitat (2024).
[47] The Global Goals (2024).
[48] OECD (2024_2).

The emergence of a sustainability-centric economic model

The emergence of a sustainability-centric economic model shifts the focus from GDP-driven growth to long-term resilience, environmental stewardship, and social equity. This new paradigm prioritises circularity, regenerative systems, and sustainable finance, redefining economic success by integrating environmental and social well-being into business, policy, and investment strategies for a more sustainable future.

Megatrend description

The emergence of a sustainability-centric economic model signals a departure from the traditional GDP-centric approach to economic growth. For decades, global economies have been driven by the pursuit of growth measured by Gross Domestic Product (GDP), often at the expense of environmental health and social well-being. This new economic paradigm shifts the focus towards long-term resilience, environmental regeneration, and social equity, prioritising well-being over short-term economic gains. A sustainability-centric economic model addresses the inherent limitations of GDP as a sole indicator of prosperity, embracing a more holistic approach that considers the finite limits of planetary resources and the need to ensure a just and equitable society.[49]

At the core of this transition are several converging trends. A rethinking of **corporate sustainability** (1.1.1) is emerging as a guiding principle, moving beyond "business as usual" to fundamentally reshape how corporations plan and act. This transformation requires embedding sustainability into core strategies and operations, rather than treating it as an add-on. Similarly, **sustainable finance** (1.1.4) is driving a shift in capital allocation, promoting business models that align with proactive environmental, social, and governance (ESG) principles.[50] The **circular economy** (1.1.3) is transforming resource use and product design, replacing the outdated 'take-make-dispose' paradigm with systems that prioritise resource efficiency and waste minimisation.[51] Furthermore, the **regenerative bioeconomy** (1.2.2) is advancing industries that leverage biological resources to create economic value while actively restoring ecosystems.[52] By the mid- to long-term, these developments are expected to culminate in a **decarbonised economy** (1.3.1) and **sustainable supply chains** (1.3.2), reflecting a more integrated and regenerative economic approach.

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[49] WEF (2024:4); Stiglitz J., Fitoussi J. and M. Durand (2018); Ward JD, Sutton PC, Werner AD, Costanza R, Mohr SH, Simmons CT (2016).

[50] Eccles R. G., Ioannou I., Serafeim G. (2014); Caldecott, B., Clark, A., Harnett, E. et al. (2024).

[51] Ellen MacArthur Foundation (2023).

[52] WBCSD (2022).

Trend implications

The shift to a sustainability-centric economic model carries profound implications for industries, financial systems, governments, and societal norms, transforming the very foundation of economic thinking:

1. **A redefinition of economic success:** The sustainability-centric model challenges the traditional notion of success defined by GDP growth. Instead, it introduces new metrics that account for environmental sustainability, social well-being, and long-term economic resilience. Indicators such as natural capital (the value of ecosystems), social capital (community well-being), and carbon reduction targets are being integrated into national and corporate performance assessments. This shift places a greater emphasis on generating value that supports the planet and its people over sheer economic expansion.[53]

2. **Circular and regenerative business models:** The rise of circular economy (1.1.3) principles is a key driver of this new economic model. Businesses are moving away from linear production models and focusing on keeping resources in circulation, reducing waste, and regenerating natural systems. The growth of resource efficiency (1.2.6) innovations and advanced recycling (1.3.8) technologies supports this trend, allowing businesses to create more sustainable and resilient value chains. The expansion of regenerative bioeconomy (1.2.2) models further emphasises the need to restore ecosystems while creating economic value from biological resources.[54]

3. **Financial systems for sustainable growth:** The transformation of financial markets is central to this new model. Sustainable finance (1.1.4) and the rise of green finance (1.2.1) are encouraging investors to prioritise ESG performance, pushing capital towards sustainable industries and projects. Green bonds, impact investing, and sustainability-linked loans are examples of how finance is evolving to support businesses that contribute to climate resilience, social inclusion, and environmental restoration. Over time,

[53] WEF (2024:4); Stiglitz J., Fitoussi J. and M. Durand (2018); Ward JD, Sutton PC, Werner AD, Costanza R, Mohr SH, Simmons CT (2016).
[54] Ellen MacArthur Foundation (2023); WBCSD (2022).
[55] Eccles R. G., Ioannou I., Serafeim G. (2014); Caldecott, B., Clark, A., Harnett, E. et al. (2024); Fisher PG, ed. (2020); Robins N., Zadek S., Li W., Rooprai,G., Perry, F., Avendaño, F., Levitanskaya, K., Nguyen, Q. T., Lavagne D'Ortigue, O., McDaniels, J., Stein, P. B. W., Yuan, W., Usher, E., Maheshwari, A., Mendoza, J. C., Maimbo, S. M., Zhang, R., Agha, M., Santamaria Rojas, S. L.; Yeh, B. K., Henderson, I. (2017).

this will reduce reliance on GDP growth as a marker of success and shift focus to value creation that promotes long-term sustainability.[55]

4. **Decarbonisation and clean energy transition:** The decarbonisation of the global economy (1.3.1) is a central tenet of this new economic model. Businesses and governments are accelerating investments in clean technologies (1.2.3), such as renewable energy, electric mobility, and carbon capture solutions, to transition to a low-carbon economy. This shift reduces the environmental impact of economic activities while creating new opportunities for sustainable growth, driving job creation in green industries and reducing the overall dependence on fossil fuels.[56]

5. **A shift in policy and governance:** Governments are beginning to rethink how economic policy and governance systems are structured to support sustainability-centric economies. Policies that promote sustainable supply chains (1.3.2), resource conservation, and regenerative land use are gaining traction. At the same time, governments are exploring alternative measures of prosperity, such as the Gross National Happiness Index or the Human Development Index, to capture a more complete picture of societal well-being and environmental sustainability.[57]

Quantitative indicator

One key quantitative indicator that reflects the shift to a sustainability-centric economic model is the **Percentage of GDP aligned with ESG principles.** This measures the portion of national economic activity that is dedicated to industries, investments, and initiatives contributing to long-term sustainability goals.

- **Current status:** As of 2023, approximately **15%** of global GDP is linked to industries or activities that align with ESG principles.[58]

- **Target for 2030:** By 2030, it is expected that at least **30%** of global GDP should be aligned with ESG objectives, supported by growth in **sustainable finance and circular economy** practices.[59]

- **Target for 2050:** By 2050, the sustainability-centric economic model aims for at least **50%** of global GDP to be dedicated to sustainable industries, with fossil fuel-intensive sectors significantly reduced or transformed.[60]

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[56] IEA (2021); Araújo, O.Q.F., de Medeiros, J.L. (2022).

[57] Adger WN, Jordan A, eds. (2009); Hirai, T. (2022); Ozili, P.K. (2024).

[58] Percentage estimated based on extrapolating trends from reports on ESG investments, sustainable finance, and decarbonization, aligned with global GDP projections.

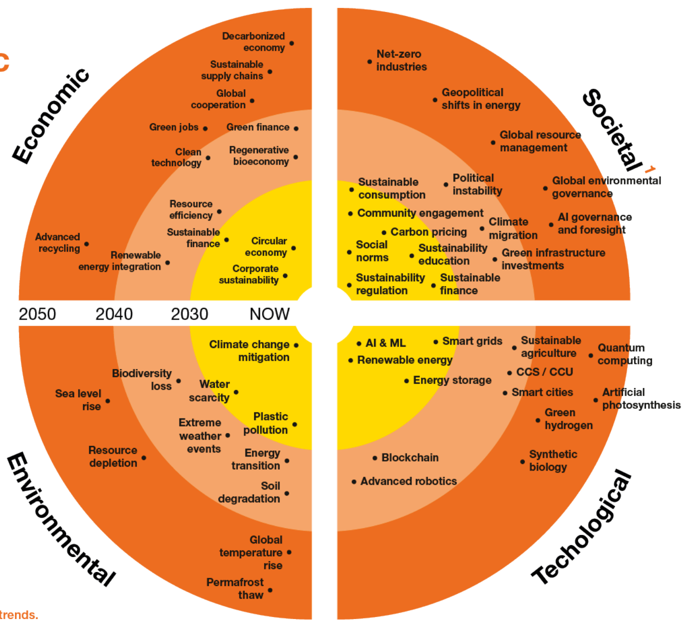
[59] Percentage estimated based on extrapolating trends from reports on ESG investments, sustainable finance, and decarbonization, aligned with global GDP projections.

[60] Percentage estimated based on extrapolating trends from reports on ESG investments, sustainable finance, and decarbonization, aligned with global GDP projections.

Individual trends covered

The emergence of a sustainability-centric economic model represents a profound shift away from the traditional GDP-focused approach, recognising that true prosperity must balance economic growth with the well-being of people and the planet. By integrating **corporate sustainability** (1.1.1), circular economy (1.1.3), **green finance** (1.2.1), and **decarbonisation** (1.3.1) principles, this new model offers a pathway to a more resilient, regenerative, and equitable global economy. In the decades ahead, this economic transformation will redefine success, foster sustainable innovation, and create long-term value that benefits both society and the environment.

The emergence of a sustainability-centric economic model



1) Societal dimension includes political, social and regulatory trends.

Sustainable food systems and consumption

The **sustainable food systems** and consumption megatrend focuses on transforming agriculture and food production to reduce environmental impact, improve resilience, and promote healthier, ethical consumption patterns. By integrating circular economy principles and sustainable practices, this megatrend addresses food security, resource efficiency, and climate-smart agriculture for a more sustainable global food ecosystem.

Megatrend description

The transformation towards **sustainable food systems and consumption** is a critical megatrend that addresses the environmental, social, and economic challenges of traditional agriculture and food production. This megatrend reflects the growing need to transition to agricultural practices that are resilient to climate change, reduce resource consumption, and promote biodiversity, while also supporting healthier, more sustainable consumption patterns.[61]

At its core, this megatrend encompasses trends like **sustainable agriculture** (1.1.6), which focuses on improving food production efficiency, reducing the use of harmful chemicals, and enhancing soil health through practices like organic farming, precision agriculture, and regenerative farming.[62] At the same time, the rise of **sustainable consumption** (4.1.1) is pushing consumers to make choices that minimise environmental impacts, reduce waste, and prioritise ethically sourced food products.[63] Together, these trends are creating a more sustainable food ecosystem that integrates **climate-smart agriculture** (1.2.9) and **circular economy** (1.1.3) principles to ensure the long-term health of both people and the planet.[64]

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[61] IPCC (2019); FAO (2022).

[62] McKinsey (2023).

[63] Reichheld A., Peto J., Ritthaler C. (2023).

[64] Schipfer, F., Burli, P., Fritsche, U. et al. (2024).

Trend implications

The shift towards sustainable food systems and consumption will have wide-ranging implications for agriculture, food industries, and consumer behaviour:

1. **Resilient and climate-smart agriculture:** As the impacts of climate change become more pronounced, there is a growing need for **climate-smart agriculture** (1.2.9) that adapts to changing weather patterns, uses water efficiently, and minimises emissions. Sustainable agricultural technologies, such as **precision farming** (3.2.1) and new crop protection methods, help farmers optimize resource use while maintaining productivity.[65]

2. **Circularity in food systems:** The integration of **circular economy** (1.1.3) principles into food systems is becoming more important, as reducing food waste and reusing agricultural by-products help lower the environmental footprint of food production. Innovations in **advanced recycling** (1.3.8) and **sustainable supply chains** (1.3.2) are driving the shift toward a closed-loop approach in agriculture, where waste becomes a resource for new production cycles.[66]

3. **Health and well-being:** Sustainable food systems promote healthier diets by encouraging the production and consumption of more plant-based and locally sourced foods. **Sustainable consumption** (4.1.1) trends, driven by consumers' growing awareness of the environmental and health impacts of food, are pushing food producers to offer more eco-friendly, nutritious options while reducing overconsumption and waste.[67]

4. **Technological innovation in agriculture:** Technological advances are reshaping agriculture, with **AI & ML** (3.1.1), IoT (3.1.3), and biotech (3.2.7) providing farmers with tools to optimise crop yields, conserve resources, and improve resilience. These technologies contribute to the broader trend of **sustainable agriculture technologies** (3.2.1), enhancing productivity while reducing the sector's environmental footprint.[68]

5. **Policy and regulation:** Governments and international bodies are increasingly setting policies that promote **sustainable agriculture** (1.1.6), through incentives for adopting climate-smart practices, reducing food waste, and ensuring fair labour conditions. The role of **sustainability regulation** (4.1.6) is critical in accelerating the shift toward sustainable food production and consumption.[69]

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[65] Zheng, H., Ma, W. & He, Q. (2024); Zhao, J., Liu, D., & Huang, R. (2023).

[66] Ellen MacArthur Foundation (2021); Zhang Q., Dhir A., Kaur P. (2022); Iqbal M. W., Kang Y (2024).

[67] Herrero, M., Hugas, M., Lele, U., Wirakartakusumah, A., Torero, M. (2023); FAO & WHO (2019).

[68] Aminetzah D., Katz J., Mannion P. (2020); Iqbal M. W., Kang Y (2024).

[69] European Commission (2020); European Commission: Directorate-General for Research and Innovation and Group of Chief Scientific Advisors (2020); European Commission: Directorate-General for Research and Innovation and Group of Chief Scientific Advisors (2021).

Quantitative indicator

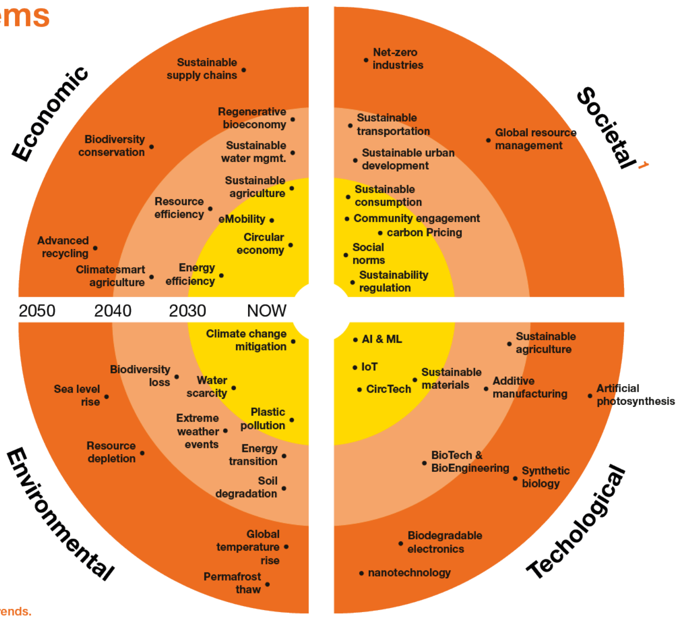
A key quantitative indicator for tracking the progress of sustainable food systems and consumption is the **percentage reduction in food waste** across production, distribution, and consumption stages. This indicator reflects improvements in food system efficiency and consumer behaviour.

- **Current status:** According to the UN, roughly **30% of food** produced globally is wasted annually.[70]
- **Target for 2030:** The goal is to **halve global food waste per capita** at retail and consumer levels by 2030, in line with the UN Sustainable Development Goals.[71]
- **Target for 2050:** By 2050, the food system should operate with minimal waste, supported by **circular food systems** and sustainable consumption practices.[72]

Individual trends covered

This megatrend reflects the growing momentum towards creating food systems that are resilient, circular, and focused on health and sustainability. By integrating **sustainable agriculture** (1.1.6), **circular economy** (1.1.3), and **sustainable consumption** (4.1.1) principles, the global food industry can reduce its environmental footprint while ensuring food security and promoting healthy, ethical consumer choices.

Sustainable food systems and consumption



1) Societal dimension includes political, social and regulatory trends.

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[70] United Nations Environment Programme (2024_7).
[71] Champions 12.3 (2024).
[72] WRI (2018).

5/ The trend radar

Overview

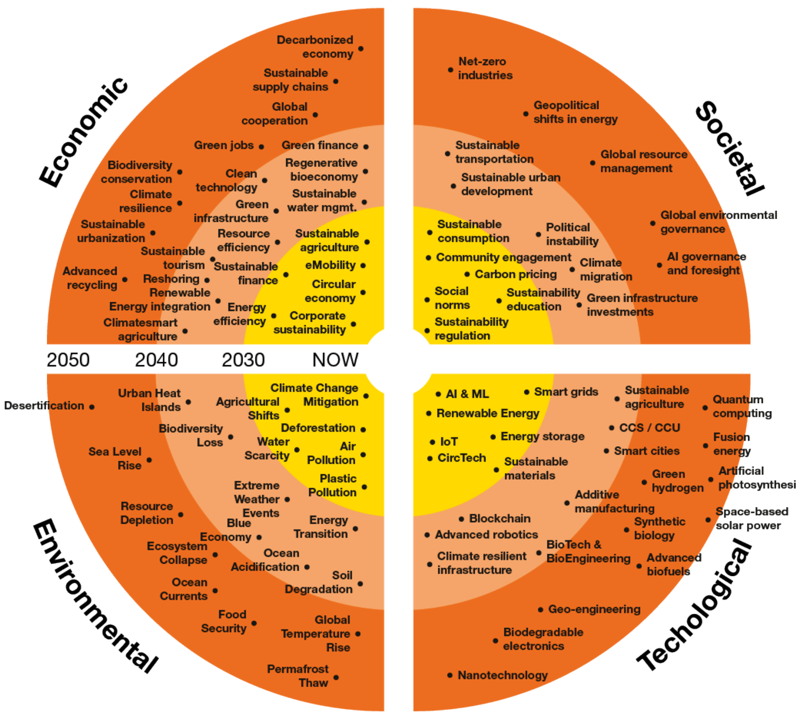
The “Future of sustainability” trend radar is a forward-looking tool designed to identify and analyse emerging trends that will shape the sustainability landscape in the coming decades.

By mapping out key developments across short-term, mid-term, and long-term horizons, the trend radar provides a comprehensive overview of the economic, environmental, technological and social sustainability factors driving change. It highlights policy advancements, innovations in green technology, and shifts in consumer behaviour that are paving the way for a more sustainable future.

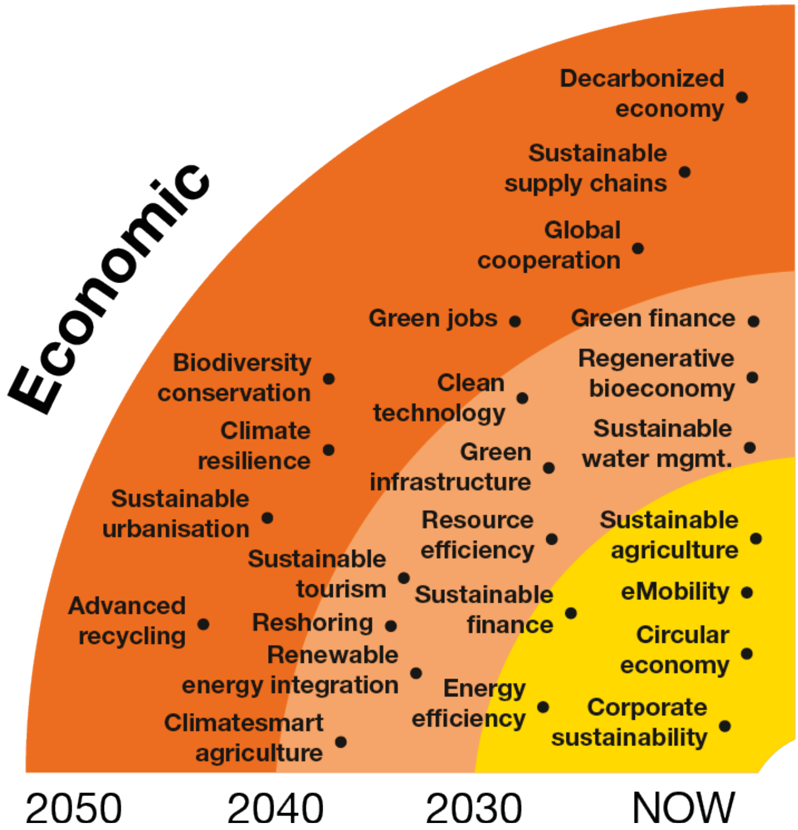
The tool is essential for businesses, policymakers, and individuals seeking to understand and navigate the complex and evolving sustainability landscape, ensuring that they are well-prepared to meet the challenges and opportunities ahead.

A detailed guide on how to read the trend radar can be found in Appendix 1.

Future of sustainability



Economic trends in sustainability



The global shift toward sustainability is fundamentally transforming economic models and practices across industries. As businesses, governments, and consumers increasingly recognise the urgent need to address environmental and social challenges, economic trends are evolving to integrate sustainability into core strategies. These trends reflect the growing demand for responsible corporate behaviour, resource-efficient production processes, and long-term value creation that balances profit with environmental stewardship. From the rise of green finance to the expansion of circular economy business models, the integration of sustainability into economic systems is reshaping how industries operate, how investments are made, and how future growth is measured. This chapter explores key economic trends that are driving the transition toward a more sustainable global economy, highlighting both immediate changes and long-term shifts in how resources are valued and managed.

ECONOMIC TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 1/2

Trend	Description
1.1.1 Corporate sustainability[73]	Corporate sustainability is becoming a core business imperative, with 90% of S&P 500 companies publishing ESG reports in 2022, compared to 20% in 2011.[74] Investor pressure is a key driver: asset managers overseeing $120 trillion under the PRI framework demand greater transparency.[75] Consumer behaviour also plays a role, as 64% of consumers prefer brands with strong ESG commitments, and 80% express loyalty to sustainable companies.[76] Total assets in sustainable funds landed at $286 billion in 2022.[77] Furthermore, 88% of surveyed companies in the Nordics integrate circularity/sustainability into their strategy.[78]
1.1.2 Energy efficiency[79]	Energy efficiency is central to mitigating climate change and addressing rising energy costs. Globally, improvements in energy efficiency contributed to avoiding **15% of annual energy demand growth in 2022**, saving billions in energy costs. In the industrial sector, investments in energy-efficient machinery and production processes reduce operational expenses while supporting decarbonisation goals. The building sector, responsible for **30% of global energy use**, is rapidly adopting retrofitting practices and smart building technologies to achieve energy savings of **20–30%**. Energy-efficient appliances, supported by government policies such as energy labelling and incentives, play a critical role in reducing global energy demand, with efficiency improvements across all sectors avoiding the equivalent of approximately **13% of total energy demand in 2022**.[82]
1.1.3 Circular economy[83]	Circular economy business models – focused on recycling, reusing, and reducing waste – are increasingly recognised as essential for sustainable development. While adoption rates remain modest, the need for these models has grown significantly due to resource scarcity and the environmental consequences of linear systems. Globally, only **8.6% of materials are reused or recycled**, highlighting vast untapped potential.[84] For example, implementing circular economy strategies globally **could reduce resource use by 28% and greenhouse gas emissions by 39% by 2032**, aligning with climate targets and resource efficiency goals.[85]
1.1.4 Sustainable finance[86]	Sustainable finance is rapidly gaining momentum as green bonds and sustainable investment funds drive capital toward environmentally and socially responsible initiatives. In 2023, aligned annual volume of the green bond market reached **~USD590bn**, breaking through the half trillion mark for the third consecutive year.[87] Additionally, the assets under management (AUM) of ESG-focused investment funds grew to over **$2.8 trillion**, with Europe leading at **84% of global ESG fund AUM**.[88] Investors increasingly favour companies with robust ESG practices, as 75% of respondents to the PwC 2023 Global Investor Survey consider a company's ability to manage sustainability-related risks and opportunities being an important factor in investment decision-making.[89]

[73] de Oliveira, U.R., Menezes, R.P. & Fernandes, V.A. (2024); Florez-Jimenez, M.P., Lleo, A., Ruiz-Palomino, P. et al. (2024).
[74] G&A Institute (2022).
[75] PRI (2024).
[76] First Insight (2022).
[77] Morningstar (2023).
[78] Bajuk M., Linder M. (2024).
[79] Kadir, M.O., Deka, A., Ozdeser, H. et al. (2023); Renna, P., & Materi, S. (2021).
[80] IEA (2023).
[81] IEA (2023).
[82] IEA (2023).
[83] Markkula A., Pihkola H., Arnold M. et al. (2024); Nikolaou, I.E., Jones, N. & Stefanakis, A. (2021).
[84] Circle Economy (2023).
[85] Circle Economy (2023).
[86] Caldecott, B., Clark, A., Harnett, E. et al. (2024); United Nations Global Compact (2024).
[87] Climate Bonds Initiative (2024).
[88] Morningstar (2023:2).
[89] PwC (2023).

ECONOMIC TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 2/2

Trend	Description
1.1.5 eMobility[90]	The adoption of electric vehicles (EVs) is accelerating, driven by advancements in technology, expanded charging infrastructure, and government incentives. In 2023, global EV sales neared **14 million units**, up from 10 million in 2022, accounting for **18% of all vehicle sales**.[91] Government initiatives, such as subsidies and tax breaks, have significantly lowered the upfront cost of EVs, while investments in charging networks are showing results with the global number of installed public charging points up 40% in 2023 relative to 2022. [92] EVs are crucial for reducing air pollution, with lifetime CO_2 emissions per EV being **~70% lower than those of comparable internal combustion engine vehicles**. [93]
1.1.6 Sustainable agriculture[94]	Sustainable agriculture is increasingly recognised globally, though approaches vary by region. In Western societies, precision farming technologies. such as GPS-guided machinery, sensors, and drones, are reducing water, fertiliser, and pesticide use, while increasing yields by **15-30%**.[95] However, in low- and middle-income countries, solutions like agroecology, crop diversification, and regenerative agriculture are critical. For example, agroecology practices in sub-Saharan Africa have improved yields while enhancing soil fertility and resilience to climate change. [96] Globally, organic farming is growing steadily, accounting for **1.6% of agricultural land** in 2021.[97]

[90] Zaino, R., Ahmed, V., Alhammadi, A. M., & Alghoush, M. (2024); Singh, G., Misra, S.C., Daultani, Y. et al. (2024).
[91] International Energy Agency (2024).
[92] International Energy Agency (2024).
[93] Bieker G. (2021).
[94] Alam, M.W., Junaid, P.M., Gulzar, Y. et al. (2024); Mgendi, G. (2024); OECD (2016).
[95] Mesfin S., Kefale H., Gelaye Y. (2024).
[96] Sithole A., & Olorunfemi O. D. (2024).
[97] Willer H., Schlatter B., Trávníček J. [Eds.] (2023).

ECONOMIC TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 1/2

Trend	Description
1.2.1 Green finance[98]	Green finance is projected to significantly expand by 2030–2040, underpinned by growing demand for sustainable investments and evolving regulatory frameworks. Financial products like green loans, which align with borrowers' environmental objectives, and sustainable insurance products, are anticipated to see exponential growth. A 2023 study estimates that **USD6.2 trillion of climate finance** is required annually between now and 2030, and **USD7.3tn** by 2050, to deliver Net Zero – a total of almost **USD200tn**.[99] Furthermore, global assets under management for impact investments are estimated at **$1. 6 trillion**, reflecting the growing mainstream appeal of this financial strategy.[100]
1.2.2 Regenerative bioeconomy[101]	The regenerative bioeconomy is gaining momentum as industries shift toward bio-based products and processes to address climate and sustainability challenges. The global bio-based chemicals market size was **USD 73 billion in 2023** and is projected to grow from **USD 100 billion in 2024 to USD 208 billion in 2032** at a CAGR of 9.6% during the period 2024–2032.[102] Bioenergy, another key pillar of the bioeconomy, accounted for **4% of global renewable energy consumption** in 2023, with further expansion anticipated as countries aim to meet net-zero targets.[103] Beyond economic gains, the regenerative bioeconomy focuses on ecosystem restoration, such as increasing carbon sequestration through sustainable forestry and soil management and enhancing community well-being through local resource utilisation.
1.2.3 Clean technology[104]	Clean technologies are essential for achieving negative emissions and transitioning to a low-carbon economy. These include energy storage, electric vehicles (EVs), carbon capture and storage (CCS), carbon capture and utilisation (CCU), and clean hydrogen. While other strategies are needed for immediate emission reductions, clean technologies address residual emissions and enable net-zero goals. CCS captures and permanently stores both fossil-based and biogenic CO_2, preventing release, while CCU repurposes CO_2 into fuels and materials. Global CCS capture capacity is **51 megatonnes per anum (Mtpa)**, with over **550 projects in different stages of development**.[105] The global hydrogen project pipeline has grown by a factor of seven to **1,572 projects in 2024** across the value chain and an **expected production capacity of 48 Mtpa in 2030**.[106] By 2030–2040, clean technologies will become scalable and cost-effective, driven by falling costs and supportive policies, enabling the large-scale removal of greenhouse gases.
1.2.4 Sustainable water mgmt.[107]	Sustainable water management is becoming increasingly vital as global water demand is projected to rise by **30% by 2050**.[108] Advanced irrigation systems, such as drip irrigation, can reduce water use in agriculture by as much as **60%** while increasing crop yields by **90%**.[109] While an estimated 52% of wastewater is treated globally, treatment rates vary drastically between high-income (74%), upper-middle income (43%), lower-middle income (26%) and low-income (4.3%) countries.[110] Desalination technologies, which supply drinking water to more than **300 million people worldwide**, are also advancing with energy-efficient methods like reverse osmosis reducing costs and environmental impact.[111]
1.2.5 Green infrastructure[112]	Green infrastructure is becoming a cornerstone of sustainable urban development, focusing on reducing environmental impact while enhancing the quality of life in cities. Investments in building decarbonisation **exceeded US$285 billion in 2022** and investments in energy efficiency should **exceed US$500 billion annually by 2030**.[113] The World Resources Institute in 2016 estimated a need to expand global investments in public transportation systems by **US$2 trillion by 2050** from the 2016 estimated baseline of between $1.4 and $2.1 trillion annual investments.[114] Additionally, the implementation of Smart City solutions applied to the management of vehicle traffic and electrical grids could produce **$160 billion in benefits and savings** through reductions in energy usage, traffic congestion and fuel costs.[115]

[98] OECD (2024); Bakhsh, S., Alam, M.S. & Zhang, W. (2024).
[99] Allen & Overy and Climate Policy Initiative (2023).
[100] Hand, D., Ulanow, M., Pan, H., Xiao, K. (2024).
[101] Philp, J. and D. Winickoff (2018); Venkatesh, G. (2022); WBCSD (2020)
[102] Fortune Business Insights (2024).
[103] KIRENA (2024:4).
[104] Tangato, K.F. (2024); Rotman D. (2023);
[105] Global CCS Institute (2024).
[106] Hydrogen Council (2024).
[107] Hasan, N., Pushpalatha, R., Manivasagam, V.S. et al. (2023); OECD (1998).
[108] UNESCO (2024).
[109] Chu (2017).
[110] Jones E. R., van Vliet M. T. H., Qadir M., Bierkens M. F. P. (2021).
[111] Aende A., Gardy J., Hassanpour A. (2020).
[112] Sokolova, M. V., Fath, B. D., Grande, U., Buonocore, E., & Franzese, P. P. (2024); OECD (2024:2)
[113] United Nations Environment Programme (2024:7).
[114] Lefevre B., Chaudhary A.I., Yavrom D., Srivastava A. (2016).
[115] Accenture (2017).

ECONOMIC TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 2/2

Trend	Description
1.2.6 Resource efficiency[116]	Innovations in manufacturing are significantly enhancing resource efficiency by reducing waste and energy consumption. Techniques such as **additive manufacturing** (3D printing) enable the production of complex components with minimal material waste, streamlining supply chains and reducing lead times. The development of **lightweight materials**, including advanced composites, is also pivotal. These materials maintain structural integrity while reducing weight, thereby lowering energy consumption in industries such as automotive and aerospace.[118] Additionally, **digital manufacturing** integrates IoT, AI, and big data analytics to build smart factories, enabling real-time monitoring, predictive maintenance, and optimised production, further improving resource efficiency.[119]
1.2.7 Sustainable tourism[120]	The tourism industry is increasingly embracing sustainable practices, emphasising eco-tourism and minimising environmental impacts. This shift includes efforts to reduce carbon footprints, conserve natural resources, and support local communities. For instance, more than **50 countries have signed the UN Sustainable Tourism Declaration,** committing to making tourism more climate-friendly.[121]
1.2.8 Renewable energy integration[122]	The integration of renewable energy sources is advancing through grid upgrades, energy storage, and smart grid technologies. The International Energy Agency (IEA) projects the need for **80 million km of new transmission lines by 2040** to support renewable energy growth.[123] Energy storage, such as batteries and pumped hydro, is critical for managing renewable variability, with deployment needing significant scaling.[124] These advancements are key to ensuring stability and meeting future energy demands.
1.2.9 Climate-smart agriculture[125]	Climate-smart agriculture (CSA) is an integrated approach to managing agricultural systems for enhanced productivity, resilience to climate change, and reduced greenhouse gas emissions. Practices such as crop diversification, soil conservation, and the use of climate-resilient crop varieties are being increasingly adopted. Improved crop varieties and advanced soil management techniques have demonstrated yield increases of up to **116%–122%** in some regions, particularly in climate-vulnerable areas.[126] These methods also improve soil health, reduce erosion, and enhance water retention, creating more sustainable agricultural ecosystems.
1.2.10 Reshoring[127]	Reshoring, the practice of bringing manufacturing back to home countries, is gaining momentum due to factors like geopolitical tensions, supply chain disruptions, and technological advancements. The COVID-19 pandemic exposed **vulnerabilities in global supply chains**, prompting firms to reconsider offshoring strategies. Additionally, the rise of **automation and advanced manufacturing technologies** has made domestic production more economically viable. For instance, the European Central Bank notes that **subsidies linked to local production** requirements, such as the U.S. Inflation Reduction Act, are influencing reshoring decisions.[128]

[116] Hu, K., Kuang, W. & Qin, Q. (2024); de Sa, P. and J. Korinek (2021).
[117] Fidan, I., Huseynov, O., Ali, M. A., Alkunte, S., Rajeshirke, M., Gupta, A., Hasanov, S., Tantawi, K., Yasa, E., Yilmaz, O., Loy, J., Popov, V., & Sharma, A. (2023).
[118] Hassan, H.Z., Saeed, N.M. (2024).
[119] Adam, A.A.E., Al Mubarak, M. (2024).
[120] Agarwal, R., Mehrotra, A., Mishra, A., Rana, N. P., Nunkoo, R., & Cho, M. (2024); OECD (2024:3).
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[123] International Energy Agency (2023).
[124] International Renewable Energy Agency (2015).
[125] Zhao, J., Liu, D., & Huang, R. (2023); Aishwarya, Kumar, P. (2024).
[126] Branca G., McCarthy N., Lipper L., Jolejole M.C. (2011).
[127] Dikler, Jennifer (2021); Broecke, S. (2024).
[128] Attinasi M.G., Boeckelmann L., Hespert L., Linzenich J. and Meunier B. (2024).

ECONOMIC TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 1/2

Trend	Description
1.3.1 Decarbonized economy[129]	By 2040 and beyond, the global transition to a low-carbon economy is expected to be largely complete, characterised by widespread adoption of renewable energy and significant reductions in fossil fuel use. The International Energy Agency (IEA) projects that, under current policies, the share of low-carbon energy sources in global power generation will increase from 32% today to 80% by 2050.[130]
1.3.2 Sustainable supply chains[131]	The evolution toward fully sustainable and transparent supply chains is anticipated to mature by 2040 and beyond, ensuring ethical sourcing and minimal environmental impact. This transformation requires extensive collaboration across industries and regions. Currently, major market players like Home Depot, Gap, and IKEA have adopted sustainability standards in their supply chains, adhering to voluntary codes such as ISO 14001 and the UN Global Compact.[132]
1.3.3 Global cooperation[133]	Global cooperation on sustainability is expected to become increasingly robust by 2040 and beyond, enabling more effective responses to pressing environmental challenges. Enhanced collaboration will be essential for achieving emissions reduction targets, conserving biodiversity, and driving sustainable development. For instance, international agreements like the Paris Agreement aim to limit global warming to 1.5°C, but stronger and enforceable commitments are anticipated as climate impacts intensify. Similarly, frameworks like the Kunming-Montreal Global Biodiversity Framework target the conservation of **30% of global land and sea areas by 2030**, setting a foundation for long-term global collaboration.[134]
1.3.4 Green jobs[135]	The transition to a sustainable economy is projected to create a substantial number of green jobs in sectors such as renewable energy, sustainable agriculture, and environmental conservation. Projections indicate that global employment in clean energy technology manufacturing could more than double, **from 6 million jobs today to nearly 14 million by 2030**.[136] Within the EU, the anticipated building renovation wave is expected to create approximately **160,000 jobs in the construction sector** alone.[137] However, realising this potential requires addressing the existing skills gap. The European Centre for the Development of Vocational Training (Cedefop) emphasises the necessity for vocational education and training (VET) systems to adapt, ensuring the workforce is equipped with the competencies essential for the green transition.[138]
1.3.5 Biodiversity conservation[139]	Large-scale efforts to protect and restore biodiversity are anticipated to expand significantly. Initiatives such as the 30 by 30 target, aiming to protect 30% of Earth's land and ocean areas by 2030, have been adopted by over 190 countries, reflecting a global commitment to conservation.[140] Additionally, habitat restoration projects are being implemented to revive degraded ecosystems, providing critical support for endangered species. Conservation breeding programmes are also in place to bolster populations of threatened species, ensuring their survival and genetic diversity. While restoring ecosystems and achieving measurable biodiversity improvements require extended periods, often spanning decades, these comprehensive conservation strategies are expected to yield significant ecological benefits, contributing to the preservation of global biodiversity and the health of our planet by 2040 and beyond.
1.3.6 Climate resilience[141]	Investments in climate-resilient infrastructure and technologies are crucial for adapting to changing environmental conditions. This includes constructing flood defenses, developing drought-resistant crops, and enhancing disaster response systems. Studies indicate that making infrastructure more climate-resilient can add up to 3% to upfront costs but offers a benefit-cost ratio of about 4:1, yielding significant net benefits.[142] By 2040 and beyond, these investments are expected to significantly mitigate the impacts of climate change, safeguarding communities and economies.

[129] D'Arcangelo, F. et al. (2022)
[130] McKinsey & Company (2024).
[131] Amofa B, Oke A and Morrison Z (2023); Velázquez Martínez, J.C., and Arnold, V. (2024).
[132] ISO 14001:2015 (2015); United Nations (2024:4).
[133] UNCTAD (2024); Hosli M, Garrett T, Niedecken S, Verbeek N (2021).
[134] UNEP (2022).
[135] IMF (2024); David A T (2023).
[136] IEA (2023:2).
[137] European Commission (2020).
[138] Cedefop (2021).
[139] UNEP (2022).
[140] The Nature Conservancy (2024).
[141] IPCC (2023); OECD (2024:2).
[142] Wu D. (2024).

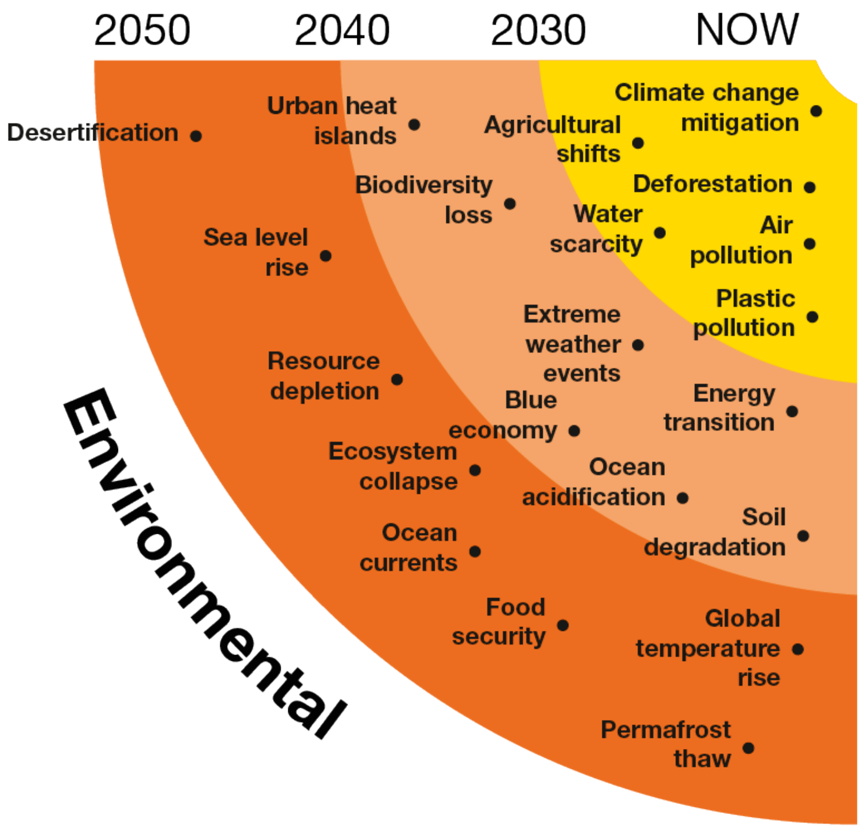
ECONOMIC TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 2/2

Trend	Description
1.3.7 Sustainable urbanisation[143]	Sustainable urbanisation focuses on developing cities that are energy-efficient, climate-resilient, and conducive to healthy living. By 2050, urban areas are projected to house **70% of the global population**, intensifying the need for sustainable city planning.[144] According to the IEA, almost **10% of the increase in global emissions** since 2015 can be attributed to urbanisation, while investments in infrastructure and technology to decarbonise the energy sector can **reduce greenhouse gas emissions by up to 75% by 2050.**[145] Achieving sustainable urbanisation is a long-term endeavour, with significant milestones anticipated by 2040 and beyond.
1.3.8 Advanced recycling[146]	Advanced recycling technologies, including chemical recycling, bioplastics, and waste-to-material processes, will transform material recovery. Chemical recycling methods like pyrolysis can achieve **up to a 60% reduction in CO_2 emissions** by turning plastic waste into reusable monomers[147], with the market for advanced recycling projected to exceed **$151 billion by 2030**.[148] Bioplastics, growing at a **CAGR of 18%** between 2022 to 2030, are expected to reach around **$30 billion by 2030**, but require new chemical recycling solutions to ensure circularity.[149] Waste-to-material technologies, such as turning mixed waste into construction materials, have demonstrated efficiency in reducing landfill use and creating valuable outputs. Scaling advanced technologies, constructing specialised infrastructure, and ensuring regulatory support are long-term processes critical for widespread adoption and significant global impact.

143 Toor, G., Tater, N.G. & Chandra, T. (2024); UN Habitat (2020).
144 United Nations, 2018.
145 IEA (2024:3).
146 United Nations Environment Programme (2024:5); World Bank (2022).
147 Plastics Industry Association (2024).
148 Future Data Stats (2023).
149 Custom Market Insights (2022).

Environmental trends in sustainability



Environmental challenges such as climate change, biodiversity loss, and resource depletion are reshaping the global landscape and driving the need for sustainable solutions. As the pressure on natural ecosystems intensifies, industries, governments, and societies are increasingly focusing on preserving and restoring the environment while reducing their ecological footprint. The evolving environmental trends in sustainability highlight the urgent need to mitigate greenhouse gas emissions, protect critical ecosystems, and manage natural resources more efficiently. From efforts to combat climate change and reduce plastic pollution to the adoption of circular models that conserve water and land, these trends are shaping how the world responds to environmental crises. This chapter delves into the key environmental trends that are influencing global sustainability efforts, outlining both the immediate actions and long-term strategies required to ensure a thriving planet for future generations.

ENVIRONMENTAL TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 1/2

Trend	Description
2.1.1 Climate change mitigation[150]	Accelerated efforts to reduce greenhouse gas emissions are underway to limit global warming to 1.5°C above pre-industrial levels. The Intergovernmental Panel on Climate Change (IPCC) emphasises that **global emissions must peak before 2025** and **decline by 43% by 2030** to achieve this target.[151] In response, numerous countries have set ambitious short-term goals. For instance, the European Union has committed to a **55% reduction by 2030** compared to 1990 levels.[152] These initiatives are driving the rapid deployment of renewable energy technologies, energy efficiency improvements, and the development of low-carbon infrastructure. The International Energy Agency (IEA) reports that **global renewable energy capacity is expected to grow by 2.7 times by 2030**, surpassing countries' current ambitions by nearly 25%, but still falling short of tripling.[153]
2.1.2 Deforestation[154]	Deforestation persists as a critical environmental issue, driven predominantly by agricultural expansion and urban development. **Agriculture accounts for nearly 90% of global deforestation**, with **cropland expansion responsible for 49.6%** and **livestock grazing for 38.5%**.[155] This ongoing loss of forests significantly threatens biodiversity, as **forests are home to 80% of terrestrial species**, and contributes to climate change by releasing stored carbon dioxide. Forests play a vital role in carbon sequestration, and their destruction exacerbates global warming. Despite international commitments to halt deforestation by 2030, current trends indicate that these goals are unlikely to be met without substantial policy interventions and sustainable land management practices. The urgency of addressing deforestation in the short term (now–2030) is underscored by its immediate impacts on climate regulation, biodiversity conservation, and the livelihoods of over 1.6 billion people who depend on forests for their sustenance and economic activities.[156]
2.1.3 Water scarcity[157]	By 2030, global freshwater demand is projected to exceed supply by 40%, **intensifying water scarcity**, particularly in arid regions.[158] **Agriculture, consuming 70% of freshwater,** faces increased strain to meet food production needs for a growing population.[159] Industrial water use is also rising, driven by economic growth and energy demands. Household consumption is escalating due to urbanisation and improved living standards. Climate change exacerbates the situation by altering precipitation patterns, leading to more frequent droughts and reduced water availability. The United Nations emphasises the urgency of enhancing water-use efficiency and sustainable management to address this crisis.[160] Immediate action is essential to mitigate the impacts of water scarcity on ecosystems, economies, and human health.
2.1.4 Air pollution[161]	Rapid urbanisation and industrialisation are intensifying air quality issues, especially in developing regions. As of 2018, **55% of the global population** resided in urban areas, a figure **projected to rise to 68% by 2050**.[162] This urban expansion correlates with increased emissions from transportation, energy production, and industrial activities. While air quality has improved in the past years due to actions taken, it still falls short in terms of fully protecting public health leading to an estimated **4.2 million people dying due to ambient air pollution**.[163] The World Health Organization (WHO) reports that **99% of the global population** lives in areas where air pollution levels exceed WHO guideline limits.[164]

[150] William J Ripple, Christopher Wolf, Jillian W Gregg, et al. (2024); Future Earth, The Earth League, WCRP (2024).
[151] Intergovernmental Panel on Climate Change (2022).
[152] European Commission (2024:2).
[153] IEA (2024:4).
[154] Center for Climate and Energy Solutions (2024); Forest Declaration Assessment Partners. (2024).
[155] United Nations (2024:4).
[156] Benschop T. (2023).
[157] United Nations (2024); Jones E.R., Bierkens M.F.P. & van Vliet M.T.H. (2024); Grafton, R.Q., Fanaian, S., Horne, J. et al. (2024).
[158] United Nations (2016).
[159] World Bank (2022:2).
[160] United Nations (2024:4).
[161] EEA (2024:2); Health Effects Institute (2024).
[162] United Nations, Department of Economic and Social Affairs, Population Division (2019).
[163] United Nations (2024:4).
[164] WHO (2024).

ENVIRONMENTAL TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 2/2

Trend	Description
2.1.5 Plastic pollution[165]	Plastic pollution continues to be a pressing environmental issue, with global plastic waste production projected to **nearly triple by 2060**, reaching **1,231 million tonnes annually**. Without significant policy interventions, the short-term period leading up to 2030 is expected to witness a substantial increase in plastic waste generation, exacerbating environmental challenges.[166] The European Environment Agency has set ambitious targets for 2030, aiming to **reduce marine litter by 50% and microplastic release by 30%**. Achieving these goals requires immediate and concerted efforts to curb plastic waste generation and enhance waste management practices.[167] The United Nations Environment Programme emphasises that a **drastic reduction in unnecessary, avoidable, and problematic plastic** is crucial to addressing the global pollution crisis. An **accelerated transition from fossil fuels to renewable energies**, the removal of subsidies, and a shift towards circular approaches will help reduce plastic waste at the needed scale.[168]
2.1.6 Agricultural shifts[169]	Climate change is altering growing seasons and crop viability, necessitating immediate adjustments in agricultural practices and crop selection. In Europe, rising temperatures and changing precipitation patterns are projected to reduce crop productivity in southern regions, while potentially improving conditions in northern areas.[170] Farmers are adapting by selecting crop varieties better suited to new climatic conditions and implementing sustainable practices to enhance resilience. The European Environment Agency emphasises that adapting to climate change must be a top priority for the EU's agriculture sector to improve resilience to extreme events like droughts, heatwaves, and floods.[171] Given the rapid progression of climate impacts, these agricultural shifts are critical in the short term to ensure food security and sustainable livelihoods.

[165] Pottinger A. S. et al.(2024); Villarrubia-Gómez P., Almroth B.C., Eriksen M., Ryberg M., Cornell S.E. (2024).
[166] OECD (2022:2).
[167] EEA (2021).
[168] United Nations Environment Programme (2021).
[169] OECD/FAO (2024); McKinsey (2023).
[170] EEA (2019).
[171] EEA (2019:2).

ENVIRONMENTAL TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 1/2

Trend	Description
2.2.1 Urban Heat Islands[172]	As urbanisation accelerates, the concentration of buildings and impervious surfaces intensifies the Urban Heat Island (UHI) effect, leading to elevated local temperatures. This phenomenon exacerbates heatwaves, increases energy consumption, and poses health risks to urban populations. The Intergovernmental Panel on Climate Change (IPCC) reports that urban centres are consistently warmer than their rural surroundings due to factors like reduced ventilation and heat retention by infrastructure.[173] Mitigation strategies are being implemented, including increasing urban green spaces, adopting cool roofs, and enhancing urban planning. For instance, the World Bank highlights Singapore's innovative measures against UHI effects, such as integrating greenery into urban infrastructure and utilising reflective materials.[174] The mid-term focus on UHI mitigation aligns with urban planning cycles and policy implementation timelines. Developing and deploying effective strategies require time for research, infrastructure development, and community engagement.[153]
2.2.2 Biodiversity loss[175]	Biodiversity loss is projected to continue through the mid-term period (2030–2040), driven by habitat destruction, climate change, pollution, and overexploitation. Since 1990, nearly **420 million hectares of forests**, an area equivalent to the European Union, have been lost globally, primarily due to deforestation and land use changes.[176] Climate change further threatens biodiversity, with **one in six species** globally at risk of extinction.[177] Invasive species, introduced through human activity, have contributed to **60% of extinctions** and cause economic damages exceeding **$423 billion annually**. The Kunming-Montreal Global Biodiversity Framework, adopted in 2022, aims to halt and reverse biodiversity loss by 2030.[179] However, current trends highlight the urgency of mid-term actions to mitigate further degradation. This timeline reflects the time needed for widespread implementation of conservation and restoration measures.
2.2.3 Extreme weather events[180]	Climate change is projected to escalate the **frequency and intensity of extreme weather events**, including hurricanes, floods, and heatwaves, between 2030 and 2040. The Intergovernmental Panel on Climate Change (IPCC) reports that human-induced warming has already intensified such events, with further increases anticipated in the coming decades.[181] The World Bank highlights that the number of people exposed to extreme weather is rising, with climate change exacerbating vulnerabilities, particularly in low-income regions.[182] The mid-term period of 2030 to 2040 is critical for observing significant changes in extreme weather patterns due to **cumulative emissions, climate feedback loops, and insufficient mitigation efforts**.
2.2.4 Energy transition[183]	The shift from fossil fuels to renewable energy sources between 2030 and 2040 presents significant challenges in infrastructure, technology, and policy. The OECD highlights that achieving net-zero emissions by 2050 necessitates substantial investments in low-carbon energy infrastructure, requiring coordinated policy efforts to mobilise resources and address economic impacts.[184] The World Bank emphasises the need for expanding and upgrading electricity grids to support the energy transition, achieve universal access, and manage increasingly complex power flows.[185] Additionally, the United Nations notes that global demand for critical minerals essential for renewable technologies is expected to quadruple by 2040, underscoring the need for sustainable resource management.[186] The timeframe between 2030–2040 is critical for implementing large-scale infrastructure projects, advancing technological innovations, and enacting comprehensive policies to facilitate the energy transition. The decade allows for the maturation of emerging technologies, the mobilisation of necessary investments, and the establishment of regulatory frameworks essential for a sustainable energy future.

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ENVIRONMENTAL TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 2/2

Trend	Description
2.2.5 Ocean acidification[187]	Elevated **CO_2 emissions** are causing a decline in **ocean pH levels**, leading to increased acidity that adversely affects marine ecosystems. Since the industrial era, **surface ocean pH has decreased by approximately 0.1 units**, equating to a **26% rise in acidity**.[188] Projections indicate that by **2030–2040**, continued CO_2 emissions will further lower pH levels, intensifying risks to marine life, particularly **calcifying organisms like corals and shellfish**.[189] This acidification disrupts **marine food webs** and jeopardises **fisheries**, threatening **food security** and economies reliant on marine resources.[190] Current emission trajectories suggest **significant ecological impacts** in the mid-term period (2030–2040), necessitating immediate mitigation efforts to protect **ocean health** and dependent communities.
2.2.6 Soil degradation[191]	Intensive farming practices and deforestation are accelerating soil degradation, leading to significant environmental and economic impacts. The European Commission reports that soil degradation results in the loss of ecosystem services valued at approximately **€38 billion annually** within the EU, with erosion alone costing European farmers about **€1.25 billion per year**.[192] Projections indicate that, under a business-as-usual scenario, arable land expansion will continue at faster annual rates than in previous decades, with land degradation only partially addressed.[193] Additionally, climate change is expected to exacerbate degradation, as **rainfall erosivity increases by 2050**.[194] The cumulative impact of current farming and deforestation practices will become more pronounced over the next two decades. Policies like the EU Soil Strategy for 2030 require time for implementation, with tangible restoration outcomes expected closer to 2040.
2.2.7 Blue economy[195]	The blue economy encompasses the sustainable utilisation of ocean resources to drive economic growth, enhance livelihoods, and safeguard marine ecosystems. Key sectors include fisheries, tourism, maritime transport, and emerging industries like marine renewable energy. The European Union's blue economy generates approximately **€650 billion in turnover annually**, supporting **4.5 million jobs**, demonstrating its economic significance.[196] However, **overfishing, pollution, and climate change pose significant challenges**, necessitating robust management and conservation efforts. **Innovations in offshore wind farms and aquaculture** are emerging as critical solutions to balance economic development with marine ecosystem preservation.[197] By 2040, a well-established blue economy aims to balance economic development with marine conservation, ensuring the health of ocean ecosystems for future generations.

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ENVIRONMENTAL TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 1/2

Trend	Description
2.3.1 Sea level rise[198]	Sea level rise poses a significant threat to coastal communities and ecosystems, leading to land loss and increased flooding. The Intergovernmental Panel on Climate Change (IPCC) projects that, under high-emission scenarios, global mean **sea levels could rise by 0.45 to 0.82 metres by 2100**, relative to 1986–2005 levels.[199] This escalation endangers **approximately 680 million people residing in low-lying coastal zones and 65 million in small island developing states.**[200] The IPCC further concluded in 2021, that **sea levels are rising at rates unprecedented** in at least the last 3,000 years due to human-induced global warming.[201] In the long-term, without substantial mitigation efforts, sea level rise is expected to cause significant displacement, economic losses, and ecological disruptions.
2.3.2 Global temperature rise[202]	Continued greenhouse gas emissions are projected to increase global temperatures, significantly affecting weather patterns, agriculture, and human health. The Intergovernmental Panel on Climate Change (IPCC) reports that, without substantial emission reductions, **global temperatures could rise by 1.4°C to 5.8°C by 2100**, relative to pre-industrial levels. These numbers vary based on the model being used as outlined by IPCC.[203] This warming is expected to intensify heatwaves, droughts, and heavy precipitation events, disrupting agricultural productivity and increasing health risks such as heat-related illnesses. The World Meteorological Organization (WMO) indicates **that 2024 is set to be the hottest year on record**, surpassing a 1.5°C increase in global temperatures compared to the pre-industrial era.[204] The full extent of global temperature rise and its associated impacts are anticipated to manifest more prominently in the long term. Cumulative emissions largely determine surface warming by the late 21st century and beyond, with projections varying based on socio-economic development and climate policy. Therefore, while some effects are already observable, the most severe consequences are expected to unfold post-2040, necessitating long-term strategic planning and sustained mitigation efforts.
2.3.3 Resource depletion[205]	The overexploitation of natural resources, including minerals, fossil fuels, and freshwater, is leading to significant scarcity and potential conflicts. For instance, global demand for **lithium** is projected to increase nearly **ninefold by 2040**, driven by the rise in electric vehicle battery production. Similarly, **copper** demand is expected to nearly double by 2040, essential for electrical applications.[206] Freshwater resources are also under severe stress; estimates indicate that over **40% of the world population** currently lives in water-scarce areas, a figure expected to rise with population growth and climate change impacts.[207] The **OECD Environmental Outlook to 2050** warns that without more ambitious green policies, the mismanagement of natural assets could undermine human development.[208] Addressing resource depletion necessitates long-term strategies focused on sustainable consumption, efficient resource management, and the development of alternative materials to mitigate the risks associated with scarcity and potential conflicts.
2.3.4 Ecosystem collapse[209]	The convergence of climate change, pollution, and habitat destruction poses a significant threat to critical ecosystems, including coral reefs and rainforests. The Intergovernmental Panel on Climate Change (IPCC) reports that coral reefs are highly sensitive to temperature increases, with projections indicating that even a 1.5°C rise could lead to a **70–90% decline in reef cover**, and a 2°C increase could result in over 99% loss.[210] Similarly, the OECD Environmental Outlook to 2050 warns that without more ambitious green policies, **biodiversity is projected to decline by an additional 10% by 2050**, with significant losses in tropical forests.[211] These ecosystems provide essential services, such as carbon sequestration and support for biodiversity; their collapse would have profound environmental and socio-economic consequences. While some ecosystem degradation is already observable, the most severe impacts, including potential collapses, are projected to manifest in the long term. This timeline reflects the cumulative nature of environmental stressors and the delayed response of ecosystems to these pressures.

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206 IEA (2024:5).; United Nations Environment Programme (2024:6).
207 World Bank (2022:2).
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ENVIRONMENTAL TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 2/2

Trend	Description
2.3.5 Desertification[212]	Desertification, the degradation of land in arid, semi-arid, and dry sub-humid areas, poses a significant threat to global food security. Currently, over **75% of Earth's land area is degraded**, with projections indicating that more than **90% could become degraded by 2050**.[213] This degradation leads to reduced agricultural productivity, threatening the livelihoods of millions. The Intergovernmental Panel on Climate Change (IPCC) reports that **climate change exacerbates desertification** through increased temperatures and altered precipitation patterns, further diminishing arable land.[214] Desertification is a gradual process, with its most severe impacts unfolding over decades. Without immediate and sustained intervention, the cumulative effects will become increasingly apparent post-2040, leading to significant reductions in arable land and heightened food insecurity. Addressing this challenge requires long-term strategies focused on sustainable land management and climate change mitigation.
2.3.6 Ocean currents[215]	Changes in ocean currents, driven by melting polar ice and temperature shifts, are projected to significantly impact **global climate patterns** and **marine ecosystems**. The **Atlantic Meridional Overturning Circulation (AMOC)**, a crucial component of Earth's climate system, is very likely to weaken over the 21st century under all considered scenarios (**high confidence**). An abrupt collapse, while not expected before 2100, would cause abrupt shifts in **regional weather patterns** and **water cycles**, such as a southward shift in the tropical rain belt, with large impacts on ecosystems and human activities (**medium confidence**).[216] These alterations can disrupt **marine ecosystems**, affecting **species distribution** and **productivity**, with cascading effects on biodiversity and fisheries. The projected time of emergence for primary drivers of marine ecosystem change, including **surface warming**, **acidification**, and **oxygen loss**, is anticipated before 2100 for over **60% of the ocean area** under high-emission scenarios (**very likely**).[217] While some changes in ocean currents are already being observed, the most profound impacts on **global climate patterns** and **marine ecosystems** are projected to manifest in the latter half of the 21st century and beyond. The **inertia within climate processes** means that significant alterations, such as a potential collapse of the AMOC, are anticipated over extended timescales, making this a critical **long-term environmental trend**.
2.3.7 Permafrost thaw[218]	Permafrost, the perennially frozen ground in polar regions, acts as a significant carbon reservoir, storing approximately **1,700 gigatonnes of organic carbon**, nearly double the current atmospheric carbon content.[219] As global temperatures rise, permafrost thaws, releasing stored greenhouse gases like carbon dioxide and methane, which intensify climate change. Projections indicate that, even with global warming limited to well below 2°C, around **25% of near-surface permafrost** (3–4 meters deep) will thaw by 2100. Under high-emission scenarios, this loss could escalate to about **70%**, potentially releasing **tens to hundreds of billions of tonnes of carbon** into the atmosphere by 2100.[220] Permafrost thawing is a progressive phenomenon, with substantial carbon release and associated climatic impacts expected to become more pronounced in the latter half of the 21st century. The amplification of climate change due to permafrost carbon feedbacks is anticipated to have significant environmental consequences in the long term, influencing global climate patterns beyond 2040.
2.3.8 Food security[221]	Long-term climate changes and resource constraints are projected to significantly challenge global food production and distribution systems. **Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events** are expected to reduce crop yields and disrupt supply chains. The **World Bank** indicates that, under high-emission scenarios, **global crop yields could decline by up to 30% by 2050**, intensifying food insecurity, particularly in regions like **Sub-Saharan Africa and South Asia**.[222] The cumulative effects of climate change on agriculture are progressive, with more severe impacts anticipated in the latter half of the 21st century. The **OECD** emphasises that, without substantial adaptation measures, **food systems' resilience will be increasingly compromised**, leading to heightened food insecurity **beyond 2040**.[223]

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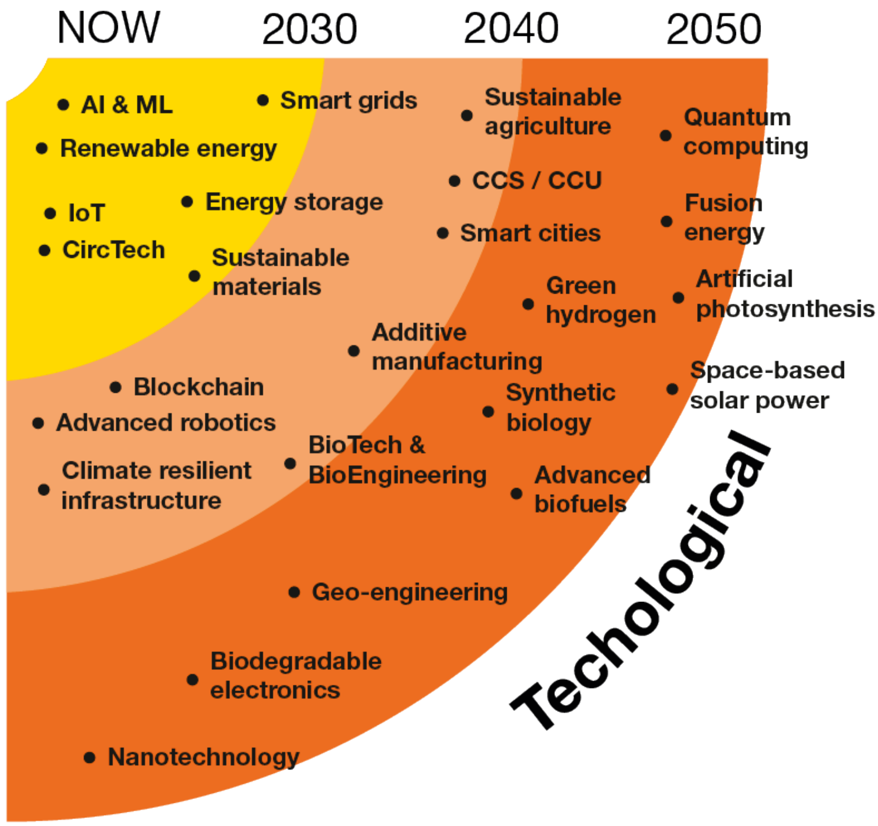
Technological trends in sustainability



Technology is a critical enabler in the global shift toward sustainability, offering tools and innovations that can support more sustainable production and resource use. However, the adoption of these technologies often comes with trade-offs, including increased energy consumption, resource dependency, and economic challenges. Emerging technologies such as artificial intelligence (AI), renewable energy systems, the Internet of Things (IoT), and carbon capture solutions hold great potential to improve operational efficiency and reduce environmental impacts. Yet, their implementation must be carefully managed to avoid burden shifting, such as exacerbating energy demand, over-reliance on critical raw materials, or creating unintended social and environmental consequences.

This chapter examines the dual nature of technological advancements: their capacity to drive sustainability while also presenting new complexities and challenges. It highlights the need for companies to integrate strategic foresight into technology adoption, considering economic costs, resource trade-offs, and the broader impact on ecosystems. Furthermore, the chapter delves into clean technology, smart infrastructure, and data-driven solutions, emphasising how these innovations can support long-term ecological and economic resilience. Achieving this resilience, however, will require addressing critical questions around funding, accessibility, and the alignment of green investments with areas of greatest need.

TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 1/2

Trend	Description
3.1.1 AI & ML[224]	AI and Machine Learning (ML) are revolutionising sustainability by optimising resource use, predicting environmental impacts, and enhancing decision-making. AI systems can improve energy efficiency in buildings by up to **20%**[225] and model climate impacts to **optimise mitigation strategies**.[226] However, AI's significant energy consumption, driven by its computational demands, risks offsetting these benefits.[227] AI adoption in sustainability is already underway, with immediate applications in climate modeling, energy optimisation, and policy planning.
3.1.2 Renewable energy[228]	Advancements in solar, wind, and bioenergy technologies are **driving energy efficiency and reducing reliance on fossil fuels**. The UN estimates that achieving net-zero by 2050 requires **$4.5 trillion annually** in renewable investments until 2030.[229] These **technologies reduce greenhouse gas emissions but can have negative impacts**, such as land degradation from solar farms and marine ecosystem disruption from offshore wind.[230] The next decade is critical for scaling renewables. The IEA warns the world is **not on track with the UN goal to triple renewable capacity by 2030**, highlighting the urgency of action. Renewables provide key sustainability benefits but require careful implementation to balance positive and negative impacts.
3.1.3 IoT[232]	IoT enhances sustainability by enabling efficient **resource monitoring and management** across sectors. In agriculture, **IoT devices, for example, optimise water usage**, with precision irrigation reducing water consumption by **up to 30%**.[233] In energy management, **smart grids and meters** improve real-time energy distribution efficiency and facilitate renewable energy integration.[234] However, the proliferation of IoT devices raises concerns about **increased electronic waste** and energy consumption.[235] The **European Commission** emphasises the need for **sustainable design and recycling protocols** to mitigate these impacts. Given the rapid adoption of IoT technologies, their significant influence on sustainability is expected in the **short term (now to 2030)**. This timeframe allows for the development of **supportive policies and infrastructure** to maximise benefits while addressing challenges.
3.1.4 Smart grids[236]	**Smart grids** enhance sustainability by improving **energy distribution efficiency**, reducing losses, and facilitating the integration of **renewable energy sources**. By employing **digital technologies**, they enable **real-time monitoring and management** of electricity flows, leading to more efficient energy use and decreased **greenhouse gas emissions**. For instance, the **European Commission's SUSTAINABLE project** demonstrated that combining smart meter data with short-term weather forecasts can optimise power system management, avoiding congestion and overload.[237] However, the deployment of smart grids presents challenges, including the need for **substantial infrastructure investment**, potential **cybersecurity risks**, and concerns about **data privacy**.[238] Addressing these issues is crucial to fully realise the sustainability benefits of smart grids. The **rapid advancement of digital technologies** and increasing **policy support** make the widespread implementation of smart grids feasible in the **short term (now to 2030)**. This period allows for the necessary **infrastructure development** and **regulatory frameworks** to maximise positive sustainability impacts.

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TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 2/2

Trend	Description
3.1.5 Energy storage[239]	Innovations in energy storage, such as **solid-state batteries** and **advanced supercapacitors** are enhancing renewable energy systems by improving reliability and scalability. **Solid-state batteries** provide higher energy density and safety, enabling better integration of solar and wind energy.[240] **Advanced supercapacitors**, with rapid charge/discharge capabilities, support grid stability and efficient energy storage.[241] However, these technologies pose environmental challenges due to resource-intensive production processes, emphasising the need for sustainable manufacturing and recycling.[242] The rapid development of energy storage technologies and supportive policies positions them for significant impact in the **short term (now to 2030)**. This timeline allows for technological maturation, production scaling, and addressing sustainability concerns.
3.1.6 CircTech[243]	**Circular economy technologies (CircTech)**, such as **advanced recycling** and **waste-to-material systems**, are pivotal for reducing waste and enhancing resource efficiency. **Advanced recycling** methods like chemical recycling can convert **up to 90% of plastic waste** into reusable monomers.[244] **Waste-to-material systems** achieve reuse rates of over **50%** for construction and demolition waste in Europe, producing valuable aggregates. **Waste-to-material systems** in the EU-27 achieve high recovery rates for construction and demolition waste, with an average recovery rate of **88% in 2020**, repurposing waste into valuable materials such as aggregates for new construction projects.[245] However, circular technologies face significant barriers, including high capital costs, regulatory uncertainty, and technical difficulties in processing mixed waste streams. The lack of standardised metrics and reliable data limits transparency and market confidence, while low consumer awareness reduces demand for circular products. Addressing these challenges is crucial to scaling circular solutions effectively.[246] Despite these challenges, CircTech is positioned in the **short-term timeline (now to 2030)** due to rapid advancements, increasing demand for circular solutions, and supportive regulatory developments.
3.1.7 Sustainable material[247]	**Innovations in sustainable materials** are driving eco-friendly products and reducing environmental impacts. The global sustainable materials market, valued at **USD 296.47 billion in 2023**, is projected to reach **USD 942.38 billion by 2030**, growing at a **CAGR of 12.4%**.[248] Key examples of sustainable materials include **bio-based materials**, **recycled content products**, and **energy-efficient building components**, which contribute to reducing resource use and carbon footprints in industries like construction, as highlighted in the OECD's approach to sustainable materials management.[249] However, challenges like the **carbon footprint of bio-based materials** and difficulties in recycling composites require innovation and lifecycle assessments.[250] Rapid advancements, market growth, and evolving regulations position sustainable materials as short-term (now to 2030) drivers of sustainability, addressing environmental challenges and resource efficiency.[251]

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TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 1/3

Trend	Description
3.2.1 Sustainable agriculture[252]	Advances in sustainable agriculture technologies, including **precision farming**, **new plant breeding techniques**, and **vertical farming**, are poised to enhance food production efficiency and reduce environmental impact. Precision farming employs data-driven approaches to optimise input usage, potentially **reducing fertiliser and pesticide application by up to 20%**, thereby minimising environmental pollution.[253] New plant breeding techniques, such as CRISPR-Cas9, enable the development of **crop varieties with improved yield, drought tolerance, and disease resistance**, contributing to food security and resource conservation.[254] Vertical farming offers a **sustainable solution for urban agriculture**, utilising controlled environments to achieve higher yields per unit area while reducing land and water use. However, these technologies also present challenges. The **high initial investment and operational costs** associated with precision farming and vertical farming can be prohibitive for small-scale farmers, potentially exacerbating economic disparities. Additionally, the **rapid adoption of new plant breeding techniques raises ethical and regulatory concerns** that require careful consideration. The mid-term period (2030 to 2040) is critical for the maturation and widespread adoption of these technologies. This timeframe allows for the development of supportive policies, infrastructure, and market conditions necessary to address existing challenges and fully realise the sustainability benefits of advanced agricultural practices.
3.2.2 CCS / CCU[256]	Advancements in **Carbon Capture and Storage (CCS)** and **Carbon Capture and Utilization (CCU)** technologies are enhancing the effective capture, storage, and utilisation of carbon emissions, thereby contributing to climate change mitigation. **CCS** is particularly vital for addressing **fossil-based emissions** from industries like cement and steel, where it serves as a primary solution for significant emission reductions. In contrast, **CCU** is more suitable for **biogenic emissions**, converting captured CO_2 into products such as biofuels, acknowledging that these emissions may eventually be released back into the atmosphere. The **International Energy Agency (IEA)** emphasises that CCUS is essential for achieving net-zero emissions, especially in sectors where emissions are hard to abate.[257] **Positive impacts** of these technologies include substantial reductions in greenhouse gas emissions and the promotion of a circular carbon economy. However, **negative impacts** encompass high implementation costs, energy intensity of the capture processes, and the need for extensive infrastructure development. Considering the current pace of technological progress and the necessity for large-scale deployment, the period from **2030 to 2040** is projected to witness significant advancements and broader adoption of CCS and CCU technologies, aligning with global climate targets.
3.2.3 Smart cities[258]	**Smart cities** integrate advanced technologies to optimise resource use, reduce pollution, and enhance quality of life. **Smart grids**, for instance, enable energy efficiency by balancing supply and demand, with studies showing **20-30% reductions in energy waste** through grid optimisation.[259] **Intelligent transportation systems** reduce emissions by managing traffic flows, as seen in Stockholm, where congestion pricing cut traffic congestion by **20%** and emissions by **14%**.[260] District heating with small modular reactors (SMRs) offers a highly sustainable energy solution, with studies from the VTT Technical Research Centre of Finland showing that nuclear-based district heating emits just **2.4 gCO_2/kWh**, compared to **515 gCO_2/kWh** for coal, a **reduction of over 99%**.[261] Challenges include high infrastructure costs, potential increases in e-waste, and data privacy risks. However, frameworks such as the **EU Green Deal** address these issues with policy and funding support.[262] The mid-term timeframe aligns with the necessary policy evolution, infrastructure deployment, and technology maturation to achieve full-scale implementation of smart city solutions.

[252] Alam, M.W., Junaid, P.M., Gulzar, Y. et al. (2024); Mgendi, G. (2024); OECD (2016).
[253] European Parliament (2016).
[254] Adane M., Alamnie G. (2024).
[255] Rajashekar V., Faisal A., Mukherjee A., More R., Bhowmick G.D. (2024).
[256] Global CCS Institute (2024); IEA (2020); Butnar I., Cronin J., Pye S. (2020).
[257] IEA (2020).
[258] European Commission (2024); OECD (2023); Majumdar, S., Kandpal V., Anthopoulos L.G. (Editors) (2024)
[259] Kumar, S., Pathak, U., Astha, Bhatia, B. (2023).
[260] San Francisco County Transportation Authority (2020)
[261] Sokka L., Kirppu H., & Leppänen J. (2024).
[262] European Commission (2019).

TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 2/3

Trend	Description
3.2.4 Additive manufacturing[263]	**Additive Manufacturing (AM)**, commonly known as **3D printing**, enables the **layer-by-layer construction of products**, leading to **material efficiency** and **waste reduction** in production processes. This method contrasts with traditional subtractive manufacturing, which often results in significant material waste. For instance, the EU-funded **AMAZE Project, Additive Manufacturing Aiming Towards Zero Waste & Efficient Production of High-Tech Metal Parts**, demonstrated that **AM could reduce material waste to negligible amounts** in metal part production.[264] However, the **energy consumption** of AM processes, particularly those involving high-power lasers, can be substantial, potentially offsetting some environmental benefits. A study in the *Journal of Industrial Ecology* found that the **energy demand of selective laser melting (SLM) is higher** compared to traditional manufacturing methods.[265] The time window from 2030–2040 is crucial for advancing AM technologies to enhance **energy efficiency** and **material utilisation**. Ongoing research and development, such as the **DIAMETER project**, aim to integrate **circular economy principles** into AM, promoting **remanufacturing**, **refurbishing**, and **recycling strategies**.[266] By 2040, these advancements are expected to **significantly enhance the sustainability** of manufacturing processes, aligning with global environmental goals.
3.2.5 Blockchain[267]	**Blockchain technology** enhances **transparency and traceability** in supply chains, promoting sustainable practices and reducing fraud. By providing an immutable ledger, blockchain allows stakeholders to verify product origins, monitor environmental impacts, and ensure ethical sourcing. The **European Parliament** notes that blockchain can add a level of tracking, traceability, and transparency to trade, useful for enforcing trademarks and property rights.[268] For example, **IBM Food Trust** uses blockchain to **trace food supply chains**, **reducing waste and fraud** while ensuring food safety.[269] Similarly, **Everledger** leverages blockchain to **certify the origins of critical minerals**, ensuring ethical sourcing and reducing fraud.[270] However, blockchain's environmental impact is a concern. The **European Environment Agency** highlights that blockchain's **energy-intensive nature** could undermine climate change mitigation efforts.[271] The widespread adoption of blockchain in supply chains requires technological maturation, standardisation, and regulatory frameworks, aligning with a mid-term horizon of 2030 to 2040. This period allows for the development of energy-efficient blockchain solutions and integration into global supply chains.
3.2.6 Advanced robotics[272]	**Advanced robotics** is transforming manufacturing, agriculture, and waste management, enhancing efficiency and reducing environmental impact. In manufacturing, systems like the ones developed in the **AREUS project** reduced energy consumption by up to 20%.[273] In agriculture, robots enable precision farming, significantly reducing pesticide use and resource waste. For instance, the **Food and Agriculture Organization (FAO)** reports that **agricultural robotics** and automated equipment can support sustainable crop production by optimising input usage and improving efficiency.[274] In waste management, AI-powered robots like ZenRobotics' fourth-generation models enhance efficiency by sorting up to **80 items per minute** across over **500 waste categories**, boosting recycling rates and reducing landfill use.[275] However, widespread adoption of robotics raises concerns, including potential job displacement and the environmental impact of producing and disposing of robotic equipment. The **OECD** emphasises the need for policies that address these challenges to ensure that the deployment of robotics contributes positively to sustainability goals.[276]

263 Srivastava, M., Rathee, S. (2022); Graziosi, S., Faludi, J., Stanković, T. et al. (2024).
264 AMAZE Project (2017).
265 Faludi J., Baumers M., Maskery I., Hague R. (2017).
266 DIAMETER Project (2024).
267 Neumeyer X., Cheng K., Chen Y., Swartz K. (2021); Abbas, Z., & Myeong, S. (2024).
268 EPRS (2020).
269 IBM (2024).
270 Everledger (2024).
271 EEA (2020).
272 Mai V. et al. (2022); Indurkhya B., Sienkiewicz B. (2024).
273 AREUS (2016).
274 Santos Valle S., Kienzle J. (2020).
275 Recycling Today (2024).
276 Lagarde Z. (2019).

TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 3/3

Trend	Description
3.2.7 BioTech & bioengineering[277]	**Biotechnology and bioengineering** are advancing **sustainable agriculture**, **biofuels**, and **waste management**, supporting environmental sustainability. In agriculture, **drought-resistant crops** developed through genetic engineering enhance food security. The **OECD** highlights biotechnology's role in improving yields and reducing chemical inputs.[278] Biofuels from agricultural residues, like **second-generation biofuels**, offer a low-emission alternative to fossil fuels.[279] Additionally, projects like the EU's PERCAL **convert organic waste into bio-based chemicals**, supporting a circular economy.[280] While these technologies offer substantial environmental benefits, considerations include the ethical implications of genetic modifications and the need for sustainable biomass sourcing to prevent unintended ecological impacts.
3.2.8 Climate-resilient infrastructure[281]	Developing **climate-resilient infrastructure** is critical to adapting to climate change impacts, reducing risks, and ensuring sustainability. This includes designing systems capable of withstanding extreme weather, such as floods, heatwaves, and storms, while maintaining functionality. The **World Bank** highlights that resilient infrastructure can reduce disaster-related economic losses by up to **$4.2 trillion annually**, saving lives and livelihoods.[282] However, implementation requires **significant investment** and careful planning to **minimise environmental impacts** during construction. The **OECD** emphasises integrating resilience into infrastructure design to ensure longevity and reduce vulnerabilities.[283]

[277] Arora, N.K., Fatima, T. (2024); OECD (2001).
[278] Solleiro Rebolledo J. (1995).
[279] Eisentraut A. (2010).
[280] PERCAL (2020).
[281] OECD (2024:2); ICSI (2023).
[282] World Bank (2024:3).
[283] OECD (2024:2).

TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 1/3

Trend	Description
3.3.1 Quantum computing[284]	**Quantum computing** has the potential to revolutionise data processing and problem-solving capabilities, offering more **efficient solutions for complex sustainability challenges**. By leveraging quantum phenomena, these computers can **perform intricate simulations and optimisations beyond the reach of classical systems**. For instance, quantum simulations could **enhance climate modelling, enabling accurate predictions of weather patterns and more effective mitigation strategies**.[285] Additionally, quantum algorithms can optimise **energy distribution networks**, improving efficiency and minimising waste.[286] However, challenges include **substantial energy demands** for quantum systems and the **environmental impact** of producing specialised quantum hardware.[287] Quantum computing remains in its early stages, with widespread adoption requiring advancements in scalability, error correction, and energy efficiency. The long-term timeline allows for addressing these technological and sustainability challenges.
3.3.2 Fusion energy[288]	**Fusion energy** holds the promise of providing a **virtually limitless and clean energy source**, potentially revolutionising the global energy landscape. By replicating the **nuclear reactions that power the sun**, fusion combines hydrogen isotopes to produce helium, releasing substantial energy without emitting **greenhouse gases**.[289] The **primary fuels, deuterium and tritium**, are abundant and widely available, reducing **geopolitical risks** associated with energy resources. Fusion reactors are designed to be **inherently safe**, with minimal risk of accidents and producing **no long-lived radioactive waste**.[290] However, challenges remain, including the **technological and engineering hurdles** in achieving and maintaining the **high-temperature conditions** necessary for fusion reactions, as well as the **significant costs** of developing fusion infrastructure.[291] Given these complexities, the widespread deployment of fusion energy is anticipated in the **long term (2040 and beyond)**, allowing time to overcome existing obstacles and integrate fusion into the sustainable energy mix.
3.3.3 Artificial photosynthesis[292]	**Artificial photosynthesis** aims to produce clean fuels by mimicking natural processes, utilising **sunlight, water, and carbon dioxide** to generate energy-dense fuels like hydrogen or hydrocarbons. This technology offers a **sustainable alternative to fossil fuels**, potentially reducing **greenhouse gas emissions** and contributing to **energy security**. For example, the **EU-funded A-LEAF project** has developed a **photo-electro-catalytic cell** that directly converts water and CO_2 into fuels and oxygen using solar energy.[293] However, challenges remain, including improving **conversion efficiencies**, ensuring the **scalability** of the technology, and addressing the **environmental impact** of large-scale deployment. Given these hurdles, significant advancements and widespread implementation of artificial photosynthesis are anticipated in the **long term (2040 and beyond)**, allowing time for **research**, **development**, and the establishment of necessary infrastructure.
3.3.4 Green hydrogen[294]	**Green hydrogen**, produced via electrolysis powered by renewable energy, offers a **sustainable alternative to fossil fuels** across various industries. It holds significant potential for **decarbonising sectors such as steel production, ammonia synthesis, and heavy transportation**, where direct electrification is challenging. For instance, the **OECD projects that by 2050, at least two-thirds of global hydrogen** production will be green hydrogen, supporting the transition to a net-zero emissions energy system.[295] However, **high production costs** and **substantial energy requirements** pose challenges to its widespread adoption. The **World Bank highlights that producing 500 million tonnes of green hydrogen annually would require approximately 22,000 TWh of green electricity**, underscoring the need for significant renewable energy infrastructure.[296] Large-scale deployment of green hydrogen technologies is anticipated in the **long term (2040 and beyond)**, allowing time to overcome economic and technical barriers and to develop the necessary infrastructure.

[284] Cooper P., Ernst P., Kiewell D., Pinner D. (2022); Deloitte. (2023).
[285] Ashwani S., Tripathy A. J., Karna S., Reddy Jahanve P., Rajagopal S. M. (2024).
[286] Heinen X. , Chen H. (2024).
[287] Forbes D. N. (2024).
[288] MIT Energy Initiative (2024).
[289] EUROfusion (2018).
[290] Fusion for Energy (2025).
[291] EUROfusion (2018).
[292] Machín, A., Cotto, M., Ducongé, J., & Márquez, F. (2023); Najafpour, M.M., Shen, JR. & Allakhverdiev, S.I. (2022).
[293] A-Leaf (2021).
[294] Sebbagh, T., Şahin, M.E. & Beldjaatit, C. (2024); IRENA (2024:2).
[295] Cordonnier, J. and D. Saygin (2022).
[296] Kane M. K., Gil S. (2022).

TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 2/3

Trend	Description
3.3.5 Space-based solar power[297]	**Space-based solar power (SBSP)** systems aim to **capture solar energy in space** and transmit it to Earth, providing a continuous and reliable source of renewable energy. Operating above Earth's atmosphere, these systems can harness solar radiation without interruptions from weather or the day-night cycle, potentially supplying **uninterrupted clean energy**. The European Space Agency's **SOLARIS initiative** is exploring the **feasibility of space-based solar power (SBSP) systems as a clean energy solution for Europe**. While the timeline for deployment depends on technological and economic advancements, the initiative aims to address key challenges by the mid-21st century, potentially contributing significantly to Europe's renewable energy mix.[298] However, challenges include the **high costs of development and launch**, potential environmental impacts from microwave or laser energy transmission, and the accumulation of **space debris**, which poses risks to orbital operations.[299] Given these technological and infrastructural hurdles, **SBSP is projected to become viable in the long term**, aligning with global sustainability goals and the transition to renewable energy sources.
3.3.6 Advanced biofuels[300]	**Advanced biofuels** derived from non-food biomass, such as agricultural residues and waste, offer a sustainable alternative to fossil fuels, particularly for **hard-to-decarbonise sectors** like aviation, maritime, and heavy-duty machinery. These biofuels can significantly reduce greenhouse gas emissions compared to conventional fuels. For instance, the European Commission notes that advanced biofuels are currently the only viable option to decarbonise aviation and maritime sectors in the short term.[301] However, challenges persist, including higher production costs due to processing complexities and the need for substantial investments in new refinery units. Additionally, ensuring the sustainability of feedstock sourcing and meeting stringent certification requirements are critical to maximising environmental benefits. Given these factors, the widespread adoption of advanced biofuels in these sectors is anticipated in the **long term**, allowing time to overcome economic and technological hurdles and to scale up production capacities effectively.
3.3.7 Synthetic biology[302]	**Synthetic biology** enables the design and construction of new biological systems and organisms for the **sustainable production of chemicals, materials, and energy**. By engineering microorganisms, it is possible to create **bio-based alternatives to petrochemical products**, reducing reliance on fossil fuels and **decreasing greenhouse gas emissions**.[303] For example, **engineered bacteria strains** have been developed to convert **agricultural waste into biopolymers** like polyhydroxyalkanoates (PHAs), **which are biodegradable and used as substitutes for conventional plastics**.[304] However, the release of **synthetic organisms into the environment** poses potential risks to ecosystems and biodiversity, necessitating **comprehensive risk assessments and regulatory frameworks**.[305] Given the **current pace of technological development** and the need for thorough evaluation of ecological impacts, the widespread application of synthetic biology in sustainable production is anticipated in the **long term**.
3.3.8 Geoengineering[306]	**Geoengineering technologies** are being developed to mitigate climate change impacts, focusing on **carbon dioxide removal (CDR)** and **solar radiation management (SRM)**. **CDR** aims to extract CO_2 from the atmosphere, storing it in natural or geological sinks to directly reduce greenhouse gas concentrations. SRM seeks to reflect a portion of solar radiation back into space, potentially cooling the planet, but it carries risks such as altered precipitation patterns and temperature anomalies. Geoengineering is increasingly being floated as one of the solutions that could forestall the worst consequences of global warming. However, it poses significant risks, including **scientific uncertainties, environmental and ethical issues, governance challenges, geopolitical tensions, and public resistance**. These concerns highlight the complexities and potential dangers of using geoengineering as a climate solution.[308] Given these challenges, the widespread deployment of geoengineering is anticipated beyond 2040, allowing for comprehensive research, risk assessment, and the establishment of international regulatory frameworks to ensure safe and effective implementation.

[297] Rodgers E., Gertsen E., Sotudeh J., Mullins C., Hernandez A., Nguyen Le H., Smith P, Joseph N. (2024); Frazer-Nash (2022); Roland Berger (2022).
[298] European Space Agency (2024).
[299] Rodgers E., Gertsen E., Sotudeh J., Mullins C., Hernandez A., Nguyen Le H., Smith P, Joseph N. (2024).
[300] Maharjan A., Kim M., Choi W., Kim H., Park J. (2024); Motola, V., Hurtig, O., Scarlat, N., Buffi, M., Georgakaki, A., Letout, S. and Mountraki, A. (2023).
[301] European Commission (2023).
[302] WEF (2024); WEF (2021).
[303] European Environment Agency (2020).
[304] Kurashima, Y., Amiya, T., Nochi, T. et al. (2012).
[305] European Commission (2015).
[306] Van Woensel L., Fernández Álvarez M. (2021); Sacco N., Janssens-Maenhout G., Galmarini S., Michel Q. (2022).
[307] Sacco N., Janssens-Maenhout G., Galmarini S., Michel Q. (2022).
[308] Trakimavičius L. (2024).

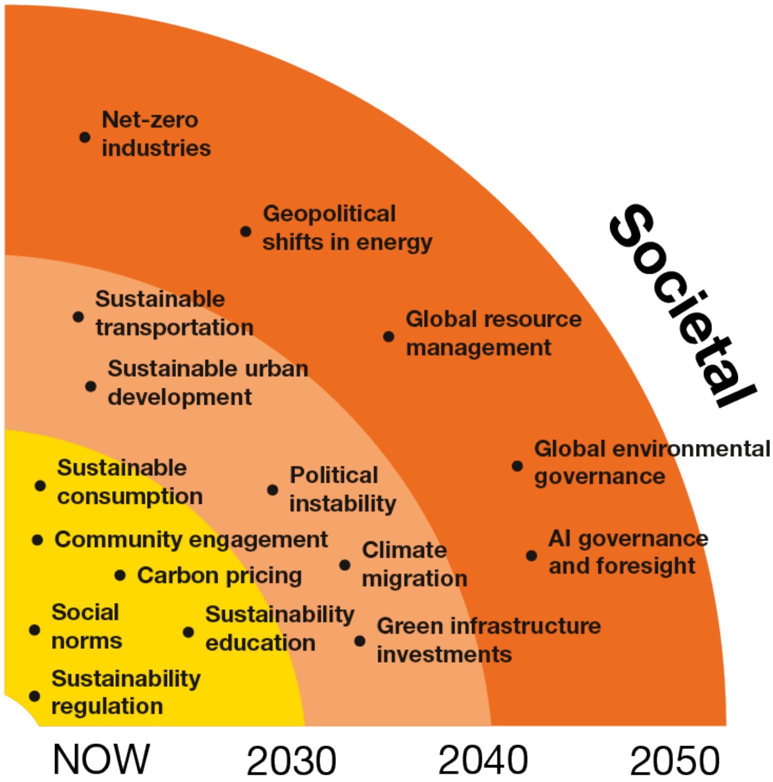
TECHNOLOGICAL TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 3/3

Trend	Description
3.3.9 Biodegradable electronics[309]	**Biodegradable electronics** are emerging as a promising solution to reduce **electronic waste** and environmental impact, contributing to a **circular economy**. These devices are designed to **decompose naturally** after their functional lifespan, minimising the accumulation of **e-waste in landfills**. For example, the **European ECOsystem for greeN Electronics (EECONE)** project is focusing on creating environmentally sustainable electronics to tackle Europe's rising e-waste challenge.[310] However, challenges include ensuring **device performance, stability during use, and scalability of manufacturing processes**. Additionally, the environmental impact of producing **biodegradable materials** must be assessed to ensure a **net positive effect** on sustainability. The widespread adoption of biodegradable electronics is expected in the **long term (2040 and beyond)**, allowing time for **technological advancements**, the establishment of **industry standards**, and large-scale integration into mainstream production.
3.3.10 Nanotechnology[311]	**Nanotechnology** holds significant promise for developing advanced materials and processes aimed at **cleaning up pollutants and restoring ecosystems**. For instance, **nanoremediation** techniques employ nanoparticles to treat contaminated soil and groundwater, effectively degrading pollutants like chlorinated solvents and heavy metals. The European Union's NanoRem project has demonstrated the practical application of such technologies in environmental remediation.[312] However, the deployment of nanomaterials raises concerns regarding their **potential toxicity** and **long-term environmental impacts**. The United Nations emphasises the necessity for comprehensive risk assessments to ensure that nanotechnology applications do not inadvertently harm ecosystems.[313] While laboratory research has shown promising results, the **widespread implementation** of nanotechnology in environmental remediation requires further development to address safety, scalability, and regulatory challenges. Therefore, its significant impact is anticipated in the **long term**, allowing time for technological advancements and the establishment of appropriate governance frameworks.

309 Himalyan, S., Gupta, V. (2024); Tan M. J., Owh C., Chee P.L., Kyaw A. K. K., Kai D., Loh X. J. (2016).
310 EECONE (2023).
311 Fan, Y.V. (2024); Kumar, A., Tyagi, P.K., Tyagi, S. et al. (2024).
312 NanoRem (2017).
313 Kolodziejczyk B. (2016).

Societal trends in sustainability



Societal attitudes toward sustainability are rapidly evolving, with individuals, communities, and organisations increasingly demanding environmental responsibility and social equity. As awareness of climate change, resource scarcity, and social justice grows, consumer behaviour, cultural norms, and public expectations are shifting toward more sustainable and ethical practices. People are prioritising sustainable consumption, supporting businesses with strong environmental and social values, and actively participating in local and global sustainability initiatives.

However, these positive shifts coexist with opposing trends. For instance, some organisations are scaling back commitments to diversity, equity, and inclusion (DEI) policies or deprioritising other social sustainability practices due to economic pressures or changing leadership priorities. Such contradictions reflect the complexity of societal dynamics, where progress in some areas is counterbalanced by resistance or retrenchment in others.

Societal trends are reshaping how industries produce, how governments regulate, and how communities interact, making sustainability not only an environmental imperative but also a contested social value. This chapter examines the societal trends driving sustainability – both advancements and challenges – highlighting changes in consumer behaviour, education, community engagement, and social norms that are fostering or hindering a more sustainable and equitable future.

SOCIETAL TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 1/2

Trend	Description
4.1.1 Sustainable consumption[314]	**Consumers are increasingly conscious of their environmental impact**, driving demand for **sustainable products and services**. This shift is evident in **high-income countries**, where consumer spending constitutes about **60% of GDP**[315], and **lifestyle changes could reduce global greenhouse gas emissions by up to 40–70% by 2050**.[316] However, in **low-income and developing countries**, where gross national income per capita is less than **$1,145**[317], immediate economic needs often overshadow environmental considerations.[318] While increased demand for **eco-friendly products** can lead to positive environmental outcomes, challenges include the **risk of greenwashing** and **limited accessibility** of sustainable options across different income levels. Addressing these issues requires **comprehensive policies** and **consumer education** to support informed choices globally.
4.1.2 Community engagement[319]	**Communities worldwide are increasingly participating in local sustainability initiatives**, such as **community gardens** and **renewable energy projects**. This **grassroots involvement fosters environmental stewardship**, enhances social cohesion, and promotes sustainable development. In **low-income countries, community and local development (CLD)** programs have effectively addressed local challenges by empowering residents to manage resources and implement tailored solutions. For example, the **World Bank highlights that CLD approaches** have led to efficient and inclusive delivery of basic services, resulting in **measurable reductions in poverty and inequality**.[320] However, **challenges persist**, including **limited access to funding, technical expertise, and potential disparities in participation** among different socioeconomic groups. Addressing these issues is crucial to ensure **equitable and effective community engagement** in sustainability efforts. The **United Nations emphasises** that achieving the **Sustainable Development Goals (SDGs)** by 2030 requires **active community involvement**, making this trend particularly relevant in the **short term**.[321]
4.1.3 Carbon pricing[322]	**Carbon pricing mechanisms**, such as carbon taxes and cap-and-trade systems, are being increasingly adopted worldwide to mitigate greenhouse gas emissions. As of 2023, these instruments cover close to **25% of global emissions**, a significant rise from **5% in 2010**.[323] In 2023, revenues from carbon taxes and Emissions Trading Systems (ETS) reached a record high of about **$104 billion**, indicating a growing commitment to integrating environmental costs into economic activities.[324] The **short-term timeframe (now to 2030)** is critical for expanding carbon pricing, as immediate action is essential to meet international climate targets. Positive impacts include incentivising low-carbon technologies and generating public revenue that can be reinvested in sustainable initiatives. However, challenges persist, such as potential economic disparities and the risk of carbon leakage, where businesses relocate to regions with laxer emission constraints. Addressing these issues requires careful policy design to balance economic growth with environmental sustainability.
4.1.4 Social norms[325]	**Shifting social norms** are reshaping the social aspects of sustainability, influencing behaviours and policies that promote inclusivity and equality. The increasing emphasis on **Diversity, Equity, and Inclusion (DEI)** is driving organisations to adopt practices that address systemic inequalities, fostering environments where **diverse perspectives are valued**. This shift contributes positively to **social sustainability** by promoting **equal opportunities** and reducing **discrimination**. However, these evolving norms can also create divisions between groups, particularly when changes challenge **long-standing cultural beliefs** or face resistance from those benefiting from the status quo. The **World Bank Group Gender Strategy 2024-2030** highlights the importance of addressing **gender norms** to achieve equitable development, emphasising that without tackling biased social norms, **gender equality** and the **Sustainable Development Goals** cannot be realised.[326] The period up to **2030** is critical for embedding these shifting norms into societal frameworks, aligning with global agendas like the **United Nations' 2030 Agenda for Sustainable Development**, which underscores the need for transformative steps to shift the world onto a **sustainable and resilient path**.[327]

[314] Bäckström K., Egan-Wyer C., Samsioe E. [Editors] (2023);
[315] World Bank (2025), Households and NPISHs final consumption expenditure.
[316] OECD (2023:2).
[317] World Bank (2025:2).
[318] Mohseni-Cheraghlou A., Evans H. (2023).
[319] Wells, E.C., Lehigh, G.R., Vidmar, A.M. (2021); Dushkova, D., Ivlieva, O. (2024).
[320] World Bank (2023).
[321] United Nations (2019).
[322] World Bank (2024); ICC (2023).
[323] Financial Times (2024).
[324] World Bank (2024).
[325] You, L. (2024); Alisha, Kumar, S. (2024); FSG (2024).
[326] World Bank Group (2023:2).
[327] United Nations (2015).

SOCIETAL TRENDS IN SUSTAINABILITY

Short-term (now-2030) – 2/2

Trend	Description
4.1.5 Sustainability education[328]	Educational institutions are increasingly integrating **climate change and sustainability topics** into their curricula to raise awareness among students. This integration aims to equip learners with the **knowledge and skills** necessary to address environmental challenges and promote sustainable development. For example, the **Higher Education Sustainability Initiative (HESI)** supports universities in embedding **Sustainable Development Goals (SDGs)** into teaching and research, fostering a holistic understanding of sustainability across disciplines.[329] The **OECD** highlights that incorporating sustainability into education can **drive societal change** towards more sustainable practices.[330] However, challenges such as **curriculum overload** and the need for **teacher training** can impede effective implementation. Given the **urgency of environmental issues**, sustainability education is prioritised in the **short term (now to 2030)** to empower the current generation to contribute to sustainable solutions.
4.1.6 Sustainability regulation[331]	**Sustainability policy regulations** are rapidly increasing worldwide, particularly within **G20 countries**, driven by the urgency of addressing environmental challenges and meeting international commitments such as the **Paris Agreement** and **UN Sustainable Development Goals**. These regulations focus on carbon neutrality, resource efficiency, and circular economy practices. For instance, the **OECD highlights** the G20's efforts in fostering global policy coherence and green transitions.[332] However, the fragmented regulatory landscape poses challenges for businesses, as countries implement diverse rules. For example, variations in carbon pricing and reporting requirements complicate compliance for multinational companies.[333] While these regulations can significantly drive sustainable practices, inconsistencies across borders increase compliance costs, hinder innovation, and create competitive disparities. Harmonising global standards is essential to enable smoother transitions and equitable implementation. The next decade is critical as global regulatory frameworks align to meet mid-century climate targets. This period demands urgent action, making the short-term focus necessary.

[328] Avelar, A.B.A., Pajuelo-Moreno, M.L. (2024); Mittal, P., Bansal, R. (2024).
[329] United Nations (2012).
[330] Nusche D., Fuster Rabella M., Lauterbach S. (2024).
[331] MSCI (2023).
[332] OECD et al. (2024).
[333] IMF, OECD, UNCTAD, WTO (2024).

SOCIETAL TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 1/2

Trend	Description
4.2.1 Green infrastructure investments[334]	**Green infrastructure investments**, including **parks, green roofs, and sustainable drainage systems**, are increasingly prioritised for their **environmental, social, and economic benefits**. These investments enhance urban resilience by **mitigating flood risks** through natural water absorption and **improving air qualit**y via increased vegetation. For example, the **European Commission's Green Infrastructure Strategy** aims to preserve, restore, and enhance green infrastructure to help stop biodiversity loss and enable ecosystems to deliver services to people.[335] Additionally, integrating **green spaces in urban areas** can **boost property values** and provide **recreational opportunities**, contributing to **community well-being**. However, challenges include **higher upfront costs** and **maintenance requirements**, which may deter investment. To address these barriers, the **OECD** emphasises the need for effective governance to mobilise public policy and expenditure tools for an effective green transition. Given the growing recognition of these benefits and the time needed for planning and implementation, significant societal impacts from **green infrastructure investments** are anticipated in the **mid-term (2030 to 2040)**.
4.2.2 Political instability[337]	**The global rise of authoritarianism is undermining democratic norms and sustainable development**. Authoritarian regimes increasingly exploit political polarisation, restrict freedoms, and erode accountability through advanced control mechanisms, including the use of **AI for surveillance and repression. According to the European Parliament, AI is now a central tool for authoritarian governments**, enabling mass data collection, predictive policing, and targeted repression of dissent, which exacerbates political instability.[338] The **Stockholm Environment Institute** highlights a **16-year decline in global freedom**, as regimes exploit democratic deficits to weaken civic participation and societal resilience.[339] Meanwhile, the **University of Birmingham** emphasises how **authoritarianism disrupts governance, stifles innovation, and obstructs sustainability** efforts.[340] **This trend reduces societal cohesion, trust, and inclusivity, all of which are essential for achieving the UN's Sustainable Development Goals**. By 2030–2040, as regimes refine these methods with evolving technologies, this trend will pose increasing challenges to global governance and sustainable development.
4.2.3 Climate migration[341]	**Rising sea levels and extreme weather events** are projected to **displace millions**, forcing migration from vulnerable regions and posing significant social and economic challenges. The **World Bank's Groundswell report** estimates that, without urgent climate and development action, over **216 million people** could become internal climate migrants by **2050**, with **hotspots emerging as early as 2030**.[342] This mass movement may lead to **overcrowded urban centres**, straining **infrastructure and resources**, and potentially escalating **conflicts over diminishing resources**. Conversely, migration can serve as an **adaptive strategy**, allowing affected populations to seek **improved livelihoods and safety**. The **United Nations** emphasises that **proactive planning and investment in sustainable development** are crucial to mitigate adverse effects and harness potential benefits.[343] The **mid-term period (2030–2040)** is critical, as **climate migration hotspots** are expected to intensify during this time, necessitating **immediate policy interventions** to address sustainability challenges.

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[335] European Commission (2025).
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[339] Stockholm Environment Institute (2022).
[340] University of Birmingham (2023).
[341] C40 Cities Climate Leadership Group (2024); Schewe J, Karim Zantout K (2024).
[342] Clement VV, Rigaud K. K., de Sherbinin A.; Bryan J.; Adamo S., Schewe J., Sadiq N., Shabahat E. (2021).
[343] International Organization for Migration, UN Migration (2020).

SOCIETAL TRENDS IN SUSTAINABILITY

Mid-term (2030-2040) – 2/2

Trend	Description
4.2.4 Sustainable urban development[344]	**Sustainable urban development** involves cities implementing policies that promote environmental, social, and economic sustainability. This includes adopting **green building standards**, enhancing **sustainable transportation**, and ensuring access to **basic infrastructure**. In **Europe**, cities have made significant progress, integrating renewable energy sources and expanding public transit networks, which has reduced carbon emissions and improved urban living standards.[345] Conversely, **megacities in Africa and Asia** face significant challenges such as inadequate **access to clean water, electricity, and sewage systems**, hindering sustainable urban development efforts.[346] Addressing these disparities **requires substantial investments in basic infrastructure** to establish a foundation for sustainable growth.[347] Achieving sustainable urban development in these regions requires time for planning, resource mobilisation, and the implementation of policies to overcome existing deficits. This makes the **mid-term period (2030 to 2040)** a realistic timeline.
4.2.5 Sustainable transportation[348]	**Sustainable transportation policies** are increasingly promoting the adoption of **electric vehicles (EVs)** and other eco-friendly mobility solutions. The **European Union (EU)** has implemented stringent **CO_2 emission performance standards** for new passenger cars, aiming for a **55% reduction by 2030** and a **100% reduction by 2035**, relative to 2021 levels.[349] **Norway** exemplifies successful policy implementation, where comprehensive **tax exemptions** and incentives have led to **two-thirds of new passenger vehicles sold in 2021** being fully electric.[350] However, challenges persist. The **World Bank** notes that while **EVs can reduce greenhouse gas emissions**, their **environmental benefits are maximised** only when the electricity used is generated from **renewable sources**.[351] Additionally, the **European Environment Agency (EEA)** emphasises that EVs alone cannot achieve sustainable road transport; a holistic approach, including improved public transit and infrastructure, is essential.[352] These policies are crucial steps toward sustainable transportation, but a comprehensive strategy addressing energy sources and broader mobility systems is necessary for long-term success.

[344] UN-Habitat (2024); OECD/UN-Habitat (2024).
[345] European Commission (2025:2); Portico (2025).
[346] Delbridge V., Harman, O., Oliveira-Cunha J., Venables T. (2022).
[347] Farvacque-Vitkovic C., Godin L. (2010).
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[349] European Commission (2023:2).
[350] OECD (2022:2).
[351] Okaima Piette J. (2021).
[352] European Environment Agency (2016).

SOCIETAL TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 1/2

Trend	Description
4.3.1 Net-zero industries[353]	The **European Union (EU)** is accelerating its commitment to achieving **net-zero industrial transformation**, focusing on the expansion of **renewable energy** and the overhaul of **energy and transport infrastructures**. This initiative aims to reduce greenhouse gas emissions, enhance energy security, and stimulate economic growth through the creation of green jobs. The **Net-Zero Industry Act** is a pivotal component of this strategy, targeting a 40% domestic production capacity for clean technologies by 2030.[354] However, this transition presents challenges, including the need for substantial investments, potential disruptions to existing industries, and the imperative to ensure a just transition for the workforce. The **OECD** emphasises that well-designed green industrial policies are essential to address these challenges and maximise the benefits of the net-zero transition.[355] Achieving net-zero industries is a long-term societal goal, with significant milestones anticipated by 2040 and beyond. This extended timeline allows for the development and implementation of necessary technologies, infrastructure, and policies to facilitate a sustainable and equitable industrial transformation.
4.3.2 Geopolitical shifts in energy[356]	The global transition from fossil fuels to renewable electricity is set to **redistribute geopolitical power**, creating new winners and losers on the international stage. Historically, nations rich in oil and gas, such as Russia and Saudi Arabia, have wielded significant influence. As the world shifts toward renewables, countries abundant in critical minerals like lithium and cobalt, or those with substantial renewable resources, may gain prominence. For instance, the **United Nations** projects that global demand for critical minerals such as lithium will **quadruple by 2040**, highlighting the importance of sustainable and equitable resource management.[357] While this transition could reduce greenhouse gas emissions and promote sustainability, it also raises challenges, such as resource monopolies and supply chain vulnerabilities. According to the **European Economic and Social Committee**, managing the geopolitical impact of energy transition will require coordinated international efforts to ensure fair resource distribution and avoid conflicts.[358] Given the complexity and scale of the energy transition, these profound geopolitical shifts are expected to materialise primarily in the **long term (2040 and beyond)**. The **International Energy Agency** emphasises that renewable energy growth, coupled with declining fossil fuel demand, will reshape global energy dynamics over the coming decades.[359]
4.3.3 Global resource management[360]	The **unsustainable exploitation of Earth's finite resources**, coupled with **biodiversity loss** and **freshwater pollution**, poses significant challenges to global sustainability. An estimated **4 billion people** currently live in **water-scarce regions**, with projections indicating that by **2030, global freshwater demand will surpass supply by 40%**.[361] This scarcity threatens **food security, economic stability**, and **human health**. Additionally, the world is experiencing an alarming rate of **biodiversity decline**, with **over a quarter of all known plant and animal species threatened with extinction**, primarily due to human activities such as large-scale agriculture and overexploitation of natural resources.[362] These environmental stresses can **exacerbate geopolitical tensions**, particularly in transboundary regions where shared resources become points of contention. The **World Bank** emphasises that **effective transboundary water management** is crucial for **sustainable development and peace**.[363] Given the current trajectory, these issues are expected to **intensify**, placing **global resource management** as a critical societal concern in the **long term**.

[353] WEF (2024:2); Material Economics (2019).
[354] European Commission (2023:3).
[355] OECD (2024:8).
[356] Hafner M, Tagliapietra S (2020); IRENA (2024:3).
[357] Grynspan R. (2024).
[358] EESC (2022).
[359] IEA (2024:6).
[360] Sarpong, S. (2021); Kyem, P.A.K. (2021); Ratner, B.D., Meinzen-Dick, R., May, C. and Haglund, E. (2013).
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[363] United Nations. (2023:2).

SOCIETAL TRENDS IN SUSTAINABILITY

Long-term (2040 and beyond) – 2/2

Trend	Description
4.3.4 Global environmental governance[364]	**Strengthening environmental governance** at national and international levels is essential for addressing complex sustainability challenges. **Enhancing international climate agreements**, such as the Paris Agreement, is crucial to effectively combat climate change and promote sustainable development. However, challenges persist, including the **fragmentation of environmental policies** and the need for **coordinated action** among nations. The OECD highlights that better regulation is necessary to meet present and future environmental challenges, advocating for an inclusive, cooperative, outcome-based, and global approach to regulating.[365] Given the complexity and scale of these challenges, **significant advancements in global environmental governance are anticipated in the long term (2040 and beyond)**. This extended timeframe allows for the development and implementation of comprehensive policies, fostering international cooperation, and ensuring effective enforcement mechanisms to achieve sustainability goals.
4.3.5 AI governance and foresight[366]	The implementation of **AI governance and foresight** is crucial for understanding AI's impact on sustainability, encompassing **social, ethical, political, and economic dimensions**. Effective governance frameworks can **mitigate risks** such as **algorithmic bias, data privacy concerns, and job displacement**, while promoting **responsible AI development** that aligns with **human rights and equity principles**. The **OECD's AI principles** advocate for a **human-centric approach**, emphasising **transparency and accountability** in AI systems.[367] Similarly, **UNESCO's recommendation on the ethics of Artificial Intelligence** emphasises the importance of **ethical AI governance** to prevent exacerbating inequalities and ensure AI contributes positively to sustainable development goals. The recommendation outlines principles such as **human-centered values, fairness, and accountability**, aiming to guide the ethical development and deployment of AI globally.[368] Given the rapid evolution of AI technologies, establishing **robust governance mechanisms** is essential to harness AI's potential for societal benefit. Considering the complexity and global nature of AI governance, its comprehensive implementation is anticipated in the **long term (2040 and beyond)**, allowing time to develop and harmonise **international policies and ethical standards**.

[364] IISD (2024)
[365] OECD (2023:3).
[366] van Wynsberghe, A. (2021); WEF (2024:3).
[367] OECD (2024:9); Russo L., Oder N. (2023).
[368] UNESCO (2022).

6/ Conclusion: Navigating the future of sustainability

The "*Future of sustainability*" report highlights a complex and dynamic landscape where countless sustainability trends are unfolding simultaneously, interacting and amplifying one another across environmental, social, technological, and economic dimensions. This interrelated web of trends creates an operating environment for decision-makers that is both challenging and transformative. The pace of change is rapid, the stakes are high, and the need for decisive, strategic action has never been greater.

The challenge of a radically changing landscape

In this radically changing environment, many businesses and public organisations are still anchored in a business-as-usual approach, struggling to adapt to the evolving realities. This mindset is increasingly at odds with a world where sustainability is no longer optional but fundamental. Companies that fail to recognise and respond to this paradigm shift risk not only their competitive edge but, in many cases, their very survival or relevance. Similarly, public institutions that lag in creating frameworks to address sustainability imperatives may hinder societal progress, undermining global efforts to secure a viable future.

For decision-makers in all sectors, the challenge lies in keeping pace with the sheer volume and complexity of trends. It is easy to become overwhelmed or distracted by the "noise," losing sight of the key trends that will have the most significant and existential impacts. This is why understanding the big picture and focusing on the most critical elements is essential.

The path forward: Strategic clarity and action

To navigate this complex landscape, decision-makers in both business and public organisations must adopt a strategically centred approach to materiality analysis. This involves identifying and prioritising the sustainability trends that are most relevant and existential for their organisation or society at large. By doing so, they can allocate resources effectively, align efforts with long-term goals, and ensure that they are addressing the most pressing challenges and opportunities.

For **business leaders**, this means incorporating key sustainability trends into their organisation's short-, mid-, and long-term strategic direction. Decision-makers must:	For **public decision-makers**, the emphasis should be on crafting policies and frameworks that enable businesses and societies to thrive in a sustainability-first world. Governments and public institutions must:
1. **Understand the landscape** Develop a deep understanding of how sustainability trends are shaping their industry, markets, and stakeholders. 2. **Prioritise key trends** Focus on the trends that have the greatest potential to impact their operations, risk profile, and value creation. 3. **Integrate into strategy** Embed these insights into their strategic planning processes, ensuring that sustainability is a core component of their decision-making.	1. **Establish clear regulations** Define ambitious yet achievable sustainability goals, supported by clear regulatory frameworks that provide guidance and accountability. 2. **Incentivise innovation** Support research, development, and deployment of technologies and practices that advance sustainability. 3. **Foster collaboration** Facilitate partnerships between private, public, and civil society actors to align efforts and resources.

A call to action for all

For **individuals**, the journey toward a sustainable future begins with awareness and engagement. Each person has a role to play in driving change, whether as a consumer, employee, or citizen. By making informed choices, advocating for sustainability, and holding organisations and governments accountable, individuals can be powerful agents of transformation.

The existential threats posed by many sustainability trends underscore the urgency of adopting a sustainability-first mindset. This is not just about reducing risks but also about seizing opportunities to create a future that is resilient, equitable, and prosperous. By acting strategically and decisively, we can collectively rise to the challenges of this critical moment and shape a sustainable future for generations to come.

Closing thoughts

The "Future of sustainability" is not a distant concept, it is unfolding now. The choices made by decision-makers today will define the trajectory of businesses, societies, and the planet for decades to come. This report calls upon all stakeholders to embrace the complexity of the sustainability landscape and to act with clarity, purpose, and urgency. Only through a unified and strategic approach can we navigate the challenges ahead and build a world that thrives within the limits of our planet.

Appendices

Appendix 1: How to read the sustainability trend radar

The sustainability trend radar is a visual tool designed to map and analyse emerging sustainability trends across four key categories (technological, societal, environmental, and economic) and three distinct time horizons: short-term (now to 2030), mid-term (2030–2040), and long-term (2040 and beyond). It provides a structured framework to identify, understand, and anticipate the transformative forces shaping our transition toward a sustainable future.

Key components of the radar

1. Categories (sectors)

- **Technological trends:** Represent advancements in technologies that drive innovation and enable sustainable practices, such as renewable energy systems, artificial intelligence, or green hydrogen.
- **Societal trends:** Reflect shifts in societal values, behaviours, and demographics, including the rise of ethical consumption, social equity movements, or urbanisation patterns.
- **Environmental trends:** Highlight changes in the natural environment and ecological systems, such as climate adaptation strategies, biodiversity loss, or circular economy principles.
- **Economic trends:** Focus on changes in economic models, financial systems, and markets, such as the rise of sustainable finance, decarbonisation, or regenerative business models.

2. Time horizons (concentric circles)

- **Short-term (now to 2030):** Trends within this horizon are either currently having a significant impact or are expected to do so imminently. These are often the most actionable trends today.
- **Mid-term (2030–2040):** Trends in this horizon represent developments that require additional time to mature and create substantial impact. These are crucial for medium-term strategy and planning.
- **Long-term (2040 and Beyond):** Trends mapped here are those likely to emerge as major drivers of change in the distant future. While they may have limited immediate relevance, they represent critical areas for long-term foresight and innovation.

3. **Trend placement (Mapped points)**

- Each trend is placed within the radar based on the category it aligns with and the time horizon when it is expected to create the biggest impact. While some trends may already be observable today, their full implications may unfold only in future time frames.

Interpreting the radar

1. **Understand the categories**

Each quadrant represents a category of trends. Trends mapped into the technological quadrant, for instance, focus on innovations and emerging technologies. Similarly, trends in the economic quadrant reflect shifts in financial systems, economic models, or market dynamics.

2. **Identify time horizons**

The proximity of a trend to the centre indicates the time horizon of its peak impact:

- Trends closer to the centre (short-term) demand immediate attention and action.
- Trends further out (mid-term and long-term) signal areas requiring strategic foresight and preparatory investments.

3. **Analyse convergences**

Look for overlapping or intersecting trends across categories. These intersections often indicate areas of systemic change or potential for synergistic solutions. For example, a societal trend like ethical consumption may intersect with a technological trend like traceability solutions, creating opportunities for innovation.

4. **Prioritise action**

Use the radar to prioritise actions based on your organisation's goals and timelines:

- Focus on short-term trends for immediate implementation.
- Build strategies around mid-term trends to stay competitive as they mature.
- Invest in research and exploration for long-term trends to position yourself ahead of the curve.

Practical applications of the radar

- **Strategic planning:** Use the radar to align sustainability strategies with anticipated trends across all time horizons.
- **Innovation and R&D:** Identify areas for technological investment and development based on future needs.
- **Risk management:** Anticipate disruptions and prepare for emerging challenges by monitoring long-term trends.
- **Stakeholder engagement:** Communicate future-oriented sustainability goals with stakeholders using the radar as a visual reference.

By providing a structured overview of sustainability trends and their timelines, the sustainability trend radar serves as a powerful tool for navigating the complexities of the transition to a more sustainable future. Use it to stay ahead of the curve, leverage emerging opportunities, and drive impactful change.

Appendix 2: Methodology: Identification of emerging trends in sustainability using LLMs

Objective

This exercise aims to identify the emerging trends in the future of sustainability through large-scale textual analysis by LLMs. Given the vast amount of information available, this experiment focuses on data from the most reputable sources, including top consultancies and major global institutions.

Method

Identification of the sources:

1. Compile a list of the top 50 consultancies and major global organisations (e.g. OECD) recognised for their work on sustainability.

Data collection:

1. Scrape top 25 links within each identified domain that focus on sustainability-related content.
2. Scrape 100 links from 10 selected consultancies to ensure comprehensive coverage of sustainability -related content.
3. Collect data from webpages and download any PDF documents linked within the scraped pages for further analysis.
4. Include the last update date of data sources to ensure the discussion reflects recent trends.

Text processing and preparation:

1. Utilise Retrieval-Augmented Generation (RAG) for processing the collected text and documents.
2. Fine-tune RAG parameters to optimise retrieval and generation workflows.

1. Embedding and context retrieval:

- Generate text embeddings to represent the data in vector form.
- Implement context retrieval using auto-merging retrievers to enhance the relevance of retrieved information.

2. Prompt engineering:

- Design and refine prompts to guide the LLM in identifying and summarising sustainability trends.
- Structure the prompts to explore previously identified trends (including 80 trends) and uncover new trends described in the collected text.

3. Final output

- Synthesise the insights into an actionalble summary, highlighting the primary sustainability trends identified from the analysis.

Challenges

LLM model selection: The choice of LLM significantly impacts the final output.
Granularity of trends: Identified trends may vary in granularity. For instance, a broad trend like environmental conservation could encompass sub-trends such as biodiversity, natural resource preservation and pollution reduction. These sub-trends may appear separately when using other methodologies.
Overlap among trends: Overlaps between indentified trends may require manual review and sanity checks to ensure clarity.

Appendix 3: References

The big picture: The future of sustainability

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