

The background of the slide features a scenic coastal landscape at sunset or sunrise. A person is standing on a grassy cliff edge, facing away from the camera, and is holding a large, grey, three-dimensional paper airplane. The airplane has a long tail and wings. The ocean waves are visible in the distance under a warm, golden sky.

ISO Standardization
Foresight Framework

Trend Report
2022

⌚ Foreword

The future has begun.

⌚ Society

Age groups | Consumption | Movement of people | Prosperity | Tech risks | The changing nature of work

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Foreword

The future has begun.

The world around us is changing and the pace of change is faster than ever before. The future has begun and those who don't want to get left behind must ensure their ability to look ahead. That is why ISO has developed a Standardization Foresight Framework; to help us look more systematically at the long-term and to encourage discussion and exchange within the ISO system about future opportunities for International Standardization.

This trend report is the output of the first phase of the *Standardization Foresight Framework: environmental scanning*. It is designed to support the ISO community to navigate global trends as we work towards achieving the goals and priorities of the [ISO Strategy 2030](#).

In this report, we expand upon the [drivers of change](#) identified in the Strategy, breaking them down into smaller trends and analyzing their links to existing ISO work. Our ultimate aim is to better understand the context in which we operate, so that ISO can effectively meet emerging-market needs and help to shape a more sustainable future.



In this report, we expand upon the [drivers of change](#) identified in the Strategy, breaking them down into smaller trends and analyzing their links to existing ISO work.

Many of the future trends in this report will be familiar. Readers will recognize, for example, the climate emergency, accelerating and converging technologies, shifting geopolitical and economic power, changing demographics and evolving consumer preferences. Although the content may not come as a surprise, we hope that pulling together this information will provide readers with a new, macro perspective on the world around us and standardization's place in it. This broad perspective should help to inform strategy and decision-making.

The selected trends and STEEPS classification

This trend report does not claim to be all-encompassing – the trends presented here are high-level and have been selected because of their relevance to standardization or to the international landscape within which ISO operates. They are long-term driving forces that are already having a visible impact at the global level. Specific events, such as the COVID-19 pandemic or the conflict in Ukraine, are generally not mentioned at this level, although an understanding of the trends presented here can help us to better grasp the context of these events and think more broadly about their potential long-term consequences.

Taking inspiration from the [STEEPS analysis](#), which is a tool used in strategy to evaluate the external factors impacting an organization (also known as PEST or PESTLE analysis), we have chosen to classify our selected trends using the STEEPS categories of:

SOCIETY, TECHNOLOGY, ENVIRONMENT, ECONOMY, POLITICS and SCIENCE.

Convergence

Above all, what emerges clearly from the trend descriptions in this report is the high degree of convergence and interlinkages between trends. Societal trends are inextricably linked to technological advances, which are themselves affected by economic and political trends, and so on. Many future challenges will arise at the intersections of these trends, as domains that were once distinct from one another – such as biology and information technology – become increasingly intertwined. What could this mean for standardization?



How to explore this trend report

Within the high-level STEEPS categories, trends have been grouped into 15 sub-categories. The trends can be browsed in any order, according to interest.

Every trend includes an overall description, a list of ISO committees and key standards related to the trend (if any), and links to other ISO resources such as news stories or publications.

For a more interactive experience and easier access to links to committees and resources, we invite you to consult the Web version of the report: <https://www.iso.org/foresight.html>. On the Website, the trend report can be explored by clicking on the sunburst chart and an additional interactive chart allows you to visualize linkages between the trends.



We invite you to consult the web version of the report: [iso.org/foresight.html](https://www.iso.org/foresight.html)



Research and methodology

The contents of this report are the result of an environmental scanning process implemented by the ISO Central Secretariat (ISO/CS) Research and Innovation Unit (R&I).¹

In order to identify the list of trends relevant for standardization, the R&I team selected and reviewed publicly available trend reports from a wide variety of organizations (including governments, international organizations, think tanks, Non-Governmental Organizations (NGOs), research institutes and consulting firms).²

To be selected for review, the trend reports had to meet a series of criteria: less than five years old, published by a reputable source (no ideological bias and no profit motive), include references and a clear methodology for identifying and investigating trends, and be regional or global in focus. The trends chosen for inclusion in this report were those that featured most frequently across these publications and/or those that had a strong link to standardization, as revealed by mapping the trends to ISO's current and planned technical activities.

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1. The methodology was developed as part of the elaboration of the ISO Standardization Foresight Framework, in collaboration with foresight experts from Future Impacts, <https://future-impacts.de>
 2. These sources are referenced in the trend report.



Society

- Age groups
- Consumption
- Movement of people
- Prosperity
- Tech risks
- The changing nature of work

Age groups

Ageing population | Young generation influences

These trends are about demographic changes at both ends of the spectrum. Overall, the world's population is growing older, but there are nevertheless some regions where growing young populations will have significant impacts. While ageing populations will have implications for the sustainability of public financing models and healthcare, growing young populations will have implications for political behaviours and education systems. Both trends will profoundly affect workforce and employment models.

Ageing population

Populations are ageing in most countries in the world.³ Population ageing describes an increase in the size of a country's population over a certain age. Generally, the cut-off for analyzing growth in the 'old age' group is 65 years. That is, people considered to be of 'old age' are aged 65 and over. For years now, increases in the proportion of populations aged 65 and over have occurred in most countries. Population ageing occurs as a result of multiple factors:

- **Increase in average life expectancy:** Average life expectancy is generally calculated as 'life expectancy at birth'. Life expectancy can be increased by decreasing child mortality; improvements in overall population health; the elimination of diseases that contribute to premature deaths; and increased access to healthcare and other factors. In many countries, life expectancy has increased with economic development.⁴

3. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

4. Asia Pacific Megatrends 2040 (Commonwealth Scientific and Industrial Research Organisation, 2019)



Related trends: Diversifying inequalities, Gene editing, Increasing migration, Reinventing the workplace, Urbanization

In developed regions, life expectancies are increasing by about two months per year. This adds about five years to the average person's lifespan per generation (all other factors being equal).⁵ By 2040, average life expectancy will be above 80 in 59 countries⁶; in 2050, the global average life expectancy will be 76.⁷

- **Low fertility rates:** If people do not have enough children to 'replace' the population, older age groups can start to outnumber younger age groups.
- **Reduced migration:** Migration generally brings young, working-age people into a population. If migration is reduced, the proportion of the population in those age groups may grow less.

Although every country will experience an increase in its average age over the next few decades, the balance of forces driving this trend will differ from country to country.

While population ageing started in high-income countries (for example in Japan 30% of the population is already over 60 years old), it is now low- and middle-income countries that are experiencing the greatest change. By 2050, two-thirds of the world's population over 60 years will live in low- and middle-income countries.⁸ In developing countries, populations can 'age before they grow rich'^{9,10}, leading to challenging strains on public resources.

The number of people reaching working age during the coming decades will be significantly lower than in the preceding decades.¹¹ The size of the working age population relative to the population of retirees is called the 'dependency ratio'. It is likely that by 2050, the dependency ratio will be below 2:1 in 35 countries around the world. Conversely, the dependency ratio is expected to improve in many African countries and parts of Asia.

5. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)
6. Future possibilities report 2020 (UAE Government, 2020)
7. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)
8. Ageing and health (World Health Organization, 2021)
9. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)
10. Latin America and the Caribbean 2030. Future scenarios (Inter-American Development Bank, 2016)
11. Global trends. Paradox of progress (US National Intelligence Council, 2017)



Migration can be an important contributor to increasing the dependency ratio in an otherwise ageing population.¹² In many countries, migration is already an important factor in maintaining a working population that can meet the needs of the ageing population.¹³ Immigration policies, particularly in developed countries, will need to balance a growing demand for workers with internal political tensions in the future.¹⁴

While some older people will require care and support, older populations in general are very diverse and make multiple contributions to families, communities, and society more broadly. Yet the extent of these opportunities and contributions depends heavily on one factor: health. Supportive physical and social environments enable people to do what is important to them, despite losses in capacity.

At a societal level, this trend has implications for:

- **Workforce:** As people stay in the workforce for longer, companies may need to reimagine workload design, talent management and approaches to training and skilling workers.¹⁵ Some countries are already increasing retirement ages.¹⁶ We can expect that workers may approach their careers differently, with more 'portfolio careers' and life-long learning.¹⁷
- **Healthcare:** Older people may require more and different types of healthcare as they live longer within the period of life associated with declining health.¹⁸ A goal for many countries in the future will be 'morbidity compression' – the reduction of ill health to the last few years of life.¹⁹
- **Consumer trends:** Older adults, especially those with longer periods of retirement after exiting the workforce, may have specific '**Consumption**' patterns. These may include mobility, safety, and medical products, but also increased tourism, leisure, and spending.²⁰ Opportunities are expected in the

12. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)
13. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
14. [Global risks 2035 update. Decline or new renaissance?](#) (Atlantic Council, 2019)
15. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)
16. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)
17. [Future possibilities report 2020](#) (UAE Government, 2020)
18. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)
19. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
20. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)



'wellbeing economy' and '[The experience economy](#)' as the lifestyles and tastes of older consumers change.²¹ While reduced spending in retirement can contribute to slowed economic growth²², the global spending power of people over 60 is expected to have reached USD 15 trillion by 2020 and will continue to grow.²³

- **Physical and social environments:** Age friendly communities that offer safe and accessible public buildings and transport, places that are easy to walk around and opportunities for social interaction help older people to maintain their quality of life and contribute to their families and communities.

21. [Future possibilities report 2020 \(UAE Government, 2020\)](#)

22. [Global Strategic Trends. The future starts today \(UK Ministry of Defence, 2018\)](#)

23. [Future possibilities report 2020 \(UAE Government, 2020\)](#)



Relevant ISO technical committees and standards

→ ISO/TC 314, Ageing societies

- ISO 25550:2022, Ageing societies – General requirements and guidelines for an age-inclusive workforce
- ISO 25551:2021, Ageing societies – General requirements and guidelines for carer-inclusive organizations
- ISO 25552:2022, Ageing societies – Framework for dementia-inclusive communities
- ISO/WD 25554, Ageing societies – Guidelines for promoting wellbeing in local communities and organizations
- ISO/AWI TR 25555, Ageing society – Accessibility and usability considerations for home-based healthcare products, related services and environments

→ ISO/TMBG, Technical Management Board - groups

- IWA 18:2016, Framework for integrated community-based life-long health and care services in aged societies



Relevant ISO news stories

- ISO - Growing old gracefully with a new ISO technical committee for ageing societies
- ISO - Keeping up with ageing societies
- ISO - Enjoy retirement thanks to ISO 9001
- ISO - How to adapt to ageing societies
- ISO - The silver economy
- ISO - New framework helps communities adapt to ageing populations
- ISO - Active ageing



Young generation influences

While ageing populations will be an area of focus for many countries, the influences of younger generations will also create challenges and opportunities. Younger population groups will have an influence on workforces, the economy and demand for products and services. Young populations are of particular importance in sub-Saharan Africa, where half of the citizens will still be under 21 years of age by 2035.²⁴

Young people from all economic and cultural backgrounds are increasingly interacting in online spaces. They are both influencing and being influenced by a global spectrum of ideas, trends, opinions, and advertising.²⁵ These younger generations will pose challenges to governments, in their increasing political engagement, and to businesses, as their over-exposure to advertising leads to more sophisticated purchasing decisions. Many people see younger generations as having strong opinions around climate change, political issues, and social injustices.²⁶

The influence of educated and tech-savvy young people in the world of work will require responsive talent management and creative thinking about staff development and career opportunities.²⁷ The employment opportunities of today's youth have been affected by successive financial crises.

Related trends: Artificial intelligence, Spread of the Internet, Sustainable production

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- 24. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)
 - 25. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
 - 26. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)
 - 27. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)



Some suggest that traditional education systems have insufficiently prepared young people for increasingly technology-focused and/or knowledge-based work.²⁸ Young people may be negatively affected by changes in the employment market due to increasing use of technology and changes in consumer habits, leading to challenges in building economic capital.²⁹

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28. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)
29. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)



Consumption

The experience economy | Sustainable production | Customized products

Consumer attitudes and preferences are constantly changing as a result of megatrends, such as increasing 'Connectivity', 'Environmental degradation', demographic changes, shifting inequalities, and more. The trends described below are some of the more long-term driving forces that are affecting how companies think about value creation today – it is no longer just about the final product, but about the inputs that went into it along the whole value chain, how that product is produced, and how unique it is (tailored to a specific customer's needs). Indeed, it may no longer be about a product at all, as consumers move away from wanting 'things' to wanting experiences that bring them personal growth and more than material satisfaction. Given that consumer spending drives such a large part of the global economy, these consumption related trends have wide-ranging impacts and will affect many of the other trends featured in this report.



The experience economy

The growth of the experience economy reflects people's increasing desire to 'experience' rather than 'consume'; to 'do' rather than to 'have'. It is about generating memorable events that are personal and unique and have an important emotional impact. The experience economy is especially evident in the travel and tourism sector, where "*Travelers today are increasingly drawn to travel as a form of self-actualization and personal transformation and growth. They want more than a simple visit to a new destination or days spent relaxing on a beach. Instead, the travel they are seeking is an experience of the world that goes deep – one that changes them in ways they may not even be aware of.*"³⁰

30. Skift trends report. The rise of transformative travel (Skift, 2018)

Related trends: Extended reality, New business models, Rise of the middle class, Services moving online, Spread of the Internet, Sustainable production

There are several possible explanations for the growth of the experience economy. Some see it as a reaction to the increasingly digital nature of our lives – in a world where we are always connected and spend so much time interacting in cyberspace, the marginal value of the physical world increases. We may no longer *need* to go to a physical shop, office, or restaurant but we choose to do so because of the value of experiencing social interactions and different environments. In the same way, we seek out more in-person experiences and greater cultural participation, rather than simply the acquisition of more ‘stuff’.³¹

Others understand the experience economy trend as a natural progression in attitudes to consumption for the growing middle classes who may have reached ‘peak stuff’. As wealth increases, there comes a point where material status symbols become less attractive compared to services and experiences that can lead to ‘self-actualization’ by helping people achieve their aspirations.³² Some people even speak of a ‘transformation economy’ emerging, where experiences are no longer about enjoyment, but about personal transformation. Increasingly, these experiences are facilitated by new technologies (e.g. 4D cinema, virtual reality), especially since the COVID-19 pandemic.

Yet another perspective is that the experience economy is, in part, a reaction to increasing societal concern about sustainability and ‘Environmental degradation’ (see ‘Sustainable production’).

People looking to consume less are driving the growth of the sharing economy, and the rise of rent and subscription models for things (from furniture to cars and even clothes) and services (from transport to accommodation).³³ These models allow consumers to experience/use products without owning them, and to enjoy more interactive services usually linked to an idea of greater authenticity and responsibility.

Overall, what this means is an important shift in economic value-generation, from products to services, and an imperative for producers/retailers to rethink how they provide customer experiences and create a service culture. This includes using new technologies (albeit with the caveat that technological developments must support the provision of personalized service and people’s desire for emotion and intimacy, not replace them).

31. Digital megatrends. A perspective on the coming decade of digital disruption (Commonwealth Scientific and Industrial Research Organisation, 2019)

32. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

33. Future possibilities report 2020 (UAE Government, 2020)



Relevant ISO technical committees and standards

- ⇒ ISO/TC 228, *Tourism and related services*
 - ISO/DIS 3163, *Adventure tourism – Terminology*
- ⇒ ISO/TC 312, *Excellence in service*
 - ISO/TS 24082:2021, *Service excellence – Designing excellent service to achieve outstanding customer experiences*



Relevant ISO news stories

- ISO - Excellence in customer service
- ISO - Pushing the tourism limits



Sustainable production

Consumers are becoming more environmentally aware and more empowered. Studies show that around 65% of consumers are willing to pay more for products/services that are environmentally friendly and socially responsible, and they also increasingly expect companies to pay attention to the environment and be transparent about their behaviours.³⁴ This sentiment is especially strong amongst the younger generations and is predicted to grow.

At the same time, governments are putting pressure on industry through environmental regulations, as they reflect the growing environmental concerns of their electorates and put in place policies to help them achieve their commitments to the UN Sustainable Development Goals (SDGs).

As a result, 'going green' has become an important business strategy and increasingly, companies are redesigning their business models to be more environmentally friendly and sustainable. This includes adopting life cycle models such as cradle-to-cradle (circular economy), sharing economy or peer-to-peer economic models (see '[New business models](#)'), reducing emissions and creating shorter supply chains.^{35,36} And it is not just about reputation and marketing – companies also adopt sustainable business models to foster innovation, improve operational efficiency, and lower costs.

While this trend of increasing demand for eco-friendly and sustainable products has been evident (and growing) for many years now, a more recent countertrend of climate

Related trends: [Additive manufacturing](#), [Natural resource scarcity](#), [New business models](#), [New generation plastics](#), [Threatened ecosystems](#)

34. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)

35. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

36. [Global trends 2020. Understanding complexity](#) (Ipsos, 2020)



scepticism and fatigue/jadedness with environmentalism is now becoming evident. Older generations, in particular, do not trust what scientists say on environmental issues (53% of 60-74-year-olds compared to 39% of 16-24-year-olds). Climate-denying attitudes appear linked to the rise of populism in many societies.³⁷

Relevant ISO technical committees and standards

→ ISO/TC 34, Food products

- ISO 34101-3:2019, Sustainable and traceable cocoa – Part 3: Requirements for traceability

→ ISO/TC 189, Ceramic tile

- ISO 17889-1:2021, Ceramic tiling systems – Sustainability for ceramic tiles and installation materials – Part 1: Specification for ceramic tiles
- ISO/DIS 17889-2, Ceramic tiling systems – Sustainability for ceramic tiles and installation materials – Part 2: Specification for tile installation materials

→ ISO/TC 207/SC 3, Environmental labelling

- ISO 14020:2000, Environmental labels and declarations – General principles

→ ISO/TMBG, Technical Management Board – groups

- ISO/TMBG/SAG_ESG, Strategic Advisory Group on Environmental, Social, Governance (ESG) Ecosystem
- ISO 20400:2017, Sustainable procurement



Relevant ISO news stories

- ISO - Responsible Consumption and Production
- ISO - Food for the future
- ISO - Paving the way to a more sustainable world
- ISO - Food, Feed, Fibre
- ISO - Raising the bar on sustainable consumption

37. Global trends 2020. Understanding complexity (Ipsos, 2020)

Customized products

Personalization of the customer experience has been a growing trend for some years now. One clear example of this is in the digital world, where, for example, services offered by Google, Facebook, YouTube, Apple, etc. curate searches, news feeds, products, advertisements and more based on a user's personal history of searches, purchases, and online interactions.³⁸ Digital platforms and the increased connectivity of customers also offer customization of physical goods – through digital platforms, customers have products and services available at their fingertips and the digital medium allows them to specify instantly and conveniently what they want, providing feedback to companies on what to produce.

Technological advances in 'Additive manufacturing' (3D printing), machine learning and the 'Internet of Things' (IoT) will likely accelerate this trend, reducing the cost to businesses of customizing their products and services. This affects business models (most companies already view customization as a strategic priority and may move away from mass manufacturing models)³⁹ and could also affect global value chains (which need to become shorter and more flexible, leading to changes in the nature of goods being shipped and the move of production closer to markets).⁴⁰

While some industry surveys show that demand for customization and personalization is high, for example, 67% of respondents in a survey run by Adobe said customized content

Related trends: **Additive manufacturing, Artificial intelligence, Changing trade patterns, Data privacy, Rise of the middle class, Robotics, Spread of the Internet**

38. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

39. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)

40. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)



was important and 42% said impersonalized content annoys them⁴¹, there are also significant concerns about '**Data privacy**' and security (commercial use of personal data). The respondents had other concerns, notably an individual lack of agency (people feeling their experiences are determined for them without their knowledge) and the creation of group and individual 'echo chambers', i.e. recommendation systems only showing people content that confirms their existing beliefs/preferences, possibly leading to increasingly radicalized content, spreading of misinformation, and conspiracy theories.⁴² The continued trajectory of this trend will depend partly on the ability of companies to maintain consumer agency and trust.

Relevant ISO technical committees and standards

⇒ **ISO/TC 133, Clothing sizing systems – size designation, size measurement methods and digital fittings**

- [ISO/DTS 3736-2, Digital fitting – Service procedure – Part 2: Customized clothing online and off-line](#)

⇒ **ISO/TC 261, Additive manufacturing**

- [ISO/ASTM 52900:2021, Additive manufacturing – General principles – Fundamentals and vocabulary](#)
- [ISO/ASTM 52910:2018, Additive manufacturing – Design – Requirements, guidelines and recommendations](#)



Relevant ISO news stories

- [ISO - Paving the way to a more sustainable world](#)

41. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)

42. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)



Movement of people

Urbanization | Increasing migration

Whether within or between countries, by choice or by force, these trends demonstrate that people are definitely on the move. As the global population grows, so do rates of urbanization and migration, with potentially significant social, political, and environmental implications (see 'Age groups').

There is a multitude of factors pushing people to move, including economic development, conflict, political instability and, increasingly, the impacts of climate change. More people live outside their country of birth than ever before and many of them end up in cities, which are growing in number, in size and in importance. Indeed, the power of cities as economic and social centres could potentially see them overtake countries as the dominant political entities in future (see 'Changing trade pattern'). If managed well, urban centres will foster social and economic development and more sustainable living. But in places where the pace of growth outstrips the resources to support it, this trend could compound social inequalities and lead to greater conflict.

Urbanization

Increasingly, people are moving from rural areas to cities, resulting in significant growth in urban populations. People are seeking the economic opportunities and increased quality of life that living in cities can offer. It is expected that 70% of the world's population will live in cities by 2045.⁴³

43. Future Outlook: 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)



Related trends: Ageing population, Autonomous vehicles, Increased migration, Internet of Things, Multipolarity, Rise of the middle class, Smart cities, Threatened ecosystems



For individuals, urban life can offer many opportunities: improved access to services like education and healthcare, daily conveniences offered by urban infrastructure and access to broader job markets. The benefits for society as a whole are significant: cities are associated with economic growth⁴⁴, wealth generation and innovation.⁴⁵ Cities are extremely productive and contribute more than 80% of global gross domestic product (GDP).⁴⁶

For cities, increased population inflows can create strain on resources and challenges for city planners and resource managers.⁴⁷

Urbanization can be seen as a double-edged sword – it offers the possibility of increased social and economic development alongside the risk of compounding social inequity.⁴⁸

Particularly in the developing world, where urban planning has not anticipated substantial growth and resources are already stretched, increasing urbanization may create problems as well as opportunities in the coming decades. Historically, unplanned, or informal urban settlements have exacerbated inequalities⁴⁹, and in many countries, service provision in these areas is not keeping pace with urban population growth.⁵⁰ Rapid urbanization could lead to conflict in places where resources are insufficient and/or poorly managed⁵¹, but where it is well-managed it may yield significant benefits to urbanizing populations.⁵²

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- 44. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)
 - 45. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)
 - 46. [Beyond the Noise. The Megatrends of Tomorrow's world](#) (Deloitte, 2017)
 - 47. [African futures. Key trends to 2035](#) (Institute for Security Studies, 2017)
 - 48. [African futures. Key trends to 2035](#) (Institute for Security Studies, 2017)
 - 49. [African futures. Key trends to 2035](#) (Institute for Security Studies, 2017)
 - 50. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)
 - 51. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
 - 52. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)



Multiple city ‘types’ are expected to increase in number in the coming decades. Much of the attention around urbanization is focused on so-called ‘mega-cities’, usually defined as having populations of at least 10 million.^{53,54,55} While the number of mega-cities is expected to grow somewhat, the bulk of the growth in cities will occur in ‘small’ (under 1 million inhabitants), ‘medium’ sized (1-5 million inhabitants)⁵⁶ and ‘large’ (5-10 million inhabitants) cities.⁵⁷ *The World Bank*⁵⁸ offers a classification of large cities:

- **Global hubs:** Cities that wealth and talent flow through. Examples include Singapore, London, and New York.
- **Mega-cities:** Cities with large populations that are ‘population magnets’ for their respective regions. Examples include Mumbai, Sao Paolo, Jakarta.
- **Gateway cities:** Cities that function as part of regional clusters that facilitate access to specific markets. Examples include Dubai, Almaty, Johannesburg.

Thinking of these functions of cities raises interesting questions for city planners and for the role of cities in global trade, both physical and digital. According to the *European Strategy and Policy Analysis System*⁵⁹, “When we say 2030 will be urban, this is not merely an expression of residency, it will be the way of life of society as a whole.”

Perhaps paradoxically, cities can provide opportunities for increased sustainability and reduction of environmental impacts. While cities are expected to be responsible for 70% of global greenhouse gas emissions, they are also places where proactive and innovative environmental management and urban planning can yield substantial benefits. Higher density living allows for more coordination of waste management, innovative energy management, reduced reliance on cars for transport and efficient distribution of food and other resources. Public transit and sustainable transport options are a particular area of opportunity in terms of acting on the opportunities offered by increased urbanization.⁶⁰

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53. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
54. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)
55. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)
56. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
57. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)
58. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)
59. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
60. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)



Politically, urbanization can increase the power of local governments, leading to more localized decision-making and, perhaps, more empowerment of citizens.⁶¹ Cities have been described as 'virtual islands'; places where resource allocation and generation/distribution of power can be managed within a relatively closed system to the benefit of all.⁶² *The Inter-American Development Bank and the Inter-American Dialogue*⁶³ suggest we can look forward to a positive future in cities. Successful urban areas will be the ones that: improve services; enhance national and international connectivity (the Internet); ensure water and electricity supplies; raise levels of education and healthcare; anticipate adaptation to climate change plans and measures; consider greening cities; provide talent pools of technical specialists and other experts; secure efficient and reliable financial systems; cultivate cultural activity, and; provide citizens with two important benefits, i.e. an improved quality of life and increased productivity.

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- 61. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)
 - 62. [Future possibilities report 2020](#) (UAE Government, 2020)
 - 63. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)



Relevant ISO technical committees and standards

→ ISO/TC 268, Sustainable cities and communities

- ISO 37105:2019, Sustainable cities and communities – Descriptive framework for cities and communities
- ISO 37106:2021, Sustainable cities and communities – Guidance on establishing smart city operating models for sustainable communities
- ISO 37120:2018, Sustainable cities and communities – Indicators for city services and quality of life

→ ISO/TC 282/SC 2, Water reuse in urban areas

- ISO 20760-1:2018, Water reuse in urban areas – Guidelines for centralized water reuse system – Part 1: Design principle of a centralized water reuse system
- ISO 23070:2020, Water reuse in urban areas – Guidelines for reclaimed water treatment: Design principles of a RO treatment system of municipal wastewater

→ ISO/TC 297, Waste collection and transportation management

- ISO/DIS 24161, Waste collection and transportation management – Vocabulary
- ISO 24162:2022, Test method for energy consumption of refuse collection vehicles



Relevant ISO news stories

- ISO - Sustainable Cities and Communities
- ISO - How do we build sustainable cities of the future
- ISO - The future looks smart
- ISO - New ISO standard for urban resilience
- ISO - Writing the future on World Cities Day
- ISO - Stronger cities for the future: a new set of International Standards just out
- ISO - Solutions for today's urban challenges in the latest *ISOfocus*



Increasing migration

Internationally, people are on the move. Reduced costs of transportation, climate change and economic opportunities are all expected to drive increasing international migration in the coming decades.^{64,65,66,67}

While opportunistic migration has been common for some time, the effects of climate change are expected to prompt significant numbers of people to migrate internationally in the coming decades. In fact, the Intergovernmental Panel on Climate Change (IPCC) has noted that “the greatest single impact of climate change could be on human migration.”⁶⁸ The number of people displaced by conflict and political instability is also expected to increase.⁶⁹ More refugees moving along new and existing migration routes will have implications for public policy and international governance.

Economic development in the global south may also contribute to higher levels of international migration. While many assume that economic development will reduce the number of people emigrating in search of economic opportunities, in fact it is observed that economic growth leads to an initial *increase* in emigration, presumably as citizens are better educated and have more access to connectivity, transport and international job opportunities. Emigration tends to

Related trends: **Ageing population, Natural resource scarcity, Rise of the middle class, Threatened ecosystems, Urbanization**

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- 64. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)
 - 65. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)
 - 66. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)
 - 67. [Global trends 2020. Understanding complexity](#) (Ipsos, 2020)
 - 68. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)
 - 69. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)



reduce when a country is sufficiently developed that there are good opportunities for workers 'at home'.⁷⁰

For developed markets receiving migrants, this means access to an increased working-age population to support ageing societies.⁷¹ In many developed countries, migrants also help to slow the decline in population growth associated with lower fertility rates.⁷²

Companies can expect to have an increasingly mobile and diverse workforce available to them, while countries hosting migrants can enjoy the cultural benefits of diversity along with the economic benefits of an enlarged workforce.

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70. [Global risks 2035 update. Decline or new renaissance?](#) (Atlantic Council, 2019)
 71. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)
 72. [Global risks 2035 update. Decline or new renaissance?](#) (Atlantic Council, 2019)



Prosperity

Diversifying inequalities | Rise of the middle class | Stagnating happiness levels

The world is undoubtedly more prosperous today than it has ever been before. But the way that prosperity is shared across the globe is still far from equal and the trends that affect prosperity are far from simple. This is especially true if you consider the meaning of 'prosperity' to go beyond money, and include things like wellbeing and equality. Economic growth, demographic change and technological advances are just some of the complex forces driving these trends in prosperity.

Diversifying inequalities

Inequality is growing. While economic (income) inequality is often the focus of discussion, it is linked to many other types of inequality that are also on the rise, including gender, intergenerational, digital and racial/ethnic inequality.⁷³ This trend of 'diversifying inequalities' also has strong links to many other trends.

Although economic inequality between countries has reduced over the last 30 years (largely due to rapid economic growth in Asia), inequality *within* many countries has increased and is predicted to rise steeply in coming decades, if current trends continue.⁷⁴



Related trends: **Changing trade patterns, Effects of automation, Reinventing the workplace, Stagnating happiness levels, Urbanization**

73. The global risks report 2021 (World Economic Forum, 2021)

74. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

A number of interlinked factors will contribute to this rise, such as:

- slower and more volatile economic growth (compounded by high government debt, swings in financial and commodity markets and the threat of an uneven economic rebound after the COVID-19 crisis);
- potential job losses due to automation and shifts in the job market toward lower paid or more precarious employment (more freelancers, sharing economy, temporary workers and declining labour market protections);
- the impact of the technology sector exacerbating wealth concentration amongst those with the right skills and capital ownership (1% of the world's population may own two-thirds of global wealth by 2030, entrenching power in the hands of elites who will be less likely to implement economic reforms that will benefit the poor)⁷⁵; and
- population growth and mobility, particularly in developing countries (economic opportunities will be greater in urban areas, creating potential for growing urban slums and increasing urban/rural inequalities).

Not only is inequality growing, but awareness of it is growing, as increasing numbers of people gain access to the Internet and social media.

This growing inequality, together with heightened awareness, could lead to social fragmentation fuelled by perceived injustices. Discontent spurs protests and violent mobilization, increasing support for populist or nationalist leaders. It additionally leads to decreasing support for globalization and trade liberalization, which are seen as having created this situation of inequality. Crime increases in turn, as does the potential for religious radicalization.^{76,77}

75. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)

76. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

77. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)



Relevant ISO technical committees and standards

→ ISO/PC 337, *Guidelines for the promotion and implementation of gender equality*

- ISO/AWI 53800, *Guidelines for the promotion and implementation of gender equality*

→ ISO/TMB, *Technical Management Board*

- IWA 34:2021, *Women's entrepreneurship – Key definitions and general criteria*



Relevant ISO news stories

- ISO - Gender Equality
- ISO - Reduced Inequalities
- ISO - ISO raises the standard on gender equality
- ISO - ISO standards can help tackle global inequality, says UN Women expert



Rise of the middle class

The trend towards poverty reduction around the world has been ongoing for decades, in Europe for at least 50 years, and more recently in Asia and Latin America. In particular, extreme poverty (defined as living on less than USD 1.90/day) saw a huge decrease, from 36% of the world's population in 1990 to 10% in 2015.⁷⁸ Some reports predict that by 2030, the majority of the world's population will be middle class (defined as those falling between 67-200% of the median income in a country)⁷⁹, with the middle class in the Asia-Pacific growing at a tremendous rate, led by China and India. Indeed, by 2030, the Asia-Pacific region is forecast to be home to two-thirds of the global middle class, who will become the world's biggest spenders.⁸⁰

As people get richer, they can shift their focus from survival to enjoyment of life, progressively seeking better quality (and more) goods and services. The rising middle classes could become a key engine of economic growth in coming decades, as they consume higher quality goods, travel more, invest more and improve their education levels. With more purchasing power and more access to information, they may develop a stronger political voice and create pressure in many parts of the world to strengthen democratic processes and institutions.⁸¹

At the same time, however, this will also lead to increased consumption of energy (largely fossil fuels in Asia and Africa) and could exacerbate risks related to climate change and

Related trends: Customized products, Diversifying inequalities, Increasing migration, Natural resource scarcity, Stagnating happiness levels, The experience economy, Threatened ecosystems

78. [Poverty Overview](#) (World Bank, 2014)

79. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)

80. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

81. [Latin America and the Caribbean 2030. Future scenarios](#) (Inter-American Development Bank, 2016)



resource scarcity. Good governance, innovation and new technologies will be vital if we are to reconcile increasing middle class consumption and sustainability.

Of course, the economic downturn resulting from the COVID-19 pandemic has slowed progress in reducing poverty and stalled the expansion of the global middle class, so some of these predictions may have to be revised once the longer-term effects of the pandemic become clearer.⁸² In a more pessimistic scenario where economic slowdown is protracted, some predict that a frustrated middle class, fearing a backslide into poverty, may become a force for instability or a bastion of populism.



Relevant ISO news stories

- ISO - How standards can lead to better lives

82. The pandemic stalls growth in the global middle class, pushes poverty up sharply (Pew Research Center, 2021)



Stagnating happiness levels

People are becoming more prosperous overall as the global middle class grows, but this growth is mostly in developing countries. In developed countries, by contrast, middle class wages and employment could be threatened by increased automation and global competition in low-cost manufacturing (for example, McKinsey estimated that as of 2014, two-thirds of households in developed economies had real incomes at or below their 2005 levels).⁸³

Slow economic growth means that these citizens, who have come to expect regular rises in living standards over time, will no longer perceive any visible improvements, leading to public dissatisfaction, disappointment and stagnating happiness levels. As their societies also become more unequal, this dissatisfaction could even lead to social divisions and internal conflict.⁸⁴ At the same time, governments will find it increasingly difficult to fund rising welfare costs and investment in public services without sufficient economic growth.

In the absence of an economic miracle, governments will have to concentrate more on the other elements that can determine human happiness such as mental wellbeing and social connectivity.⁸⁵

Related trends: Diversifying inequalities, Rise of the middle class

83. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)

84. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

85. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)



Tech risks

Ethics of technology | Data privacy | Cyber-vulnerability

As technology becomes integrated into more aspects of our lives, the profile of risks associated with technology is also expanding. New advances in many kinds of technologies pose potentially significant ethical challenges (e.g. 'Artificial intelligence' (AI), 'Biotechnology', or decarbonization technologies). This coincides with our increasing use of these technologies, creating potential risks at a macro-level (e.g. cybersecurity of a nation's critical infrastructures) and at a micro-level (e.g. security of personal data and individuals' vulnerability to online manipulation). Such risks are certainly to be expected with the advent of disruptive technologies and they are the price we have to pay for the great benefits these technologies offer us; it is a question of how well we recognize and mitigate these risks so as to ensure that new technologies can be used for the benefit of all.



Ethics of technology

Many governments around the world are turning their attention to the ethics of technology and the implications of fast-developing technology for future societies.

Ethics related to the use of 'Artificial intelligence' for automated vehicles, automated decisions, and consumer interactions are topics that are frequently raised⁸⁶ and governments will increasingly be expected to address concerns around digital harm, disinformation, antitrust and foreign interference.⁸⁷ The AI-enabled technologies of the future must benefit

Related trends: Artificial intelligence, Autonomous vehicles, Data privacy, Gene editing, Natural resource scarcity, Robotics, Synthetic biology, Threatened ecosystems

86. Digital megatrends. A perspective on the coming decade of digital disruption (Commonwealth Scientific and Industrial Research Organisation, 2019)

87. The global risks report 2021 (World Economic Forum, 2021)



from effective ‘technical, legal, and ethical frameworks’, according to the UK Ministry of Defence.⁸⁸ Ethical questions are perhaps most critical in the area of militarized AI, and the use of technology in conflict. While machines could behave without regard for human suffering, they may also more accurately calculate the costs of conflict. Complexities can be expected to arise if countries develop conflicting ethical and legal frameworks for AI, both in military contexts and more broadly.⁸⁹ Other key ethical issues related to AI systems are about unwanted bias, eavesdropping, and safety, and industry is already busy trying to address these. The ISO/IEC committee working on AI (ISO/IEC JTC 1/SC 42) has collected 132 use cases for AI, including ethical considerations and societal concerns for each (for more details, see ISO/IEC TR 24030:2021, *Information technology – Artificial intelligence (AI) – Use cases*).

When considering the ethics of using AI, however, it is equally important to consider the ethics of *not* using AI. The risks of using AI are frequently discussed, but one question that is not addressed often enough is – when does it become unethical for us not to use AI? For example, if AI technology could predict the next pandemic or speed up vaccine development, one could argue that it would be unethical not to use this technology. There are plenty of examples like this, for

instance, a common question posed is: if an AI-enabled autonomous vehicle had to hit someone, who should it hit? But is this the right question if the proper use of AI-enabled autonomous driving can help save lives by reducing accidents overall?

Of course, AI is not the only emerging technology that could pose significant ethical challenges in the future. Advancements in biotechnology could – alone, or in combination with AI – lead to the creation of synthetic life forms or augmented human beings, with enhanced physical or cognitive abilities. How to regulate technologies that can fundamentally alter human capabilities or change the human gene pool “could prompt strident domestic and international battles” in coming decades (see ‘Gene editing’).⁹⁰ Even technological advances to treat diseases could engender political debates about the ethics of access (since treatments are likely to be available only to those who can afford them).⁹¹ Not to mention continued ethical debates about genetically engineered crops and foods and their potential ecological or health-related consequences.⁹²

As the climate crisis becomes more urgent, we may also soon face ethical issues related to the use of new technologies for

88. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

89. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

90. [Global trends. Paradox of Progress](#) (US National Intelligence Council, 2017)

91. [Global trends. Paradox of Progress](#) (US National Intelligence Council, 2017)

92. [Global trends 2040. A more contested world](#) (US National Intelligence Council, 2021)



decarbonization. While geoengineering technologies (carbon dioxide [CO₂] removal and solar-radiation management) have for many years been considered morally unacceptable, they are now gaining more attention as potential solutions of last resort.⁹³ Ethical concerns here range from distributive justice for future generations or vulnerable populations (negative effects of geoengineering actions could disproportionately affect some countries or populations e.g. by increasing drought in Africa and Asia), to procedural justice questions (who should decide to use these technologies and how?).

Relevant ISO technical committees and standards

- ④ ISO/IEC JTC 1/SC 42, Artificial intelligence
 - ISO/IEC DIS 23894, *Information technology – Artificial intelligence – Risk management*
 - ISO/IEC TR 24030:2021, *Information technology – Artificial intelligence (AI) – Use cases*
 - ISO/IEC DTR 24368, *Information technology – Artificial intelligence – Overview of ethical and societal concerns*
- ④ ISO/TC 241, Road traffic safety management systems
 - ISO/DIS 39003, *Road Traffic Safety (RTS) – Guidance on safety ethical considerations for autonomous vehicles*
- ④ ISO/CASCO, Committee on conformity assessment
 - ISO/TS 17033:2019, *Ethical claims and supporting information – Principles and requirements*



Relevant ISO news stories

- ISO - It's all about trust
- ISO - To ethicize or not to ethicize...
- ISO - Big plans for big data

93. Ethics of geoengineering (Viterbi Conversations in Ethics, 2021)

Data privacy

"Trust and accountability are the new litmus tests for businesses in a world where digital is everywhere."⁹⁴

In the future, will data privacy be a thing of the past? Many sources agree that there is a clear trend towards the progressive loss of privacy that accompanies new developments in technology. According to the UK Ministry of Defence, "In the coming decades, every facet of one's life is likely to be recorded by the ubiquitous presence of wearable devices, smart sensors and the 'Internet of Things'."⁹⁵ But at the same time, there is also a trend towards emphasizing privacy, for example, using privacy by design development. Once privacy-respecting technology is available, the market has the choice, and the global success of the European Union's General Data Protection Regulation (GDPR) principles is an indicator of this trend.⁹⁶

The use of biometric data, such as fingerprints and facial mapping, is increasing in both private (e.g. social media and personal technology products) and public (law enforcement and population surveillance) contexts.^{97,98} Consumer trust will be an increasingly important issue as technology becomes increasingly prolific in everyday activities. Already, a majority of consumers are wary of connected devices and fearful of misuse of their personal data.^{99,100}

Related trends: Artificial intelligence, Blockchain, Customized products, Cyber-vulnerability, Ethics of technology, Internet of Things

94. Technology vision 2020. We, the post-digital people (Accenture, 2020)

95. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

96. Two years of GDPR: Questions and answers (European Commission, 2020)

97. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)

98. 20 New technology trends we will see in the 2020s (BBC Science Focus Magazine, 2020)

99. Technology vision 2020. We, the post-digital people (Accenture, 2020)

100. Beyond the Noise. The Megatrends of Tomorrow's World (Deloitte, 2017)



Some even suggest there may be a ‘digital bubble’, the bursting of which will be due in part to privacy concerns – “Concerns about data privacy have called into question whether digital technologies will continue to grow at this rate.”¹⁰¹ At the same time, companies are adjusting to market conditions and, if the market demands privacy, industry will develop appropriate products.¹⁰² Industry needs to realize that privacy-respecting products are not much more expensive (if well done), but can instead provide a competitive advantage, since trust is a key decision factor for consumers faced with multiple options. Initiatives allowing the creation of ‘digital trust’, such as Yelp and Foursquare, are thus likely to grow in popularity.¹⁰³ Once society acknowledges that data has a value and therefore the data owner needs to be paid, a ‘new balance’ will be established. The question is, if and when such an acknowledgement may come...?

In the meantime, to reassure consumers, both government regulation and business leadership are necessary to establish privacy and data management standards that keep pace with emerging needs.¹⁰⁴ Indeed, this will be a growing consumer expectation.¹⁰⁵ Ultimately, it seems inevitably that technology will permeate almost everything we do and lead to enormous improvements in quality of life across society. However, these benefits will need to be carefully balanced with the accompanying risks to privacy and security.¹⁰⁶

101. [Beyond the Noise. The Megatrends of Tomorrow’s World](#) (Deloitte, 2017)

102. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)

103. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

104. [20 New technology trends we will see in the 2020s](#) (*BBC Science Focus Magazine*, 2020)

105. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)

106. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)



Relevant ISO technical committees and standards

- ISO/IEC JTC 1/SC 27, *Information security, cybersecurity and privacy protection*
 - ISO/IEC 27009:2020, *Information security, cybersecurity and privacy protection – Sector-specific application of ISO/IEC 27001 – Requirements*
 - ISO/IEC 27701:2019, *Security techniques – Extension to ISO/IEC 27001, and ISO/IEC 27002, for privacy information management – Requirements and guidelines*
- ISO/PC 317, *Consumer protection: privacy by design for consumer goods and services*
 - ISO/DIS 31700, *Consumer protection – Privacy by design for consumer goods and services*



Relevant ISO news stories

- ISO - Protecting privacy and consent online
- ISO - Safe, secure and private, whatever your business
- ISO - How Microsoft makes your data its priority
- ISO - Tackling privacy information management head on: first international standard just published
- ISO - Data privacy by design: a new standard ensures consumer privacy at every step



Cyber-vulnerability

Increasing reliance on technology and the proliferation of digital devices in daily life will create increasing risks related to 'Data privacy', cyberattacks, and consequences of system failure.^{107,108} The key factor for prevention is risk awareness and proactive risk mitigation.

New digital technologies present serious challenges for governments and organizations and cybersecurity will remain a priority as critical infrastructure is increasingly connected to online systems and technological dependence on the Internet continues to rise (see 'Spread of the Internet'). Internationally, countries will have to respond to evolving cyber-threats and prepare for cyberattacks as an instrument of war, counterintelligence, and political interference.^{109,110,111} One data breach can impact multiple nations sharing online systems.¹¹² If they are aware, national leaders may take appropriate steps to protect large-scale systems such as electrical, communications, financial, logistical, and food-production grids.¹¹³ They need to be proactive. Common Criteria for Information Technology Security Evaluation or the EU Cybersecurity Act are two examples of such proactive ventures.

Related trends: Artificial intelligence, Autonomous vehicles, Blockchain, Data privacy, Internet of Things, Quantum technologies, Spread of the Internet

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- 107. Global Trends to 2030. Challenges and choices for Europe (European Strategy and Policy Analysis System, 2019)
 - 108. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)
 - 109. Global Trends to 2030. Challenges and choices for Europe (European Strategy and Policy Analysis System, 2019)
 - 110. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)
 - 111. Global risks 2035 update. Decline or new renaissance? (Atlantic Council, 2019)
 - 112. Asia Pacific Megatrends 2040 (Commonwealth Scientific and Industrial Research Organisation, 2019)
 - 113. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)



Questions around ‘cyber borders’ may be part of the discussion around ensuring protection from attacks therefore countries and organizations alike must prepare for developments in cyber-crime.¹¹⁴ As increasing numbers of citizens are connected to, and reliant on, online networks, the potential for terrorist attacks will grow, if the system is not resilient enough and sufficiently protected.¹¹⁵ For developing countries in particular, preparedness for cyber-threats will need to accompany digitalization programmes and development of connected systems.¹¹⁶

Finally, cyber-vulnerability does not exist only at the level of countries and organizations. Looked at from a slightly different perspective, the vulnerability of individuals is also set to increase because of their online exposure. For example, more people will get their information online, leaving them potentially more exposed to misinformation ('fake news'), which could be used to manipulate individuals or even on a larger scale to influence public opinion.¹¹⁷

To effectively mitigate these risks related to cyber-vulnerability, people cannot rely on government action alone – society needs to be the driving force. Society needs to demand that organizations maintain highly sophisticated information security systems to foster consumer trust and remain competitive.¹¹⁸

114. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

115. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)

116. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)

117. [Global Trends to 2030. Challenges and Choices for Europe](#) (European Strategy and Policy Analysis System, 2019)

118. [The Global Risks Report 2021](#) (World Economic Forum, 2021)



Relevant ISO technical committees and standards

- ISO/IEC JTC 1/SC 27, *Information security, cybersecurity and privacy protection*
 - ISO/IEC PRF TR 5895, *Cybersecurity – Multi-party coordinated vulnerability disclosure and handling*
 - ISO/IEC 29147:2018, *Information technology – Security techniques – Vulnerability disclosure*
 - ISO/IEC 30111:2019, *Information technology – Security techniques – Vulnerability handling processes*
- ISO/TC 22/SC 32, *Electrical and electronic components and general system aspects*
 - ISO/SAE 21434:2021, *Road vehicles – Cybersecurity engineering*
- ISO/TC 215, *Health informatics*
 - ISO/AWI TS 6268-1, *Health informatics – Cybersecurity framework for telehealth environment – Part 1: overview and concepts*
 - ISO/IEEE 11073-40101:2022, *Health informatics – Device interoperability – Part 40101: Foundational – Cybersecurity – Processes for vulnerability assessment*



Relevant ISO news stories

- ISO - Cybersecurity in cars
- ISO - The cybersecurity skills gap
- ISO - Keeping cybersafe
- ISO - Cybersecurity in the driver's seat
- ISO - Smart manufacturing: new ISO guidance to reduce the risks of cyber-attacks on machinery
- ISO - How to tackle today's IT security risks
- ISO - The quest for cyber-trust
- ISO - Are we safe in the Internet of Things?



The changing nature of work

Effects of automation | Reinventing the workplace

History has seen several industrial revolutions that have each dramatically changed the labour market, as means of production and levels of productivity have continually evolved with the introduction of new technologies. Today, new technologies are converging to make for even faster progress and more disruptive changes to the nature of work. Automation will change the kinds of jobs needed in the future, while digital technologies and societal preferences will change how and where we work. Thus, not only is the definition of 'workforce' changing, but the scope and focus of what a human resource department does may be shifting from being 'workforce focused' to 'human capital focused'.

Effects of automation

The increasing automation of industry is already a very observable and well-studied trend. With advances in 'Artificial intelligence', 'Smart manufacturing', and 'Robotics', the ability of machines to perform tasks more effectively than people is steadily increasing. This will have enormous consequences for the global employment landscape, with some studies predicting that, at the global level, "automation could eliminate 9% of existing jobs and radically change approximately one-third in the next 15 to 20 years".¹¹⁹ What sets this industrial transformation apart from those that came before it is the speed at which it is occurring. This 'Fourth Industrial Revolution', as it is often known, is happening so rapidly that careful governance will be required in order to maximize its potential benefits.



Related trends: Additive manufacturing, Artificial intelligence, Autonomous vehicles, Diversifying inequalities, Robotics, Stagnating happiness levels

^{119.} Global trends 2040. A more contested world (US National Intelligence Council, 2021)

While many studies focus on the potential job losses that could result from automation, it is important to keep in mind that, at least in the longer term, automation will also result in significant job creation. It will create new kinds of jobs, removing the need for humans to do unsafe, boring, and repetitive tasks, while increasing productivity and giving workers more flexibility and leisure time than in the past.^{120,121} These new jobs will likely require higher-level technical skills and more social and/or creative skills than the jobs that will disappear.¹²²

Of course, the ability of individual countries to benefit from automation varies significantly depending on several factors:

- **Demographics:** Countries with ageing populations will likely promote faster adoption of automation to replace and augment their ageing workforces, especially in sectors such as health, aged care, mining, and agriculture.^{123,124} Automation in countries with younger populations and a growing workforce could, on the one hand, have more disruptive effects and potentially exert a downward pressure on wages. On the other hand,

these countries could also be more agile in responding to changes brought about by automation, as long as they can provide the required education to train new workers.¹²⁵

- **Level of industrialization:** There is some concern that automation could disadvantage developing countries, as these countries tend to have a high number of jobs in manufacturing. What's more, a lot of manufacturing could be 're-shored' back to developed countries by using robots, which would decrease opportunities for developing countries to grow their economies through export-led manufacturing.¹²⁶ But advanced economies will not be unchallenged either – they may see revenue shortages as the number of workers paying tax decreases, and they may be more susceptible to societal upheaval as segments of their populations who are used to experiencing a steady growth in living standards become more disadvantaged.¹²⁷

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120. Digital Economy Report 2019. Value creation and capture: implications for developing countries (UN Conference on Trade and Development, 2019)
121. Digital megatrends. A perspective on the coming decade of digital disruption (Commonwealth Scientific and Industrial Research Organisation, 2019)
122. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)
123. Global trends 2040. A more contested world (US National Intelligence Council, 2021)
124. Asia Pacific Megatrends 2040 (Commonwealth Scientific and Industrial Research Organisation, 2019)
125. Global trends 2040. A more contested world (US National Intelligence Council, 2021)
126. Digital Economy Report 2019. Value creation and capture: implications for developing countries (UN Conference on Trade and Development, 2019)
127. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)



- **Education systems:** The skills present in a country's workforce plus its ability to provide access to continuing education will strongly influence how well it can adapt to increased automation. In countries where women tend to have lower education levels and fewer technical skills than men, their jobs may be at greater risk from automation, and this may lead to women being disproportionately excluded from the workforce.¹²⁸ Therefore policymakers will need to ensure that sufficient retraining and upskilling initiatives are put in place to make the transition as smooth as possible, in particular for low and medium-skilled workers and (in some cases) women.¹²⁹

Relevant ISO technical committees and standards

- ⇒ ISO/TC 184, *Automation systems and integration*
 - ISO/TR 23087:2018, *Automation systems and integration – The Big Picture of standards*
- ⇒ ISO/TC 232, *Education and learning services*
 - ISO 29994:2021, *Education and learning services – Requirements for distance learning*
 - ISO/AWI TR 29996, *Education and learning services – Distance and digital learning services (DDLS) – Case studies*
- ⇒ ISO/TC 299, *Robotics*
 - ISO/TS 15066:2016, *Robots and robotic devices – collaborative robots*



Relevant ISO news stories

- ISO - New (e-)takeoff for aviation industry
- ISO - From high-tech gadgets to the smart enterprise
- ISO - Unearthing the potential of autonomous mining with ISO 17757
- ISO - Robots and humans can work together with new ISO guidance

128. Digital Economy Report 2019. Value creation and capture: implications for developing countries (UN Conference on Trade and Development, 2019)

129. Global Connectivity Outlook to 2030 (World Bank, 2019)



Reinventing the workplace

While automation is changing the kind of jobs that dominate the employment landscape, other new technologies and societal pressures are transforming workplace culture and how we work. Digital technology is allowing more people to work remotely and with much more flexible schedules. This trend did not begin with the COVID-19 pandemic but has certainly been accelerated by it – the pandemic led to a dramatic increase in the number of people working remotely and in the use of videoconferencing and virtual meetings, alongside a large decrease in business travel and the use of physical office space.¹³⁰ Surveys show that these trends align with the preferences of the great majority of millennials (92% want to work remotely and 87% want to work according to their own schedule¹³¹) and allow people to better balance their work and home lives. However, there are also potential negatives – some workers may suffer increased stress levels due to being continually connected to work¹³², while others may become disengaged and less productive, as they lose their physical connection to co-workers and a dedicated workspace.¹³³ Organizations are therefore facing the double challenge of investing in the necessary technologies to enable a hybrid or remote work environment in order to attract and retain the best talent, while also developing strategies to combat increased employee stress or fragmentation and disengagement of their workforce.

Related trends: **Ageing population, Diversifying inequalities, Spread of the Internet**

130. [The future of work after COVID 19](#) (McKinsey Global Institute, 2021)

131. [AGCS trend compass](#) (Allianz, 2019)

132. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

133. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)



Relevant ISO technical committees and standards

→ ISO/TC 260, Human resource management

- ISO 23326:2022, *Human resource management – Employee engagement – Guidelines*
- ISO 30415:2021, *Human resource management – Diversity and inclusion*
- ISO/AWI TS 30436, *Human Resource Management – Diversity and Inclusion Metrics Technical Specification*

→ ISO/TC 260/AHG, Flexible work in the gig economy

→ ISO/TC 159/SC 1, General ergonomics principles

- ISO 10075-1:2017, *Ergonomic principles related to mental workload – Part 1: General issues and concepts, terms and definitions*
- ISO 27501:2019, *The human-centred organization – Guidance for managers*

→ ISO/TC 283, Occupational health and safety management

- ISO 45003:2021, *Occupational health and safety management – Psychological health and safety at work – Guidelines for managing psychosocial risks*
- ISO/PAS 45005:2020, *Occupational health and safety management – General guidelines for safe working during the COVID-19, pandemic*

→ ISO/TC 292, Security and resilience

- ISO/TS 22330:2018, *Security and resilience – Business continuity management systems – Guidelines for people aspects of business continuity*

→ IEC/ISO SMART



Relevant ISO news stories

- ISO - Mental health matters
- ISO - The beauty of difference
- ISO - Variety is the spice of success
- ISO - How to build a resilient workforce
- ISO - Wise workplaces in the COVID-19, era
- ISO - New ISO standard rolls out practical tips for employee engagement
- ISO - Building success through people
- ISO - New ISO standard puts humans at the centre of business
- ISO - A better designed workplace with ISO standards



Technology

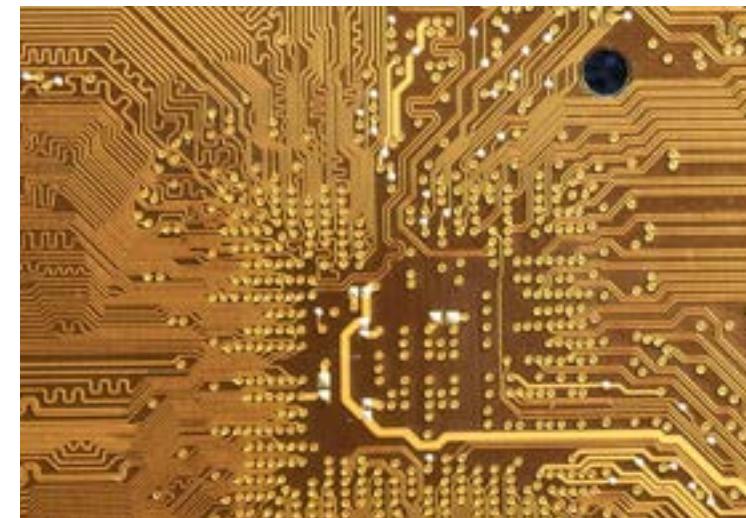
- Computing
- Connectivity
- Cyber-physical systems
- Smart manufacturing

Computing

Artificial intelligence | Extended reality | Blockchain | Edge computing |
Quantum technologies

The world is rapidly moving toward a post-digital era, where leaders will need to set their sights beyond their ongoing digital transformations. With digital capabilities alone no longer serving as a differentiator, future-minded business leaders will need more in their technology arsenals to succeed.¹³⁴

Innovative technologies are catalysts for change, offering businesses extraordinary new capabilities. 'Distributed ledger technology', 'Artificial intelligence', 'Extended reality' and 'Quantum computing' (known collectively as DARQ technologies) will be the next set of emerging technologies to spark profound change, letting businesses reimagine entire industries.¹³⁵ In fact, individual DARQ technologies are already making a difference across industries today. But collectively, the DARQ technologies will also power the innovation and opportunity uniquely associated with the coming post-digital era. As the business landscape becomes increasingly dominated by digital natives and companies that have undergone successful digital transformations, DARQ is the key that will open unimagined new pathways into the future.¹³⁶



134. Understanding the DNA of DARQ (Accenture, 2020)

135. Technology Vision 2020. We, the post-digital people (Accenture, 2020)

136. Technology Vision 2019. The post-digital era is upon us (Accenture, 2019)

Artificial intelligence

AI today includes a whole host of technologies from data science to computer science, to electronics and social disciplines.¹³⁷ It is a very broad field within information technology that is enabling the digital transformation of industry and society by creating computers that have the ability to learn as they are programmed to perform tasks normally requiring human intelligence. This includes reasoning, problem-solving, understanding language, making predictions or inferences, and perceiving situations or environments. Essentially, it involves computers being able to provide better, deeper, and otherwise practically unachievable insights in an efficient way by leveraging computer-learning algorithms.

This trend is about the rapid adoption of AI technologies whose increased capabilities and applications have the potential to reshape almost every industry and profession as they fundamentally change the ways in which humans interact with machines.¹³⁸ This should be considered a megatrend because of the scale and geographic reach of its potential economic and societal impacts.

The projected impacts of AI are significant. Many different projections and estimates exist, but to provide an example of the magnitude of these projections, *UN Conference on Trade and Development's Digital Economy Report*¹³⁹ estimates that AI has the potential to generate USD 13 trillion of additional global economic output by 2030, contributing an additional 1.2% to annual GDP growth. The Future Today Institute predicts that the global AI market will grow at a CAGR of 42.2% from 2021 to 2027¹⁴⁰

Related trends: **5G, Additive manufacturing, Autonomous vehicles, Blockchain, Data privacy, Edge computing, Effects of automation, Ethics of technology, Extended reality, Internet of Things, Robotics, Smart cities, Spread of the Internet, Quantum technologies**

- 137. Stanford University launches the Institute for Human-Centered Artificial Intelligence (Stanford University, 2019)
- 138. Digital Megatrends. A perspective on the coming decade of digital disruption (Commonwealth Scientific and Industrial Research Organisation, 2019)
- 139. Digital Economy Report 2019 (UNCTAD, 2019)
- 140. 2021 Tech Trends Report. Strategic trends that will influence business, government, education, media and society in the coming year (Future Today Institute, 2021)



AI enabling next generation applications

Over the coming decades, applications of AI have the potential to change our lives for the better in many ways. Some key examples include:

- **Changing the labour market:** With AI's huge potential to boost productivity and economic growth, it will certainly have a significant effect on the labour market. In the short term, automation driven by AI (e.g. 'Robotics') could introduce some disruption to many current jobs.¹⁴¹ But in the longer term, AI promises to create a significant number of new jobs; jobs which can remove the need for humans to do unsafe and repetitive tasks (see 'Effects of automation').¹⁴²
- **Better healthcare:** AI is already transforming healthcare in areas such as pathology and radiology, by improving the speed and accuracy of diagnosing diseases such as breast cancer.¹⁴³ In future, AI will facilitate personalized medicine and drug

development (e.g. allowing tailored, drug treatments based on an individual's genetic markers), help to eradicate infectious diseases and even to predict future disease outbreaks that may originate in animals.^{144,145}

- **Personalized education:** Like for personalized healthcare, AI could be used for personalized learning – targeting learning to the gaps in an individual student's knowledge and creating customized learning content.¹⁴⁶
- **More efficient production and consumption:** AI is widely predicted to increase industry and worker productivity, which is why so many companies are interested in adopting it in some form or other, looking to achieve a competitive advantage.¹⁴⁷ McKinsey estimates that 70% of companies may adopt at least one AI technology by 2030.¹⁴⁸ AI will also increasingly be used to identify more efficient delivery routes or supply chains¹⁴⁹ and to maximize efficiency and sustainability in agriculture¹⁵⁰, the outcome of which could lead to significant economic growth.

141. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)

142. [Digital Megatrends. A perspective on the coming decade of digital disruption](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

143. [Ten Trends That Will Shape Science in the 2020s. Medicine gets trippy, solar takes over, and humanity – finally, maybe – goes back to the moon](#) (Smithsonian Magazine, 2020)

144. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)

145. [Ten Trends That Will Shape Science in the 2020s. Medicine gets trippy, solar takes over, and humanity—finally, maybe—goes back to the moon](#) (Smithsonian Magazine, 2020)

146. [AI in Education. Change at the Speed of Learning](#) (UN Educational, Scientific and Cultural Organization, 2020)

147. [Digital Megatrends. A perspective on the coming decade of digital disruption](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

148. [Global Trends 2020. Understanding Complexity](#) (Ipsos, 2020)

149. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

150. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)



- More efficient and effective governance: AI could help formulate and evaluate the effectiveness of government policies and even be used to perform legal tasks that require the sifting and analysis of huge amounts of data.¹⁵¹

Challenges and risks

Although the expected benefits of AI are enormous, good governance of the technology will be essential if we are to realize them. The development of appropriate legal and ethical frameworks for AI will be critical to build societal trust and to mitigate the potential risks and challenges. International Standards will have an important role to play as part of such frameworks to ensure the responsible adoption of AI.

- Social implications: Because the ability to adopt and benefit from AI is dependent on the presence of adequate digital infrastructures, relevant technical skills in the workforce, and appropriate regulatory systems, AI has the potential to widen the technology gap between those that have the capabilities to benefit from it, and those who do not. This is the case in terms of both countries and companies (large corporations may

be able to determine who has access to AI and its benefits).¹⁵² Those with access to the technology could potentially use it for malicious purposes, for example, by creating deepfakes (using AI to alter videos of people) and tailored, online communications (a sort of ‘personalized propaganda’) to radicalize or manipulate people.¹⁵³ But even without malicious intentions, just the fact that AI consumes so much data creates potential privacy issues – “As AI evolves, it magnifies the ability to use personal information in ways that can intrude on privacy interests by raising analysis of personal information to new levels of power and speed”.¹⁵⁴ Indeed, AI is advancing so rapidly that it could even one day evoke difficult questions about what it means to be ‘human’. For example, AI is learning to do things that even humans often find difficult – reading human expressions, interpreting the emotions behind them, and analyzing a person’s level of emotional engagement. Researchers are even working on teaching AI to convincingly exhibit human emotions.^{155,156}

151. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

152. 2021 Tech Trends Report. Strategic trends that will influence business, government, education, media and society in the coming year (Future Today Institute, 2021)

153. Global risks 2035 update. Decline or new renaissance? (Atlantic Council, 2019)

154. Protecting privacy in an AI-driven world (Brookings, 2020)

155. 2021 Tech Trends Report. Strategic trends that will influence business, government, education, media and society in the coming year (Future Today Institute, 2021)

156. Ten Trends That Will Shape Science in the 2020s. Medicine gets trippy, solar takes over, and humanity—finally, maybe—goes back to the moon (Smithsonian Magazine, 2020)



- **Legal and ethical implications:** Advanced AI that can make autonomous decisions could be applied to medical diagnoses, legal judgements or even used in warfare. This could be problematic because of the risk of bias in AI – if given incorrect or skewed data, this could lead to algorithmic discrimination being deployed on a large scale (e.g. some facial analysis AI has been shown to be less accurate at identifying minorities and women, because the data it was trained on was not representative).^{157,158} AI has the potential to reduce the impact of human biases, but only if humans can identify and adequately address bias in AI.

What is on the horizon for AI? (a few examples of many...)

- **Edge computing:** This is a system of moving computation nearer to the sources of data or the 'Edge'. Moving AI workloads to the Edge (AI processing and decision making is performed nearer to the source of the data generation, rather than in the Cloud) to make it faster and safer.
- **System on a chip:** Development of advanced chips with a complex series of components that are designed to work on AI projects and deliver faster and more secure processing.
- **Digital twins:** The use of AI to significantly improve 'digital twin' technology (virtual representations of real-world environments or products).
- **AI to detect AI:** New measures to regulate creation and detection of deepfakes will be complemented by AI systems designed to identify deepfakes, whether these counterfeits are text or imagery.
- **Emotion AI:** Software that can read human vocal and facial expressions, understand human emotions and the cognitive states underlying them. Uses will include telehealth, online learning, and virtual meetings/events.

157. [The Global Risks Report 2021](#) (World Economic Forum, 2021)

158. [What do we do about the biases in AI](#) (Harvard Business Review, 2019)



Relevant ISO technical committees and standards

→ ISO/IEC JTC 1/SC 42, Artificial intelligence

- ISO/IEC TR 24027:2021, *Information technology – Artificial intelligence (AI) – Bias in AI systems and AI aided decision making*
- ISO/IEC TR 24028:2020, *Information technology – Artificial intelligence – overview of trustworthiness in artificial intelligence*
- ISO/IEC TR 24030:2021, *Information technology – Artificial intelligence (AI) – Use cases*

→ ISO/TC 215, Health informatics

- ISO/TR 24291:2021, *Health informatics – Applications of machine learning technologies in imaging and other medical applications*

→ ISO/PC 317, Consumer protection: privacy by design for consumer goods and services

- ISO/DIS 31700-1, *Consumer protection – Privacy by design for consumer goods and services – Part 1: High level requirements*



Relevant ISO news stories

- ISO - Tech's big growth spurt
- ISO - Enabling an AI-ready culture
- ISO - Towards a trustworthy AI
- ISO - Embracing the age of artificial intelligence in the latest *ISOfocus*
- ISO - Embracing the power of technology
- ISO - How to unlock the AI promise
- ISO - It's all about trust
- ISO - To ethicize or not to ethicize
- ISO - The new frontier for artificial intelligence

Extended reality

Extended reality (XR) refers to environments that combine the real and the virtual, through the use of computer technology and wearable devices. XR technologies consist of virtual, augmented and mixed reality (respectively VR, AR and MR).¹⁵⁹ Each of VR, AR, and MR defines a specific technology to reach XR, including the Metaverse. VR is fully digital and immersive, AR can digitally enhance our view of the real world and more recently, MR can create a hybrid reality where virtual and real worlds coexist.

XR technologies are transforming the way that people interact, live and work by offering access to a new mode of social interactions within the digital space.^{160,161} The endgame is the full development of the Metaverse, an online digital world where people can interact with each other and with the computerized environment to do a variety of activities as an extension of reality.

Part of the emerging DARQ technologies, XR is a building block in many companies' innovation strategies, with the power to significantly transform industries.¹⁶² With the combined global spending in AR and VR expected to reach USD 160 billion by 2023¹⁶³, and repercussion in both leisure and business sectors, this is a trend with rapidly increasing significance.

Related trends: **5G, Services moving online, Spread of the Internet, The experience economy**

159. A Review of Extended Reality (XR) Technologies for Manufacturing Training (*Technologies*, 2020)

160. Technology vision 2020. We, the post-digital people (Accenture, 2020)

161. Beyond the Noise. The Megatrends of Tomorrow's World (Deloitte, 2017)

162. Technology vision 2020. We, the post-digital people (Accenture, 2020)

163. Technology vision 2020. We, the post-digital people (Accenture, 2020)



The experience economy: from ownership to usership in the digital space

AR and VR immersive technologies have been in use for some time already (especially, in online games), but their application is increasingly business-focused, helping the field's rapid expansion. Epic Games' Unreal Engine for example, used in the popular *Fortnite* game, created an online, digital space for users to exchange and participate in a multiplicity of experiences. This gaming engine can also be used for business purposes, with architectural firms using it to showcase their designs to clients, or Finnair using it to build a digital twin of Helsinki Airport for staff training purposes, for example.¹⁶⁴

The uptake of XR technology in business can be linked back to other societal trends, such as the development of '[The experience economy](#)'. The experience economy is slowly replacing consumerism, where businesses sell experiences rather than a product. The customer is fully involved in the customization process, shifting its role from ownership to usership.¹⁶⁵ With XR technologies becoming cheaper and more sophisticated, the opportunities for customization are endless, allowing users to

immerse themselves in places or situations, whether it is to shop, interact, work, or travel.

In addition, the COVID-19 pandemic is accelerating the need to move everyday experiences to the digital space in order to limit physical interactions, and technologies are rapidly evolving to offer virtual access to a multiplicity of experiences in response to mobility restrictions and isolation policies such as teleworking.¹⁶⁶ With such technologies, customers can try on outfits in the virtual space and see themselves from multiple angles, or travel and work from the comfort of their armchairs. XR technologies thus open the door to alternative approaches to address current social needs, from wellness tourism¹⁶⁷ to training opportunities and even criminal rehabilitation, simulating real life scenarios to prepare offenders before their reintegration into society.¹⁶⁸

164. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)

165. [Future possibilities report 2020](#) (UAE Government, 2020)

166. [Future possibilities report 2020](#) (UAE Government, 2020)

167. [Future possibilities report 2020](#) (UAE Government, 2020)

168. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)



Innovation in communication and visual technologies accelerating the uptake of XR technologies

This expansion in XR use is driven largely by innovations in communication and visual technologies that are improving the user experience and making these technologies more popular and accessible to the general public. Key enabling developments include portability, high speed Internet access, graphic and sound quality as well as GPS data, which increases the potential reach of those technologies.¹⁶⁹ With the evolution of wearable XR technologies such as smart-glasses or contact lenses that include quality sensors, users can experience their surroundings with additional computer-generated inputs that appear real.¹⁷⁰

In manufacturing, for example, the development of such sensors and AR glasses can help workers with efficiency and safety by giving hands-free access to user manuals and audio instructions, helping them locate items, tracking stock in real time or warning the wearer of equipment needing maintenance or showing defects.¹⁷¹

The most recent devices, such as the HoloLens 2 (a pair of MR smart-glasses developed and manufactured by Microsoft), can now understand the characteristics of items in their field of vision rather than simply attesting that they exist, which means they can identify and warn the wearer of hazards rather than simply point to the presence of objects.¹⁷² The extensive applications of such technologies lead experts to predict a wide increase in the use of VR and AR at an annual growth rate of over 80% over the next few years.¹⁷³ In fact, in the next few decades, electronic communication and information sharing using AR and VR, such as livestream or videos, are expected to take over from traditional text and images.¹⁷⁴

169. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

170. Beyond the Noise. The Megatrends of Tomorrow's World (Deloitte, 2017)

171. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

172. Technology vision 2020. We, the post-digital people (Accenture, 2020)

173. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

174. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)



Risks

The increasing use of cyberspace to perform everyday activities could give more influence and authority to non-traditional actors, possibly leading to the creation of new forms of authority beyond the individual countries.¹⁷⁵ Already, such groups can use social media to exert significant societal pressures – one example of this is how users of Reddit (a social news aggregation, Web content rating and discussion Website), managed to shake the stock market with ‘meme-stocks’ and the coordinated buying of GameStop stocks by retail investors in 2021.¹⁷⁶

In a pessimistic scenario, expanding the competitive space to the digital realm could also provide a new medium for conflict and warfare, which is already seen with the rise in cyber-terrorism. The virtual arena and XR technologies provide increasing opportunities for misinformation and propaganda, as well as avenues for cyber-attacks and hybrid forms of conflict.¹⁷⁷

Another risk is that XR technologies might complicate pre-existing issues linked with digital technologies and social media, such as those related to the protection of identity and ownership, as well

as the risk of misinformation and bias. Examples of fake news and deepfake videos using deep learning technologies highlight the risks of XR innovations and the increasing difficulty to distinguish what is real and what is digitally constructed.^{178,179}

Extended realities technologies such as AR and VR, and the constant evolution of the digital space towards the Metaverse is a promising field that can further user experience in business and leisure alike. Additional trending technologies such as the roll out of ‘5G’ will further support the development of XR experiences, by enabling more people to be connected at the same time to enjoy a quality experience with minimal latency.¹⁸⁰

With other DARQ technologies, it holds the power to radically modify how we behave and interact and will be directly dependent on innovation in communication and visual technologies, with which it shares similar risks that must be addressed.

175. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

176. The Reddit revolt. GameStop and the impact of social media on institutional investors (The TRADE, 2021)

177. Global Strategic trends. The future starts today (UK Ministry of Defence, 2018)

178. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

179. When seeing is no longer believing. Inside the Pentagon’s race against deepfake videos (CNN Business, 2019)

180. Technology vision 2020. We, the post-digital people (Accenture, 2020)



Relevant ISO technical committees and standards

→ ISO/IEC JTC 1/SC 24, *Computer graphics, image processing and environmental data representation*

- ISO/IEC 14772-1:1997, *Information technology – Computer graphics and image processing – The Virtual Reality Modeling Language – Part 1: Functional specification and UTF-8 encoding*
- ISO/IEC 14772-2:2004, *Information technology – Computer graphics and image processing – The Virtual Reality Modeling Language (VRML) – Part 2: External authoring interface (EAI)*
- ISO/IEC 18038:2020, *Information technology – Computer graphics, image processing and environmental data representation – Sensor representation in mixed and augmented reality*
- ISO/IEC 18039:2019, *Information technology – Computer graphics, image processing and environmental data representation – Mixed and augmented reality (MAR) reference model*
- ISO/IEC 18040:2019, *Information technology – Computer graphics, image processing and environmental data representation – Live actor and entity representation in mixed and augmented reality (MAR)*

→ ISO/IEC JTC 1/SC 29, *Coding of audio, picture, multimedia, and hypermedia information*

- ISO/IEC 23000-13:2017, *Information technology – Multimedia application format (MPEG-A) – Part 13: Augmented reality application format*

→ ISO/IEC JTC 1/SC 36, *Information technology for learning, education, and training*

- ISO/IEC TR 23842-1:2020, *Information technology for learning, education and training – Human factor guidelines for virtual reality content – Part 1: Considerations when using VR content*
- ISO/IEC TR 23842-2:2020, *Information technology for learning, education, and training – Human factor guidelines for virtual reality content – Part 2: Considerations when making VR content*
- ISO/IEC TR 23843:2020, *Information technology for learning, education, and training – Catalogue model for virtual, augmented and mixed reality content*



Relevant ISO news stories

- ISO - Putting the real world back into online education
- ISO - Silent game changers of the tech revolution



Blockchain

Blockchain technology is a form of distributed ledger technology (DLT), which provides unprecedented potential for removing intermediaries by allowing participating parties to exchange not only information but also value (money, contracts, property rights) without necessitating trust in specific, pre-determined intermediaries such as banks or servers.^{181,182,183} This is because DLT enables transaction data to be validated within a system wherein control is distributed among multiple, independent participants and stored in a manner that is tamper-evident and immutable by design. By ensuring system-wide agreement about the state of the ledger, DLT can be used to promote privacy, safety, transparency, and integrity of the transaction process.^{184,185}

Distributed ledgers open up many new possibilities; for example, for monitoring the supply chain or managing digital rights. DLT is therefore regarded as a central enabler for digital, self-executing contracts, so-called smart contracts.¹⁸⁶

Many industry leaders have already achieved significant business benefits, including greater transparency, enhanced security, improved traceability, increased efficiency, faster transactions, and reduced costs by DLTs.¹⁸⁷ Financial services and banking are the most

Related trends: Artificial intelligence, Cyber-vulnerability, Data privacy, Edge computing

181. [Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries](#) (United Nations Conference on Trade and Development, 2019)
182. [Digital Megatrends. A perspective on the coming decade of digital disruption](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)
183. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)
184. [AGCS trend compass](#) (Allianz, 2019)
185. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)
186. [AGCS trend compass](#) (Allianz, 2019)
187. [Top five blockchain benefits transforming your industry](#) (IBM, 2018)



frequently targeted sectors for DLT service providers. Capital markets are clearly dominating, followed by insurance, and trade finance.¹⁸⁸ Research from Gartner says that 300 million blockchain transactions were processed through the end of 2017 and assets worth more than USD 270 billion were being managed using DLT.^{189,190}

Blockchain is best known as the technology behind cryptocurrencies (see '[New business models](#)')^{191,192}, but is increasingly known for its role facilitating the trading of non-fungible tokens (NFTs). While cryptocurrencies (like physical money) are 'fungible', meaning they are equal in value and can be traded or exchanged for one another (one dollar is always worth another dollar; one Bitcoin is always equal to another Bitcoin), NFTs each have their own digital signature that makes it impossible for NFTs to be exchanged, as no two are equal (hence, non-fungible).¹⁹³ NFTs are digital assets with programmed scarcity, and as such are ideal to represent ownership of unique virtual assets and digital identities in Web 3.0 and the Metaverse.¹⁹⁴

But blockchain can be used for a much wider variety of applications beyond cryptocurrency and the financial services and banking sectors. Although much focus is still put on monetary uses, there is an increasing interest in non-monetary uses and applications, e.g. digital identity, healthcare, supply chain, and energy.¹⁹⁵ For example:

- In West Africa and Kenya, blockchain has enabled the efficient verification of property records and transactions, and expanded access to credit in some previously informal sectors of the economy.¹⁹⁶
- The London-based start-up Resonance uses blockchain to automate the transfer of product information between brands, manufacturers, and retailers. According to Resonance, over 30% of product data in product catalogues is wrong, with each error costing an average of USD 60 to fix. The innovative technology ensures that only trustworthy information is forwarded and is done so anonymously. The recipients first check the data sheets

188. [Global blockchain benchmarking study](#) (University of Cambridge, 2017)

189. [Will Blockchain Disrupt Financial Services](#) (Gartner, 2017)

190. [AGCS trend compass](#) (Allianz, 2019)

191. [Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries](#) (United Nations Conference on Trade and Development, 2019)

192. [Understanding the DNA of DARQ](#) (Accenture, 2019)

193. [What Is An NFT? Non-Fungible Tokens Explained](#) (Forbes, 2022)

194. [Significance of NFTs in Web 3.0 and the Metaverse](#) (Selfkey, 2022)

195. [Global blockchain benchmarking study](#) (University of Cambridge, 2017)

196. [Blockchain Opens Up Kenya's \\$20 Billion Informal Economy](#) (Bloomberg, 2018)



- they receive before integrating information into their internal systems – such as for material requirements planning.¹⁹⁷
- In Switzerland Streamr has developed an anti-theft sticker that protects valuable goods without revealing their location. The sticker is fitted with an array of sensors that identify issues such as location, acceleration, and temperature. The data collected in this way is managed by Streamr's blockchain network and based on smart contracts. The stickers can be used in the transport of goods, for example. Customers would only find out where they are currently located if the forwarder violates the previously agreed terms and conditions of transportation.¹⁹⁸
 - In Australia Power Ledger has developed a blockchain-based platform that enables users to invest in major, renewable-energy projects. This allows users who want to invest in the expansion of renewable energy to buy small stakes in projects and accelerate their growth. The first offers are parts of a commercial solar park and a grid-connected battery storage project in Australia, which will be offered via cryptocurrencies in the blockchain.¹⁹⁹
 - And CSIRO has explored using blockchain to verify food provenance, so consumers can know exactly where their food came from and what has happened to it at each step of the chain.²⁰⁰
- According to Gartner's value forecast for the blockchain business²⁰¹, after the first phase of a few high-profile successes in 2018-2021, there will be larger, focused investments and many more successful models in 2022-2026. And these are expected to explode in 2027-2030, reaching more than USD 3 trillion globally.²⁰² In 2018, China alone accounted for nearly 50% of all patent applications for technology families relating to blockchains, and, together with the United States, represents more than 75% of all such patent applications.²⁰³

197. AGCS trend compass (Allianz, 2019)

198. AGCS trend compass (Allianz, 2019)

199. AGCS trend compass (Allianz, 2019)

200. Is your honey faking it? (Commonwealth Scientific and Industrial Research Organisation, 2018)

201. Forecast: Blockchain Business Value, Worldwide, 2017-2030 (Gartner, 2017)

202. World Trade Report 2018. The future of world trade: How Digital Technologies are Transforming Global Commerce (World Trade Organisation, 2018)

203. Patent Analytics Report on Blockchain Innovation (IP Australia, 2018)



Relevant ISO technical committees and standards

- ISO/TC 307, *Blockchain and distributed ledger technologies*
 - ISO/DTR 3242, *Blockchain and distributed ledger technologies – Use cases*
 - ISO 23257:2022, *Blockchain and distributed ledger technologies – Reference architecture*
 - ISO/TS 23635:2022, *Blockchain and distributed ledger technologies – Guidelines for governance*
- ISO/IEC JTC 1/SC 41, *Internet of things and digital twin*
 - ISO/IEC TR 30176:2021, *Internet of Things (IoT) – Integration of IoT and DLT/blockchain: Use cases*
- ISO/TC 68/SC 2, *Financial Services, security*
 - ISO/AWI TR 24374, *Information technology – Security techniques – DLT and Blockchain for Financial Services*



Relevant ISO news stories

- ISO - Getting big on blockchain
- ISO - Blockchain technology set to grow further with international standards in pipeline
- ISO - Blockchain's technology of trust

Edge computing

Cloud technology allows users to access scalable technology services immediately via the Internet's existing network, promoting lower costs for infrastructure and inventory, reducing overheads, and creating leaps in computing power and speed, data storage, and bandwidth.²⁰⁴ However, it has one major problem – the latency (time lag or communication delay over the network) that results from the physical distance between users and the data centres hosting cloud-based services. This problem can be overcome using Edge computing; this is a different technology from cloud computing and its relevance is set to increase as the '[Internet of Things](#)' becomes ubiquitous and the sheer amount of data that needs to be moved and processed increases exponentially.²⁰⁵

This is because edge computing allows users to overcome the latency issue by performing computations near or at the source of data – data is processed directly on-site using dedicated hardware. Edge thus provides an important advantage when processing time-sensitive data, or when data processing is needed in a remote location where there is limited connectivity. In future, edge computing will be important for health care, automotive and manufacturing applications, because of the increased speed and security of processing data directly on devices (as opposed to sending it into the Cloud).^{206,207}

Aside from reducing latency, edge computing has several other advantages, such as saving bandwidth and network costs, and enhancing security and privacy.²⁰⁸ Microsoft, for example,

Related trends: [Artificial intelligence](#), [Blockchain](#), [Internet of Things](#), [Spread of the Internet](#)

204. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)

205. [AGCS trend compass](#) (Allianz, 2019)

206. [AGCS trend compass](#) (Allianz, 2019)

207. [2021 Tech Trends Report](#) (Future Today Institute, 2021)

208. [3 Advantages \(And 1 Disadvantage\) of Edge Computing](#) (Forbes, 2020)



claims that edge computing enables more industries to safely use the cloud and still meet their compliance requirements.²⁰⁹ McKinsey finds that the industries with the most edge computing use cases are travel, transportation, and logistics; energy; retail; healthcare; and utilities.²¹⁰ Here are just a few examples of applications of edge computing:

- ‘Autonomous vehicles’ can gather the data produced by vehicle sensors and cameras, process it, analyze it and make decisions in just a few milliseconds to keep vehicles and pedestrians safe.
- Intelligent transportation systems enable passenger information systems, vehicle monitoring and tracking systems, intelligent surveillance of transportation vehicles and stations, intelligent traffic management systems and more. Fleet management allows organizations to intelligently manage their vehicle fleets with a variety of rich information.
- Remote monitoring of oil and gas assets can be deployed in oil and gas fields where process conditions (such as extreme temperature variations) can be effectively and safely monitored and managed offsite.²¹¹

- Patient conditions can be tracked in real time and treatment can be improved through better patient treatment compliance and early identification of health complications.²¹²

According to a report by Grand View Research, the global edge computing market size is anticipated to reach USD 61.14 billion by 2028, exhibiting at a CAGR of 38.4% over the forecast period.²¹³

209. Edge Computing. What it is and how it's a game-changer (CMS WIRE, 2018)

210. New demand, new markets: What edge computing means for hardware companies (McKinsey, 2018)

211. Examples of Edge Computing (Premio, 2021)

212. New demand, new markets: What edge computing means for hardware companies (McKinsey, 2018)

213. Edge Computing Market Growth & Trends (Grand View Research, 2021)



Relevant ISO technical committees and standards

→ ISO/IEC JTC 1/SC 38, *Cloud computing and distributed platforms*

- ISO/IEC 19944-1:2020, *Cloud computing and distributed platforms – Data flow, data categories and data use – Part 1: Fundamentals*
- ISO/IEC 22624:2020, *Information technology – Cloud computing – Taxonomy based data handling for cloud services*
- ISO/IEC TS 23167:2020, *Information technology – Cloud computing – Common technologies and techniques*
- ISO/IEC TR 23188:2020, *Information technology – Cloud computing – Edge computing landscape*

→ ISO/IEC JTC 1/SC 41, *Internet of things and digital twin*

- ISO/IEC TR 30164:2020, *Internet of things (IoT) – Edge computing*



Relevant ISO news stories

- ISO - Underneath the cloud
- ISO - In the cloud

Quantum technologies

Quantum technologies rely on the principles of quantum physics and cover a broad range of applied areas like quantum communication, quantum computing, quantum cryptography, quantum imaging, quantum metrology, quantum sensors, and quantum simulation.

Quantum computing, in particular, could be a game changer and revolutionize the way we perform calculations.²¹⁴ Quantum computers are the next generation of computers, which operate based on the laws of quantum mechanics and are made up of quantum circuits. The fundamental building-block of the quantum computer is the quantum bit or ‘qubit’, the quantum analogue of the binary digit or classical computing bit. The qubit can exist in two states (analogous to the ‘1’ and ‘0’ of the classical bit) as well as a superposition state (where it is both ‘1’ and ‘0’ at the same time). Because qubits can exist in multiple states at the same time, the quantum computer has the potential to be a hundred million times faster than a traditional computer. With its help, databases can be searched faster, complex systems such as molecular-level behaviour can be modelled and simulated to make better medicines and today’s encryption technologies can be strengthened or cracked.^{215,216}

In the future, it will be possible to book and obtain quantum computing power via the Cloud from providers such as Amazon and IBM, triggering the era of hypercomputation.²¹⁷

Related trends: Artificial intelligence, Autonomous vehicles, Cyber-vulnerability, Services moving online, Spread of the Internet

214. Future technology for prosperity. Horizon scanning by Europe's technology leaders (European Commission, 2019)

215. AGCS trend compass (Allianz, 2019)

216. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

217. AGCS trend compass (Allianz, 2019)



Even though quantum could be considered the most nascent DARQ technology, investment has been growing rapidly and this investment is happening at multiple levels, e.g. from companies through to supranational institutions and countries. For example, China set up the world's first quantum cryptographic network (Jinan Project) in 2017.²¹⁸ Meanwhile, the European Union launched a **quantum flagship** initiative in 2018 covering quantum communication, quantum simulation, quantum computing, quantum metrology, and sensing as well as the basic science behind quantum technologies. With a budget of at least EUR 1 billion over ten years, the long-term vision of the flagship initiative is to develop a quantum Web in Europe, where quantum computers, simulators and sensors are interconnected via quantum communication networks.²¹⁹

In terms of private sector advancements, major players like Google, Alibaba, IBM, Baidu and Hewlett Packard are all busy doing their own research.²²⁰ In 2021, IBM Quantum unveiled the Eagle chip, delivering 127 qubits on a single IBM quantum processor for the first time with breakthrough packaging technology. Eagle broke the 100-qubit processor barrier and is leading quantum computers into a new era. IBM anticipates that, with Eagle, users will be able to explore

uncharted computational territory – and experience a key milestone on the path towards practical quantum computation.²²¹

Despite the excitement and investment, however, quantum technologies are in their very early stages, and it will be a long time before they take over the market. For example, the quantum computer market of the future is only predicted to grow to about the size of today's supercomputer market, worth around USD 50 billion (as compared to today's market for classical computing devices, which was already worth over USD 1 trillion in 2019) and, even by 2030, none of the smartphones, tablets and computers in use will be quantum powered.²²²

218. [China set to launch an ‘unhackable’ internet communication](#) (BBC, 2017)

219. [Future technology for prosperity. Horizon scanning by Europe’s technology leaders](#) (European Commission, 2019)

220. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)

221. [IBM Unveils Breakthrough 127-Qubit Quantum Processor](#) (IBM, 2021)

222. [Quantum computers. The next supercomputers, but not the next laptops](#) (Deloitte, 2018)



Relevant ISO technical committees and standards

- ⇒ ISO/IEC JTC 1/WG 14, *Quantum computing*
 - ISO/IEC CD 4879, *Information technology – Quantum computing – Terminology and vocabulary*
- ⇒ ISO/IEC JTC 1/SC 27, *Information security, cybersecurity and privacy protection*
 - ISO/IEC DIS 23837-1.2, *Information technology security techniques – Security requirements, test and evaluation methods for quantum key distribution – Part 1: Requirements*
 - ISO/IEC CD 23837-2.2, *Information technology security techniques – Security requirements, test and evaluation methods for quantum key distribution – Part 2: Evaluation and testing methods*



Connectivity

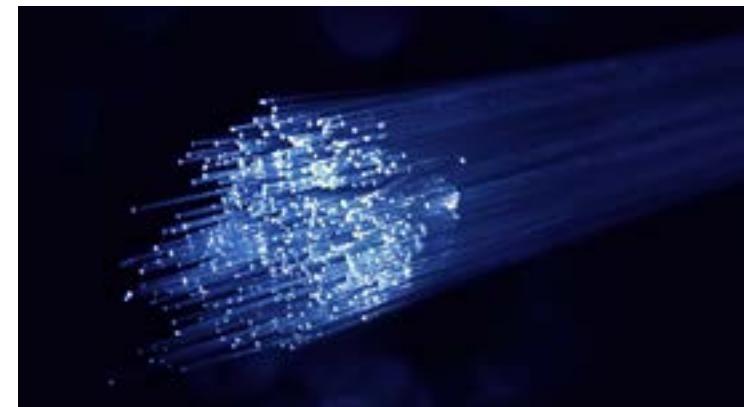
Spread of the Internet | 5G | Services moving online

Connectivity acts as one of the drivers towards a more pluralistic world, deepening connections between businesses, services, and communities across the globe. Mobile, or wireless, technologies (mobile phones, tablets, and other wireless devices) have become basic communication tools of everyday life. These enable billions of people around the world to stay connected. For many worldwide, mobile is the primary – and sometimes the only – channel for accessing the Internet and the benefits it brings.²²³ The number of connected devices on the Internet is projected to reach 50 billion any time from 2025 onwards.²²⁴

Consumer demands are shaping the development of mobile broadband services. Anticipated increases in traffic (estimated to grow between 10 and 100 times in the period from 2020 to 2030), growth in the number of devices and services, as well as demand for enhanced affordability and user experience, will require innovative solutions.

Spread of the Internet

The spread of the Internet influences almost all current and future trends, with repercussions across all sectors, connecting systems and people at an exponential rate and facilitating the digitalization of businesses and everyday services (see '[Services moving online](#)'). Indeed, "some estimates indicate that the Internet's influence over the next 15 years will exceed the



Related trends: [5G](#), [Artificial intelligence](#), [Customized products](#), [Cyber-vulnerability](#), [Diversifying inequalities](#), [Edge computing](#), [Extended reality](#), [Internet of Things](#), [New business models](#), [Quantum technologies](#), [Reinventing the workplace](#), [Rise of the middle class](#), [Services moving online](#), [Smart cities](#), [The experience economy](#), [Young generation influences](#)

223. [5G. Human exposure to electromagnetic fields \(EMF\) and health](#) (International Telecommunication Unit, 2019)

224. [5G. Fifth generation of mobile technologies](#) (International Telecommunication Unit, 2019)

impacts of the industrial revolution over the course of 50 years.²²⁵ As more people go online, information can be shared faster and more widely, increasing cooperation and efficiency at all levels, from connecting businesses, consumers, ideas, and technologies to coordinating global value chains.²²⁶ Although Internet connectivity is everywhere in both the public and private sphere, the largest growth is in the use of 'Internet of Things' connections in the industry sector, with connected industries expected to account for more than 50% of global IoT connections by 2025.²²⁷

The spread of the Internet and increasingly integrated online systems make cybersecurity improvements and digital infrastructure improvement key regulation priorities.²²⁸

With increasing Internet connectivity comes increasing '[Cyber-vulnerability](#)'. Effective cybersecurity will therefore be vital if society is to benefit from all the Internet has to offer, without exposure to threats from malicious (state and non-state) actors who can use cyberspace as a battle arena, with impacts ranging from outages of

critical infrastructure, to breaches of industrial or personal data, and election manipulation.

Meanwhile, improving digital infrastructures will be key to dealing with the major challenge of unequal access to the Internet. Access already varies greatly both within and between countries and, in least developed countries, only 20% of people use the Internet largely due to inadequate infrastructure, making it slow and expensive.²²⁹ More generally worldwide, digital divides exist between rural and urban areas, between genders, and '[Age groups](#)'. Because Internet access variability can reinforce pre-existing inequalities, connectivity differences are one factor that will contribute to defining the inequalities of tomorrow (see '[Diversifying inequalities](#)'). Taking action to address such connectivity differences will ensure more countries can access global markets and more people can connect – and benefit from technological innovation. Accounting for current efforts, optimistic scenarios suggest that global Internet penetration could reach 90% by 2030, with 75% of the world's population having mobile connectivity, and 60% having broadband access.^{230,231}

225. [Global trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)

226. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

227. [Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries](#) (UN Conference on Trade and Development, 2019)

228. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

229. [Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries](#) (UN Conference on Trade and Development, 2019)

230. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)

231. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)



Because the Internet has the power to spread false, misleading, or harmful information just as easily as it provides truth and knowledge, another challenge for regulators revolves around Internet censorship and safety. While there are legitimate reasons to censor harmful Internet content, access can also be used as a means of political control. States can limit or control platforms for Internet access, for propaganda purposes, and to restrict access to information. To date, over 23% of countries still ban or censor news, and, in some cases, shut down access to certain sites, effectively reducing their citizens' access to digital information and resources.²³² Nevertheless, the Internet remains a valuable tool for citizens to search for more sources of information beyond state-controlled media.

Relevant ISO technical committees and standards

→ ISO/IEC JTC 1, *Information technology*

- ISO/IEC 29341-8-5:2008, *Information technology – UPnP Device Architecture – Part 8-5: Internet Gateway Device Control Protocol - Wireless Local Area Network Access Point Device*

232. The Global Risks Report 2021 (World Economic Forum, 2021)



5G

In telecommunications, 5G is the fifth generation of mobile technologies and an evolution from the previous generations of mobile technologies: 2G, 3G, and 4G. Meanwhile, 5G is expected to be faster, connecting more people, things, data, applications, transport systems and cities in smart, networked, communication environments. It should transport a huge amount of data much faster, reliably connect an extremely large number of devices, and process very high volumes of data with minimal delay.^{233,234}

Whereas 4G systems, for example, have opened a new era for mobile Internet, enabling many app-based businesses used for services such as m-Learning, m-Health and mobile money, 5G is seen as opening yet another new era, supporting applications such as: smart homes and buildings; smarter and cleaner cities; self-driving cars and other intelligent transport systems; 3D video; work and play in the Cloud; remote medical services; virtual and augmented reality (see '[Extended reality](#)'), and; massive machine-to-machine communications for industry automation and manufacturing. The 3G and 4G networks currently face challenges in supporting these services.^{235,236}

Although the business cases and scope of use present challenges, these new functionalities and new services necessitate a new way of deploying advanced mobile services, as well as new approaches to making 5G technologies work together in industrial settings by machine-to-machine communications, the '[Internet of Things](#)' or with connected vehicles.²³⁷

Related trends: [Extended reality](#), [Services moving online](#), [Smart cities](#), [Spread of the Internet](#)

233. [5G. Fifth generation of mobile technologies](#) (International Telecommunication Unit, 2019)

234. [5G. Human exposure to electromagnetic fields \(EMF\) and health](#) (International Telecommunication Unit, 2019)

235. [5G. Fifth generation of mobile technologies](#) (International Telecommunication Unit, 2019)

236. [5G. Human exposure to electromagnetic fields \(EMF\) and health](#) (International Telecommunication Unit, 2019)

237. [5G. Fifth generation of mobile technologies](#) (International Telecommunication Unit, 2019)



The advent of 5G has arrived, and with it comes a world that is better connected and more powerful than ever before: 5G rollouts are happening worldwide. The US, UK, Germany, and South Korea already have 5G in some regions, with many more countries planning to follow suit.²³⁸ South Korea's SK Telecom hit one million 5G subscribers in the first 140 days of service, surpassing its 2011 4G LTE uptake.²³⁹ And 5G is expected to account for 40-50% of global mobile connections by 2034.²⁴⁰

In 2019, carriers AT&T and Verizon both launched their 5G networks in more than a dozen US sports stadiums. The concentration of people, along with an augmented reality experience use case, made these venues the ideal place to test the early rollouts. In the stadium, fans could connect to the network and participate in AR experiences through their smartphones, such as dancing with virtual National Football League players.²⁴¹

The record-breaking speeds, capacity for a higher number of connections and minimal latency of 5G are enabling a new frontier in the IoT. In the healthcare industry, technologists are already developing 5G devices to enable remote surgery, which would allow for highly specialized training of the next generation of doctors and bring previously inaccessible healthcare to populations worldwide.²⁴²

5G wireless technology is expected to be critical for the IoT due to its greater ability to handle massive volumes of data: 5G networks can process around up to 1,000 times more data than today's systems.²⁴³ In particular, it offers the possibility to connect many more devices (e.g. sensors and smart devices). It is estimated that by 2025, the United States, followed by Europe and the Asia-Pacific, will be leaders in 5G adoption. In order for developing countries to maximize the impact of the IoT, significant investments in 5G infrastructure will be required. By 2025, the share of 5G in total connections is expected to reach 59% in the Republic of Korea, compared with only 8% in Latin America and 3% in sub-Saharan Africa.²⁴⁴ Moreover, the deployment of 5G may further

238. [The Top Countries with 5G Deployments and Trials](#) (SDxCentral, 2019)

239. [5G Milestone. Korea's SK Telecom First to Pass 1M Subscribers](#) (Forbes, 2019)

240. [Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands](#) (GSMA, 2018)

241. [Now Is The Time To Load Up On 5G Stocks](#) (Forbes, 2019)

242. [5G will unlock whole new applications. Here are the most promising](#) (CNET, 2018)

243. [Evolution of wireless networks technologies, history and emerging technology of 5G wireless Network. A review](#) (*Journal of Telecommunications System & Management*, 2018)

244. [The Mobile Economy 2019](#) (GSMA, 2019)



increase the urban-rural digital divide, as setting up 5G networks in rural areas with lower demand will be commercially challenging.^{245,246}

Estimates put 5G as contributing up to USD 12.3 trillion to global economic output over the next decade.²⁴⁷ Rapidly maturing technologies are expanding businesses' experience customization capabilities, making the balance between customization and consumer choice increasingly critical: as 5G networks are expected to enable faster and more interconnected networks of people and devices, the opportunities are growing quickly. The 5G infrastructure market is expected to rise at a compound annual growth rate (CAGR) of 71% between 2019–2027, according to *Fortune Business Insights*.^{248,249}

Relevant ISO technical committees and standards

- ISO/TC 268/SC 2, *Sustainable cities and communities – Sustainable mobility and transportation*
- ISO/CD 37184, *Smart community infrastructures – Guidance on smart transportation for providing meshes for 5G communication*

NOTE: ITU plays a leading role in managing the radio spectrum and developing globally applicable standards for IMT-2020, the name used in ITU for the standards of 5G

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- 245. [Setting the scene for 5G. Opportunities & challenges](#) (International Telecommunication Unit, 2018)
 - 246. [Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries](#) (United Nations Conference on Trade and Development, 2019)
 - 247. [Future possibilities report 2020](#) (UAE Government, 2020)
 - 248. [5G Infrastructure Market Size, Share & COVID-19 Impact Analysis, By Communication Infrastructure](#) (*Fortune Business Insights*, 2020)
 - 249. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)



Services moving online

The development of digital technologies such as '5G', 'Internet of Things', 'Artificial intelligence', machine learning and big data, is leading to an increasing number of services moving online (we define services here as the result of interactions/activities performed between a supplier and a customer/user). Such services include business activities (including business to business), finance, e-commerce, education, healthcare, and the entertainment industry with e-sports, 'Extended reality' gaming and e-tourism. While such a shift towards online platforms can positively increase accessibility and connectivity, it can also increase digital inequalities and cybersecurity issues if left unregulated.

The digitalization of services has strong implication for the future of trade and business interactions: it can make shorter supply chains economically viable, in addition to increasing the market reach of companies with an online presence.²⁵⁰ Some analysts suggest that the digitalization of the economy will significantly increase in the next 20 years, where many global activities will be "digitally intermediated, customized, on demand and globally distributed."²⁵¹ During the period 2020-2021 alone, the pace of change in this trend was significantly accelerated due to the COVID-19 pandemic, which forced many businesses and individuals to both provide and access online services because of social distancing and movement restrictions. In terms of education, this meant the implementation of innovative teaching and learning methods. For healthcare, as communities faced lockdowns and isolation, and hospitals were under pressure to deal with the outbreak, the availability of virtual doctor's appointments and health tracking apps for diagnosis and monitoring enabled a certain continuity of service for the population. For both education and healthcare, the continued

Related trends: 5G, Extended reality, New business models, Quantum technologies, Rise of the middle class, Smart cities, Spread of the Internet, The experience economy

250. Asia Pacific Megatrends 2040 (Commonwealth Scientific and Industrial Research Organisation, 2019)

251. Asia Pacific Megatrends 2040 (Commonwealth Scientific and Industrial Research Organisation, 2019)



development of online services and mobile apps is expected to reduce the pressure on social and healthcare systems around the globe and increase access for vulnerable populations.²⁵²

This evolution towards online services can also provide new business and employment opportunities, especially for developing nations and small and medium sized enterprises (SMEs).^{253,254} As it stands, the African region is very active in investing for the future, with countries spending over 1% of their GDP on digital investments, and young generations especially embracing change by launching start-ups (online and apps), including, for example, mobile, banking services in Kenya. Overall, both public and private initiatives for digital platforms are emerging to offer products and services online.²⁵⁵ The effect of digitalizing some sectors will, of course, also disrupt the job market negatively, reducing the need for certain jobs. However, studies suggest that “the vast majority of jobs of the future do not exist yet”, which leaves space for adaptation to the new job market needs created by the online services sector.²⁵⁶

At the same time, the recent expansion of digitalized human interactions and online services can also exacerbate or create new inequalities. When workplaces and schools moved their operations online during the COVID-19 pandemic, those that lacked the digital knowledge and skills, the practical tools, or the available infrastructures (e.g. laptop computers and Internet connectivity – see ‘[Spread of the Internet](#)’) to successfully transition, were at risk of being excluded.²⁵⁷ These digital inequalities are growing, not only between, but also within countries, with age and socio-economic status being key players (see ‘[Diversifying inequalities](#)’).

In addition, the development of online services can be linked to power concentration and monopolies. A few digital platforms are getting most of the benefits from services moving online, and have strengthened their position thanks to the pandemic, making it difficult for new providers to enter the market.²⁵⁸ “Digital power concentration could confine political and societal discourse to a limited number of platforms that have the capability of filtering information and further reduce the already limited agency of

252. [Ten trends that will shape science in the 2020s. Medicine gets trippy, solar takes over, and humanity—finally, maybe—goes back to the moon](#) (*Smithsonian Magazine*, 2020)

253. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

254. [Global trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)

255. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)

256. [Global trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)

257. [The Global Risks Report 2021](#) (World Economic Forum, 2021)

258. [Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries](#) (UN Conference on Trade and Development, 2019)



individuals and organizations over how their data are used.²⁵⁹ This leads to an increase in regulatory pressure from governments to protect online consumer rights by targeting anti-competitive behaviour and monopolization, ensuring providers' responsibility for aspects such as illegal activities on their platforms, and the protection of privacy.

Relevant ISO technical committees and standards

- ④ ISO/TC 312, *Excellence in service*
 - ISO 23592:2021, *Service excellence – Principles and model*
 - ISO/TS 24082:2021, *Service excellence – Designing excellent service to achieve outstanding customer experiences*
- ④ ISO/IEC JTC 1/SC 36, *Information technology for learning, education, and training*
 - ISO/IEC 23127-1:2021, *Information technology – Learning, education, and training – Metadata for facilitators of online learning – Part 1: Framework*
- ④ ISO/TC 68/SC 9, *Information exchange for financial services*
 - ISO/TS 23029:2020, *Web-service-based application programming interface (WAPI) in financial services*
- ④ ISO/TC 133, *Clothing sizing systems*
 - ISO 18825-1:2016, *Clothing – Digital fittings – Part 1: Vocabulary and terminology used for the virtual human body*



Relevant ISO news stories

- ISO - QR traffic light to help stop COVID-19
- ISO - New standard for consumer warranties keeps everyone in the supply chain on the same page
- ISO - Service standards are on trend in the latest *ISOfocus*

259. The Global Risks Report 2021 (World Economic Forum, 2021)

→ ISO/TC 154, *Processes, data elements and documents in commerce, industry and administration*

- ISO 19626-1:2020, *Processes, data elements and documents in commerce, industry and administration – Trusted communication platforms for electronic documents – Part 1: Fundamentals*
- ISO 20415:2019, *Trusted mobile e-document framework – Requirements, functionality and criteria for ensuring reliable and safe mobile e-business*

→ ISO/TC 290, *Online reputation*

- ISO 20488:2018, *Online consumer reviews – Principles and requirements for their collection, moderation and publication*

→ ISO/TC 321, *Transaction assurance in E-commerce*

- ISO/WD 32120, *Guidelines on sharing of product quality assurance related traceability information in E-commerce supply chains*



Cyber-physical systems

Robotics | Autonomous vehicles | Internet of Things | Smart cities

Cyber-physical systems integrate computational components (information processing) with physical processes, which interact through a network. Technological advances in the 'Internet of Things', 'Robotics', and 'Autonomous vehicles' are the foundation for making cyber-physical systems possible, and today there are examples of successful cyber-physical systems everywhere... from driver less trains, to smart buildings, to household appliances and everyday items such as cleaning robots, wearable fitness devices or electric bikes.

Cyber-physical systems provide an opportunity to positively improve our quality of life in many domains, ranging from transportation, to healthcare, farming, manufacturing, smart grids, and everyday living. A key challenge, however, is the need for engineering innovation to work in coordination with information technology innovation, as the physical meets the digital. Developing common languages and other commonalities in this pluri-disciplinary field will facilitate future development of these systems. In addition, as with many technological advances, unintended consequences of integrating cyber-physical systems are likely to emerge in future, and it is therefore important to think ahead about the ethics surrounding these systems and how future regulation can limit risks related to safety, responsibility, liability, privacy and more.



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Foreword

Society

Technology

Environment

Economy

Politics

Science

Where to from here?

Robotics

Robotics technology is developing quickly and is already able to replace human labour for a range of tasks. Vast improvements in the capabilities of robots are expected to continue and this will lead to changes across many industries^{260,261,262}:

- Healthcare will benefit from the increased use of robots in basic medicine and diagnostics, reducing costs for individuals and the economic burden of publicly funded health services.²⁶³
- Robots will continue to take over human labour in manufacturing, displacing workers as a result – the pace of technological development may create extreme pressures on education and training systems to support the adaptation of workforces (see '[Effects of automation](#)').^{264,265} However, robotics is also expected to lead to new types of work²⁶⁶, as large numbers of robotics technicians will be required to maintain these 'fleets of robots' and the data generated and collected by robots will be immense, leading to growing demand for data scientists to make use of it.²⁶⁷

Related trends: [Artificial intelligence](#), [Autonomous vehicles](#), [Customized products](#), [Effects of automation](#), [Ethics of technology](#), [Internet of Things](#)

260. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)

261. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)

262. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)

263. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)

264. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)

265. [Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries](#) (UN Conference on Trade and Development, 2019)

266. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)

267. [Technology vision 2020. We, the post-digital people](#) (Accenture, 2020)



- The agricultural sector will increasingly use robots for manual tasks such as seeding, weeding, and harvesting, with sensors improving in their ability to identify ripe produce, harvest plants and detect disease.²⁶⁸
- A range of military applications is anticipated, raising increasingly complex ethical questions. If terrorist organizations and non-state armed groups have access to this technology, it will increase the complexity of conflict.²⁶⁹
- The automotive and transportation sector will move towards increasing production and use of 'Autonomous vehicles', made possible by advances in robotics and other emerging technologies (see '5G').²⁷⁰ The carsharing company Uber, for example, is currently expanding its driverless-car programme. This may lead to a reduction in private car ownership and use.²⁷¹

As robots increase in power, their applications are likely to grow. Computing for robots is now possible in the Cloud, increasing their processing power and speed.²⁷² Advances in sensors, speech-recognition technology and computer vision will all contribute to more advanced robotics products, including robots that are able to operate in uncontrolled settings – known as 'open-world autonomy'.²⁷³

268. Technology vision 2020. We, the post-digital people (Accenture, 2020)

269. Global risks 2035 update. Decline or new renaissance? (Atlantic Council, 2019)

270. Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries (UN Conference on Trade and Development, 2019)

271. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)

272. 20 New technology trends we will see in the 2020s (BBC Science Focus Magazine, 2020)

273. Technology vision 2020. We, the post-digital people (Accenture, 2020)



Relevant ISO technical committees and standards

→ ISO/TC 299, Robotics

- ISO/CD 5363, *Robotics – Test methods for Exoskeleton-type Walking RACA Robot*
- ISO 8373:2021, *Robotics – Vocabulary*
- ISO 10218-1:2011, *Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots*
- ISO 10218-2:2011, *Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration*
- ISO 11593:2022, *Robots for industrial environments – Automatic end effector exchange systems – Vocabulary*
- ISO 13482:2014, *Robots and robotic devices – Safety requirements for personal care robots*
- ISO/TS 15066:2016, *Robots and robotic devices – Collaborative robots*



Relevant ISO news stories

- ISO - Robots to the rescue!
- ISO - Robots and humans can work together with new ISO guidance
- ISO - Enter the first cyborg-type robot



Autonomous vehicles

Autonomous vehicle technology is not a one-size-fits-all concept, as there are different considerations and implications for road, ship, or rail transport. The degree of automation can vary as well, and classified in ranges from Level 0 (fully manual) to Level 5 (driverless). The following discussion explores autonomous vehicles as a high-level trend only, where autonomous vehicles are understood as all forms of driverless transport systems.

Autonomous vehicles are already used in industrial settings, in some public transport systems (e.g. driverless trains), and automation technology is increasingly integrated in our cars (e.g. cruise control, self-parking technology or traffic jam pilot).^{274,275} While the autonomous vehicle market is growing as a whole, with an expected CAGR of over 39% from 2019 to 2026, the deployment of fully automated (driverless) vehicles on public roads is still years away.^{276,277} The impact of more autonomous vehicles is likely to be double-sided. They may eliminate the need for drivers of vehicles of all kinds: trucks, taxis, and public transport vehicles, representing a significant labour force impact in the coming decades.²⁷⁸ At the same time, they may create opportunities for more efficient transport of goods and people to regional areas.²⁷⁹ Indeed, a significant, expected benefit to society is improved population mobility due to use of autonomous vehicles for public transport, particularly in rural areas.²⁸⁰

Related trends: Artificial intelligence, Cyber-vulnerability, Effects of automation, Ethics of technology, Quantum technologies, Robotics, Smart cities, Urbanization

274. AGCS trend compass (Allianz, 2019)

275. Global Connectivity Outlook to 2030 (World Bank, 2019)

276. What Are the Levels of Automated Driving? (Aptiv, 2020)

277. Future possibilities report 2020 (UAE Government, 2020)

278. Global trends. Paradox of progress (US National Intelligence Council, 2017)

279. Global Connectivity Outlook to 2030 (World Bank, 2019)

280. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)



Existing data on use of autonomous vehicles suggests they can reduce both safety incidents and fuel expenditure.²⁸¹ Autonomous vehicles are expected to make trade corridors significantly more efficient and, when combined with the energy efficiency of electric vehicles, increase the competitiveness of road transport against rail for the delivery of goods.²⁸²

Technology is also developing for autonomous vehicles beyond the road. Future innovations could include autonomous cargo ships and planes leading to more efficient supply chains in international trade.²⁸³

281. AGCS trend compass (Allianz, 2019)

282. Global Connectivity Outlook to 2030 (World Bank, 2019)

283. AGCS trend compass (Allianz, 2019)



Relevant ISO technical committees and standards

- ⇒ **ISO/TC 241, Road traffic safety management systems**
 - ISO/CD 39003, Road Traffic Safety (RTS) – Guidance on safety ethical considerations for autonomous vehicles
- ⇒ **ISO/TC 22, Road vehicles**
 - ISO/TR 4804:2020, Road vehicles – Safety and cybersecurity for automated driving systems – Design, verification and validation
- ⇒ **ISO/TC 127, Earth-moving machinery**
 - ISO 17757:2019, Earth-moving machinery and mining – Autonomous and semi-autonomous machine system safety
- ⇒ **ISO/TC 204, Intelligent transport systems**
 - ISO 22737:2021, Intelligent transport systems – Low speed automated driving systems for predefined routes
- ⇒ **ISO/TC 268, Sustainable cities and communities**
 - ISO/FDIS 37181, Smart community infrastructures – Smart transportation by autonomous vehicles on public roads



Relevant ISO news stories

- ISO - Low speed automated driving systems
- ISO - Unearthing the potential of autonomous mining with ISO 17757



Internet of Things

The IoT refers to a system of interconnected devices embedded with software, sensors, and other technologies (such as digital twin, cloud computing, big data and 'Artificial intelligence'), which allows them to exchange data over the Internet for the purpose of improving functionality and monitoring. IoT systems are software and data-intensive, as well as network centric. They can be quite complex, ranging from simple architecture to systems which are multi-tiered, distributed, and 'Cyber-physical systems'. IoT systems are key enablers of 'smart everything', including smart homes and buildings, 'Smart manufacturing', 'Smart cities', and smart farming, but also wearable technologies, medical devices, and vehicles.²⁸⁴ Currently, there are twice as many devices connected to the Internet as people, and IoT connections are still expected grow at 17% per year.^{285,286} Experts predict that, by 2025, an average Internet user will be interacting with IoT devices nearly 4,900 times each day.²⁸⁷

This increased device connectivity will result in massive amounts of data, creating growing needs for data storage, analytical capacity, and data protection. The data gathered by these devices can contribute to improved strategies to reduce poverty in some contexts, as well as increased sustainability and environmental protection. However, the IoT could also pose risks, if data are not sufficiently protected, or if it is used for unethical purposes.²⁸⁸

Related trends: Artificial intelligence, Cyber-vulnerability, Data privacy, Edge computing, Energy storage and distribution, Robotics, Smart cities, Spread of the Internet

284. Future possibilities report 2020 (UAE Government, 2020)

285. Future possibilities report 2020 (UAE Government, 2020)

286. Digital Economy Report 2019. Value creation and capture: implications for developing countries (UN Conference on Trade and Development, 2019)

287. Digital Economy Report 2019. Value Creation and Capture: Implications for Developing Countries (UN Conference on Trade and Development, 2019)

288. Foresight Africa. Top priorities for the continent 2020-2030 (Brookings Institution, 2020)



The rollout of emerging communications and networking technologies such as '5G' and satellite IoT will increase the reach, efficiency, and capacity of IoT devices, further growing the demand for these products.^{289,290} For example, improved IoT technology and increased connectivity are already fostering the development of remote surgery technologies, which will "bring previously inaccessible healthcare to worldwide populations."²⁹¹

289. Future possibilities report 2020 (UAE Government, 2020)

290. Technology vision 2020. We, the post-digital people (Accenture, 2020)

291. Technology vision 2020. We, the post-digital people (Accenture, 2020)



Relevant ISO technical committees and standards

→ ISO/IEC JTC 1/SC 41, Internet of things and digital twin

- ISO/IEC 20924:2021, *Information technology – Internet of Things (IoT) – Vocabulary*
- ISO/IEC 21823-1:2019, *Internet of things (IoT) – Interoperability for IoT systems – Part 1: Framework*
- ISO/IEC 21823-2:2020, *Internet of things (IoT) – Interoperability for IoT systems – Part 2: Transport interoperability*
- ISO/IEC 21823-3:2021, *Internet of things (IoT) – Interoperability for IoT systems – Part 3: Semantic interoperability*
- ISO/IEC 21823-4:2022, *Internet of things (IoT) – Interoperability for IoT systems – Part 4: Syntactic interoperability*
- ISO/IEC 30141:2018, *Internet of Things (IoT) – Reference architecture*
- ISO/IEC 30147:2021, *Information technology – Internet of things – Methodology for trustworthiness of IoT system/service*
- ISO/IEC 30162:2022, *Internet of Things (IoT) – Compatibility requirements and model for devices within industrial IoT systems*
- ISO/IEC 30165:2021, *Internet of Things (IoT) – Real-time IoT framework*

→ ISO/IEC JTC 1/SC 27, Information security, cybersecurity and privacy protection

- ISO/IEC 27001:2013, *Information technology – Security techniques – Information security management systems – Requirements*
- ISO/IEC 27701:2019, *Security techniques – Extension to ISO/IEC 27001, and ISO/IEC 27002, for privacy information management – Requirements and guidelines*



Relevant ISO news stories

- ISO - Standards hat trick for the Internet of Things
- ISO - Reference framework for the Internet of Things
- ISO - Are we safe in the Internet of Things?
- ISO - How the Internet of Things will change our lives
- ISO - On the road to transport connectivity
- ISO - The next frontier for business



Smart cities

Cities are the future of human organization, with over two-thirds of the global population expected to live in urban areas by 2030.²⁹² This raises significant challenges, including the allocation of resources to growing populations and the management of their consumption and waste. Smart cities are rising to address these challenges by integrating smart technologies to address citizens' needs more safely, sustainably, and efficiently, from goods and services to transport and logistics management. *The World Economic Forum*²⁹³ predicts that the technological tipping point for smart cities – that is, when they move from being novel entities to representing the norm – could occur as early as 2026.

'Smart' can mean different things to different people. In ISO, a 'smart city' is considered to be one with "effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens" (ISO/IEC 30182:2017, 2.14). Another helpful way to understand it is to look at smart as having three pillars: digital, physical, and economic. Digitally smart refers to the effective deployment of digital and communication technologies for city management. Physically smart refers to the adjustment and construction of sustainable infrastructures and processes that enhance the city's resilience and the residents' quality of life. Finally, economically smart refers to the effective collaboration between citizens and local businesses to share assets and resources to build a resilient community.²⁹⁴ The evolution of smart cities is closely linked to innovation in '[Internet of Things](#)', '[5G](#)' and DARQ technologies, '[Distributed ledger](#)', '[Artificial intelligence](#)', '[Extended](#)

Related trends: [5G](#),
[Autonomous vehicles](#),
[Energy storage and distribution](#), [Spread of the Internet](#), [Urbanization](#)

292. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)

293. [Global Trends to 2030. Challenges and choices for Europe](#) (European Strategy and Policy Analysis System, 2019)

294. [Technology outlook 2030. Technology & society](#) (Det Norske Veritas, 2021)



reality', 'Quantum computing', which are essential in supporting the deployment of smart cities around the globe.²⁹⁵

Smart cities can both improve the living conditions of residents and support more sustainable living arrangements. They do this by integrating smart grids (see 'Energy'), energy-saving construction materials and buildings, efficient digital management systems for waste and other logistical needs and services to citizens.²⁹⁶ This results in a more efficient use of resources and resilient, better-connected systems. However, with this increased connectivity also brings risks related to privacy and big data sharing. Because a smart city depends on a highly interdependent connected network, this increases the risk that a security breach, hacking or technical issue such as a power cut could affect the entire system, with repercussions in all sectors.^{297,298} There is also a concern about the 'Big Brother' dilemma – for smart technology to efficiently relay information and adapt systems to residents' needs, big data must be collected using things like cameras, sensors, and IoT tools.²⁹⁹

To maintain citizens' trust in the smart city concept, effective policies and regulations will be needed to protect residents' privacy and personal information. Standardization plays an important role towards bringing trust amongst citizens, thanks to transparency and open processes, which is key for citizens acceptance and confidence.

295. Technology vision 2020. We, the post-digital people (Accenture, 2020)

296. AGCS trend compass (Allianz, 2019)

297. Beyond the Noise. The Megatrends of Tomorrow's World (Deloitte, 2017)

298. Emerging Technologies And Smart Cities (Forbes, 2021)

299. Digital megatrends. A perspective on the coming decade of digital disruption (Commonwealth Scientific and Industrial Research Organisation, 2019)



Relevant ISO technical committees and standards

- ISO/TC 268, Sustainable cities and communities
 - ISO 37106:2021, Sustainable cities and communities – Guidance on establishing smart city operating models for sustainable communities
 - ISO 37122:2019, Sustainable cities and communities – Indicators for smart cities
 - ISO 37123:2019, Sustainable cities and communities – Indicators for resilient cities
- ISO/IEC JTC 1/WG 11, Smart cities
 - ISO/IEC 24039, Information technology – Smart city digital platform reference architecture – Data and service
 - ISO/IEC 30182:2017, Smart city concept model – Guidance for establishing a model for data interoperability
- ISO/TC 59/SC 17, Sustainability in buildings and civil engineering work
 - ISO 21678:2020, Sustainability in buildings and civil engineering works – Indicators and benchmarks – Principles, requirements and guidelines
- ISO/TC 205, Building environment design
 - ISO 17800:2017, Facility smart grid information model
- ISO/TMBG, Technical Management Board - groups
 - ISO/TMBG/JSCTF-TF 19, ISO, IEC and ITU Joint Smart Cities Task Force



Relevant ISO news stories

- ISO - Sustainable Cities and Communities
- ISO - How do we build sustainable cities of the future?
- ISO - Protecting our privacy in smart cities
- ISO - Building better cities for a net-zero carbon future
- ISO - Riding the bus the smart way
- ISO - Smart cities to benefit from new international standards task force
- ISO - The future looks smart
- ISO - Designing tomorrow's cities today
- ISO - Grenoble: the sustainable city
- ISO - Building resilient cities with new International Standard
- ISO - Changing the world with ISO standards on World Cities Day
- ISO - New International Standard for measuring the performance of cities going "smart"
- ISO - Standards cooperation is key to making AI and smart cities a reality
- ISO - Stronger cities for the future: a new set of International Standards just out
- ISO - The city of the future will be shaped by standards



Smart manufacturing

New generation plastics | Additive manufacturing

Smart manufacturing refers to multiple ‘new normals’ in the context of manufacturing – that is, how industry will leverage the application of new disruptive technologies such as ‘Artificial intelligence’, ‘Edge computing’, ‘Robotics’, ‘Additive manufacturing’ (3D printing), ‘Gene editing’ and the ‘Internet of Things’, to change the face of traditional manufacturing. Smart manufacturing has been described as a “fusion of the digital, biological and physical world”³⁰⁰ and represents a change that is so significant that it is sometimes referred to as the ‘fourth industrial revolution’.³⁰¹ Smart manufacturing could represent an important opportunity to boost sustainable manufacturing and, as its implementation expands, it will be essential to develop a better understanding of how it can contribute to sustainable development while improving system efficiency.³⁰² Below, we explore one industry that will hopefully benefit from smart manufacturing to increase sustainability (the plastics industry), and one key enabler of smart manufacturing that is undergoing rapid development and expansion (additive manufacturing).



300. Foresight Africa. Top priorities for the continent 2020-2030 (Brookings Institution, 2020)

301. White paper on smart manufacturing (ISO Smart Manufacturing Coordinating Committee, 2021)

302. Sustainable and smart manufacturing: an integrated approach (Sustainability, 2020)

New generation plastics

Today's plastics, with a predominantly linear material flow, unquestionably face challenges, both regarding CO₂-emissions due to their fossil-basis, and to plastic pollution (unintended leakage and subsequent accumulation of plastics in the environment or even the human body). The question is, how will we ensure we have the materials for the future without compounding these problems?

Many companies are developing alternatives based on renewable, biomass materials, including e.g. flax, mushrooms, and shrimp shells.^{303,304} The formulation of existing plastics can also be changed to make them more degradable³⁰⁵ and, finally, innovations in recycling technologies will make manufacturing the materials of the future more sustainable.

As one of the largest sectors in the manufacturing industry, innovations in plastic production systems themselves are also a key driver of change. The data collected by more efficient sensors and smart machinery (see '[Internet of Things](#)') can improve the consistency of products, limiting defects (and ultimately reducing plastic pollution), reducing energy consumption and costs, and improving competitiveness.^{306,307}

Related trends:
**Additive manufacturing,
Sustainable production**

303. [Ten Trends That Will Shape Science in the 2020s. Medicine gets trippy, solar takes over, and humanity – finally, maybe – goes back to the moon \(Smithsonian Magazine, 2020\)](#)

304. [Global Trends to 2030. Challenges and choices for Europe \(European Strategy and Policy Analysis System, 2019\)](#)

305. [Global Trends to 2030. Challenges and choices for Europe \(European Strategy and Policy Analysis System, 2019\)](#)

306. [Smart Manufacturing in Plastic Injection Molding \(Manufacturing Tomorrow, 2017\)](#)

307. [Smart Manufacturing in Plastic Injection Molding \(Manufacturing Tomorrow, 2021\)](#)



Relevant ISO technical committees and standards

→ ISO/TC 61, Plastics

- ISO 16620-1:2015, *Plastics – Biobased content – Part 1: General principles*
- ISO 17088:2021, *Plastics – Organic recycling – Specifications for compostable plastics*



Relevant ISO news stories

- ISO - Rethinking the future of plastics
- ISO - Winning the battle against plastic pollution with International Standards on World Environment Day!



Additive manufacturing

Additive manufacturing produces objects through a process of layering together raw materials. This is different to traditional (subtractive) manufacturing, which creates parts out of raw materials.³⁰⁸ Additive manufacturing is widely known as '3D printing', but this style of manufacturing also includes '4D printing', an emerging approach that allows the manufacture of products that respond to things like heat, light, and the passing of time.³⁰⁹

The use of additive manufacturing is expected to increase, with many new applications for both commercial and personal use. The ability to print products for personal use will open markets for blueprints and designs, while increasing the customization options available to consumers (see 'Customized products'). A potentially endless range of products could be manufactured using additive methods, including machinery parts, consumer goods such as shoes and furniture and healthcare products like hearing aids and prosthetics.^{310,311}

If additive manufacturing grows, we can expect an increased impact on trade – perhaps a reduction in the transport of goods, along with an increase in the transport of raw materials. Overall, this would be expected to reduce global freight volume.³¹²

Of course, additive manufacturing has some challenges, such as ensuring cybersecurity and management of intellectual property. Companies and governments will need to be attentive to emerging issues to ensure the benefits of additive manufacturing are enjoyed by all.

Related trends: Customized products, Changing trade patterns, New generation plastics, Sustainable production

308. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

309. [2021 Tech trends report. Strategic trends that will influence business, government, education, media and society in the coming year](#) (Future Today Institute, 2021)

310. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

311. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

312. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)



Relevant ISO technical committees and standards

→ ISO/TC 261, Additive manufacturing

- ISO/ASTM 52900:2021, *Additive manufacturing – General principles – Fundamentals and vocabulary*
- ISO/ASTM CD TR 52918, *Additive manufacturing – Data formats – File format support, ecosystem and evolutions*

→ ISO/IEC JTC 1, Information technology

- ISO/IEC DIS 3532-2, *Information technology – 3D Printing and scanning – Medical image-based modelling – Part 2: Segmentation*
- ISO/IEC 23510:2021, *Information technology – 3D printing and scanning – Framework for an Additive Manufacturing Service Platform (AMSP)*

→ ISO/TC 184, Automation systems and integration

- ISO/IEC TR 63306-1:2020, *Smart manufacturing standards map (SM2) – Part 1: Framework*
- ISO/IEC TR 63306-2:2021, *Smart manufacturing standards map (SM2) – Part 2: Catalogue*

→ ISO/TMBG, Technical Management Board – groups

- ISO/TMBG/SMCC, ISO Smart Manufacturing Coordination Committee
- White paper on Smart Manufacturing



Relevant ISO news stories

- ISO - Silent game changers of the tech revolution
- ISO - ISO and ASTM International unveil framework for creating global additive manufacturing standards
- ISO - Manufacturing our 3D future
- White paper on Smart Manufacturing



Environment



Energy



Environmental degradation

Energy

Energy sources | Energy storage and distribution

Global energy use is increasing dramatically, primarily driven by increasing demand for electricity. In addition, energy-related CO₂ emissions are too high to meet international commitments to the climate agenda by 2050. The only path to success will be through technological innovations leading to energy savings, low/zero carbon energy sources, carbon capture, and greater energy efficiency (see '[Environmental degradation](#)' for more on resource management and carbon storage).

The number of potential power sources is expected to increase over the next 30 years, as technological innovations in energy production and storage make renewables and new generation batteries cheaper and more efficient. Changes in electricity markets, such as growth in developing countries and regionalization of energy systems, will set the scene for future evolutions in the sector.

Although energy trends involve significant technological and societal aspects, they have been included in the environment section of this trend report because the evolution of the energy sector is so interdependent with the global climate agenda 2050. From greenhouse gas (GHG) emissions reduction to energy efficiency and the increased use of renewable-energy sources for power, heat or fuel, future innovations and standardization work in the energy sector must take a sustainability lens.

Energy as a mega trend has a multiplicity of facets, not all of which can be included in this report. We focus our discussion on energy issues including the diversification of energy sources, and innovations in access, storage, and distribution of energy, with a strong focus on the transport sector and electricity market developments.



Energy sources

The demand for energy continues to rise, linked to demographic and economic growth, especially in the transport, industry, and construction sectors.³¹³ With developing countries' growing energy needs, it is expected that global energy demand will rise by 40-60% by 2050³¹⁴ if we do not make additional energy savings.³¹⁵

In parallel, the increasing awareness, pressure and need to reduce emissions and improve energy security demonstrate the need to reconsider energy production and use patterns across the globe. Already, the diversification of energy sources highlights progress in this area, with wind, solar, water, nuclear fusion, geothermal, bioenergy and others paving the way towards low-carbon economies.

By 'energy sources', we consider here the resources or technical systems from which energy can be extracted or recovered to be transported by a medium such as fuel or electricity (see ISO/IEC 13273, all parts). Although batteries technically fit this definition, they will be reviewed in the Energy Storage section of this report.

Related trends: **Natural resource scarcity, Sustainable production**

313. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

314. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

315. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)



Towards decarbonization

While progress has been made worldwide to address climate targets, the constantly increasing energy needs of our global economy mean that GHG emission levels will need to fall by two-thirds by 2050 to remain on track with Paris Agreement targets, highlighting the urgency of decarbonization and energy-saving measures.³¹⁶

Developments in renewable technologies show promise, and renewables are the fastest growing means of energy production globally with countries like China, the US, Germany, France, and Spain investing heavily in these technologies.³¹⁷ By renewables, we mean all sources of energy that are not depleted upon extraction, because they replenish at a rate faster than extraction can occur. This includes solar, wind, hydro, and geothermal power sources. As economies become more reliant on electricity as a key energy carrier, renewables could, in combination with nuclear energy, provide over half of total electricity generation capacity by 2050.³¹⁸

In addition, renewables are becoming competitive with fossil fuels faster than expected as prices drop, which has already started to

disrupt the global energy sector.³¹⁹ The costs of producing solar energy in particular is expected to continue to fall as third generation photovoltaics (designed for high power conversion efficiency, low cost and efficient use of material) and concentrated solar power (CSP), using focused sunlight to generate heat and energy through conventional steam turbines, continue to develop.³²⁰

Another alternative to fossil fuel that may play a significant role in the decarbonization process is nuclear energy through fission. Although nuclear energy production is unpopular in some countries due to the radioactive waste it creates and its connection to several recent accidents, it is nevertheless expected to increase in the future, with countries like China, India, South Korea and Finland planning to continue using nuclear power.³²¹ In addition, technological innovations mean fusion fuel (deuterium and tritium) can now also be extracted more sustainably from water and sea water, and guidelines on waste management should increase its popularity in the future.³²²

316. Global Connectivity Outlook to 2030 (World Bank, 2019)

317. Future Foresight. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

318. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

319. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)

320. Global Connectivity Outlook to 2030 (World Bank, 2019)

321. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)

322. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)



The future of fossil fuels

Current low-emission and renewable technologies cannot keep up with increasing global energy demand.³²³ As a result, dependence on the use of coal and oil is likely to continue for the next 20 years, with projections showing that hydrocarbons might still meet around 70% of overall energy demand by 2050, even though demand is also expected to decelerate in the 2040s.^{324,325}

Trade routes may shift, however, as countries in Europe reduce their reliance on fossil fuels and energy demand increases in emerging economies (especially with an expected growth in the number of cars), leading to a rise in oil trade between Asia and the Middle East.³²⁶ Asia might become the largest global market for oil exports, with scenarios suggesting that around 75% of the world's oil will be used in Asia, and China will likely consume more oil than the US as early as 2030.³²⁷

The risk of continuing to rely on fossil fuel is that as demand for energy and resources grow, competition will increase to access lowering supplies, which could lead to conflict and international disputes.³²⁸ Technological advances to open up new energy sources and to make renewable-energy exploitation more efficient and cost-effective can address this challenge in the long run.

At the same time, transition away from coal is predicted with renewables like wind, solar and hydropower to surpass coal as the main source of electricity by 2030.³²⁹ Recent announcements during the 2021 United Nations Climate Change Conference (COP 26) seem to support this prediction, with China and the US announcing a collaboration on environmental standards related to reducing emissions of GHGs in the 2020s.³³⁰

323. Global risks 2035 update. Decline or new renaissance? (Atlantic Council, 2019)

324. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

325. Global Trends to 2030. Challenges and choices for Europe (European Strategy and Policy Analysis System, 2019)

326. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)

327. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

328. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

329. Ten Trends That Will Shape Science in the 2020s (Smithsonian Magazine, 2020)

330. U.S.-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s (U.S. Department of State, 2021)



The case of shale oil and gas, and liquid natural gas

Shale oil and gas (extracted using fracking), and liquid natural gas (LNG) are also increasingly relied on as fossil energy sources. While they have been used for years, recent technological innovations have opened more commercially-viable reserves globally. This has shifted the balance of power from traditional oil exporters, to the US, for example, which is now the world's leading oil producer.^{331,332} As a region, southwest Asia/the Middle East is still expected to remain the largest hydrocarbon-based producing region in the next decades, but these countries are likely to become net energy importers as reliance on fossil fuel decreases.³³³ In this context, it is predicted that LNG will become a key export resource.

The continued expansion of fracking will, however, strongly depend on the evolution of international efforts towards a low-carbon economy³³⁴, as drilling involves vast amounts of water, can contaminate groundwater and release harmful GHGs. With the COP 26 commitment of Ford, GM and four other automakers as well as thirty governments to phase out sales of new gasoline and diesel-

fuelled vehicles by 2040, it is likely there will be pressure to increase investment in renewables rather than in shale oil/gas and LNG.³³⁵

Conclusion

The strategy of shifting to sustainable energy sources could dramatically change the outlook of the energy sector and our capacity to limit climate change.³³⁶ However, although renewable sources of energy evolve rapidly, they are unlikely to sustain demand unless radical/disruptive innovations make them cheaper and more efficient, in combination with international agreements to impose emissions standards and subsidies to support the transition.

A key opportunity for the future is to consider green energy and alternative energy sources as a competitive advantage, rather than a costly transition, representing opportunities for development and job creation in future economies.^{337, 338}

331. Latin America and the Caribbean 2030. Future Scenarios (Inter-American Development Bank, 2016)

332. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

333. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

334. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

335. 6 Automakers and 30 Countries Say They'll Phase Out Gasoline Car (New York Times, 2021)

336. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)

337. Global Trends to 2030. Challenges and choices for Europe (European Strategy and Policy Analysis System, 2019)

338. Global Trends and the future of Latin America. Why and how Latin America should think about the future (Inter-American Development Bank, Inter-American Dialogue, 2016)



Relevant ISO technical committees and standards

- ISO/TC 301, *Energy management and energy savings*
 - ISO/IEC 13273-1:2015, *Energy efficiency and renewable energy sources – Common international terminology – Part 1: Energy efficiency*
 - ISO/IEC 13273-2:2015, *Energy efficiency and renewable energy sources – Common international terminology – Part 2: Renewable energy sources*
- ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*
 - ISO/TR 4450:2020, *Quality management systems – Guidance for the application of ISO 19443:2018,*
 - ISO/ASTM 51276:2019, *Practice for use of a polymethylmethacrylate dosimetry system*
- ISO/TC 197, *Hydrogen technologies*
 - ISO/CD 19885-1, *Gaseous hydrogen – Fuelling protocols for hydrogen-fuelled vehicles – Part 1: Design and development process for fuelling protocols*
- ISO/TC 207/SC 7, *Greenhouse gas management and related activities*
 - ISO/WD 14068, *Greenhouse gas management and related activities – Carbon neutrality*



Relevant ISO news stories

- ISO - Affordable and Clean Energy
- ISO - Climate Action
- ISO - Power of the sun
- ISO - Betting on biomass
- ISO - The rise of energy efficiency



Energy storage

Energy storage encompasses multiple technologies to accumulate or retain energy in either thermal (e.g. solar thermal plants), chemical (current batteries) or mechanical/kinetic (e.g. hydro, or compressed air) systems which can then be released when needed. The desired shift towards a net-zero economy is driving innovation in energy storage and research into direct power conversion.^{339,340} Our increasingly, complex energy sector is supplying more interdependent technologies which will require more efficient and cheaper tools to address energy demand. As a result, innovation in battery technologies, fuel alternatives, energy efficient (smart) appliances/buildings/cities, process energy-improvements (industry), and direct power conversion technologies such as fuel cells should be expected to distribute power to an increasing amount of people in the near future.³⁴¹

Related trends: Internet of Things, Natural resource scarcity, Smart cities

339. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

340. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

341. Future possibilities report 2020 (UAE Government, 2020)



Batteries

Energy storage will play a crucial role in delivering lower-cost renewable energy in a more flexible and reliable manner. A major driver of energy storage technologies is to better integrate intermittent renewable-energy sources into the grid. As intermittency requires another energy source to fill in gaps, energy storage – and large battery banks especially – can provide a solution. The race for leadership in energy storage solutions that increase the market infiltration/diffusion of renewables has already begun, with organizations investing heavily in new battery technologies. Giant battery ‘giga-factories’ are being built around the globe to address the demand, as a testament to this increased interest.

As of today, no battery can store and release significant volumes of electricity in an affordable manner. The next generations of batteries will need improvements to battery life and energy density. Battery production will also need to become cleaner and more efficient.³⁴² Lithium-ion is the current leading battery technology, powering laptops and electric cars alike, but rare and expensive materials required to build these batteries means they also need to evolve. Battery technology has improved significantly over the last two decades and progress continues. Extensive research and development are currently underway to improve battery chemistry

and identify better battery constituents, to allow a greater energy-density at lower costs. Engineers are researching new cathode materials like graphene or hexagonal boron-nitride, and at replacing lithium with sodium, aluminum, or zinc to build cheaper products. Alternative research into solid-state batteries might also pave the way forward. Such changes could lead to smaller batteries that last longer, charge faster and conduct less heat.^{343,344}

A consideration for the future, however, is the cost of energy storage using batteries. Storing and discharging electricity comes at a cost (capital plus energy consumption and losses) which must be added to electricity-production costs. Using power directly can ultimately be cheaper and investing in the efficient distribution and sharing/trading of direct power sources could be a viable alternative long-term investment choice.

342. [Ten Trends That Will Shape Science in the 2020s](#) (*Smithsonian Magazine*, 2020)

343. [Ten Trends That Will Shape Science in the 2020s](#) (*Smithsonian Magazine*, 2020)

344. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)



Power to X – Direct power conversion

Power to X technologies, also known as direct power conversion, are technologies aiming to transform sources of energy (e.g. renewable sources like sunlight or wind and gases like hydrogen and methane) directly into heat, electricity, chemicals, or fuel through a process of electrolysis or synthesis. This energy can then be stored or used to manufacture goods and power various systems.³⁴⁵ Power to X technologies therefore provide potential avenues to help decarbonize energy-intensive industries with high CO₂ emissions, such as construction, manufacturing, and transport.

Green hydrogen has received particular attention for its potential to transform the energy sector, with the International Energy Agency (IEA) highlighting the role it could play in reducing global CO₂ emissions. Green hydrogen is carbon-neutral and is produced using electrolysis from renewable resources, as opposed to the steam reforming of natural gases (fossil fuel) used to produce grey and blue hydrogen. Until recently, the high costs of producing and storing green hydrogen have been a major barrier to its widespread use, but technological advances (e.g. better electrolyzers and surplus electricity) are now making green hydrogen an attractive option³⁴⁶

– trend reports suggest that efficient electrolyzers to produce green hydrogen as cheaply as its grey or blue counterpart could be developed within the next decade.³⁴⁷ In addition, projects such as Gigastack explore the production of green hydrogen at industrial scale, integrating electrolyzers directly into offshore wind farms to produce green hydrogen.³⁴⁸

Challenges remain however for the efficient storage and conversion of hydrogen and other Power to X innovations, and existing infrastructure will need updating to effectively integrate these technologies.³⁴⁹ A current transition strategy for lower-carbon fuel sources is the integration of hydrogen into natural-gas networks (to prepare for the development of power-to-gas processes), which improves the energy efficiency of the resulting fuel mixture.³⁵⁰

345. Future technology for prosperity. Horizon scanning by Europe's technology leaders (European Commission, 2019)

346. Top 10 Emerging Technologies of 2020 (World Economic Forum, 2020)

347. Top 10 Emerging Technologies of 2020 (World Economic Forum, 2020)

348. Top 10 Emerging Technologies of 2020 (World Economic Forum, 2020)

349. Future technology for prosperity. Horizon scanning by Europe's technology leaders (European Commission, 2019)

350. Technical and economic conditions for injecting hydrogen into natural gas networks (GRTgaz, 2019)



Fuel substitution

According to some forecasts, energy use in the transport sector might rise by 45% of 2010 figures by 2040.³⁵¹ Improving energy efficiency and transitioning to alternative technologies to power the transport sector is therefore essential to achieve GHG reduction targets and reduce overall power consumption.

The desire to shift our energy use away from fossil fuels has propelled research into ‘clean cars’, which are leading innovation in energy storage and distribution, with vehicles readily available in some markets. Clean cars can be defined as electrically-propelled vehicles using hydrogen fuel cells, batteries or a combination of methods also known as hybrid. This last category does, however, still rely partly on combustion engines, so considering them as clean is debatable. The main challenges facing clean cars are ensuring fuel economy for consumers, delivering performance and reliability at a cost competitive with conventional vehicles, and ensuring that electrical grids have the capacity to cope with the increased demand from clean cars. However, the emergence of clean cars also opens up possibilities of using the transport network as distributed-energy storage system within future smart grids.^{352,353} In such a system,

electric cars could act as batteries to absorb grid excess power during times of low demand and reinject energy in power grids at peak hours.³⁵⁴

Hybrid and electric engines should soon become the norm for personal vehicles and are expected to successfully compete with internal combustion engines by 2030 thanks to new generation batteries.³⁵⁵ Similarly, the rise of shale gas and biofuels suggests the share of natural-gas powered vehicles could also increase in regions where it is abundant (and therefore cheaper), though difficulties in storing natural gas (pressurized tanks) is a challenge that still needs addressing. The shape of the private-vehicle market and which system take the lead will strongly depend on incoming innovations and be driven by consumer choices in developing countries.³⁵⁶

351. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

352. [Future possibilities report 2020](#) (UAE Government, 2020)

353. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

354. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

355. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

356. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)



Commercial fleets, however, are still likely to rely on fossil fuel and diesel for some time to come. For alternative engines to truly compete with conventional vehicles, improvements will be required in terms of battery cost, size, weight and power to increase the range possible on a single charge; the number of charging points available; and the charging time required to power up the car.^{357,358,359} One key technology to watch is hydrogen-powered fuel cells as a potential solution for shipping and heavy vehicles.³⁶⁰ Commercial transport (buses, commercial vehicles, delivery fleets, and trucks) is often seen as the most promising sector to promote hydrogen as an energy carrier in order to cut emissions, though costs and efficiency improvements are required before the technology is ready to be scaled up.³⁶¹

Innovations in other categories of the transport sector are also emerging, including hybrid systems for ships and aircraft. For ships, using natural gas, marine diesel-gas or heavy fuel-oil to power a tri-fuel diesel electric propulsion system is entering the market as a possible alternative. Another is the current transition towards shore-side power, whereby shipping ports provide electric power

to ships while at berth instead of them relying on their engines. This transition is slow, however, filled with distrust and minimal investments.³⁶² For aircraft, a full transition to electric is likely further down the line (2050+), whether it be battery or solar based, though battery-powered electric aircraft could start being deployed as early as 2025 for flights under 800 km.³⁶³

357. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

358. Global Connectivity Outlook to 2030 (World Bank, 2019)

359. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

360. Future possibilities report 2020 (UAE Government, 2020)

361. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

362. Shore-side power. A key role to play in greener shipping (Ship Technology, 2016)

363. Top 10 Emerging Technologies of 2020 (World Economic Forum, 2020)



Energy distribution

The digitalization of the energy sector

The digitalization of our economies, with advances in, for example, the ‘Internet of Things’ and big data analytics, has radically changed energy transmission, distribution requirements and demand.

Although this implies greater energy use, it also holds promises to optimize energy usage.³⁶⁴ The era of smart technologies is predicted to rapidly expand, but these technologies also raise new security and privacy questions that will need to be addressed (see ‘Tech risks’). Similarly, electricity grids will become more complex, with more actors involved, creating greater challenges for risk management and greater potential for systemic failure.³⁶⁵

Smart technologies

‘Smart’ technologies are not well defined, but generally refer to three kinds of objects: smart devices that can be programmed and have some level of automation but no connectivity (e.g. a smart thermostat or coffee machine); connected devices that are controlled via wirelessly through Bluetooth or Wi-Fi (e.g. wearables, smartphones), and IoT devices that connect to the Internet and can send and receive data between other devices and systems.

In terms of energy storage and distribution, smart technologies (such as smart grids) will blur the lines between supplier and end user, by allowing businesses and households alike to track and generate their own energy supplies (and even share or sell their surplus). By including operational and energy measures along the supply chain (e.g. smart meters), and due to big-data analytics and machine learning, smart technologies could predict system failures or allow devices and systems to adjust energy use in response to specific conditions. The latter could include, for example, being active when supply is abundant and inactive or in battery-saving mode when supply is limited.^{366,367} This could lead to overall energy savings and more efficiency in the system.

364. Global Connectivity Outlook to 2030 (World Bank, 2019)

365. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

366. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

367. Global Connectivity Outlook to 2030 (World Bank, 2019)



Beyond those promises, smart technologies, as a whole, raise new security and privacy questions, such as how household energy data is collected and stored in order to predict grid conditions. Guidelines and regulations will be required to protect users and promote good practice in how to deal with sensitive data and ensure privacy and security (see '[Data privacy](#)').³⁶⁸

Ultra high-voltage direct-current transmission lines

Ultra high-voltage direct-current (UHVDC) transmission lines are expected to become the main electricity-transmission technology to enable a more efficient, bulk-power transfer over long distances, than alternating current (AC).³⁶⁹ Currently, over 250 gigawatts of interconnectors and high-voltage transmission links are installed globally, which is expected to increase exponentially towards 2030, with countries like China, India, the US, and the EU heavily investing in the technology.³⁷⁰

The higher voltage available in energy transmission technologies will enable the movement of energy as electricity over long distances

rather than relying on moving energy resources themselves. By carrying electricity directly from the source to where it is needed and then used, it will be more efficient and potentially cheaper than existing technologies. This in turn will make it attractive to use and giving it the power to change the economics of energy distribution.³⁷¹ This will have a significant impact on shipping in particular, which will no longer be needed to transport large quantities of coal and oil. Some estimates suggest that "energy-related shipping might decline by 50% for coal and 25% for oil by 2050."³⁷²

It will also promote emissions reductions and the transition to a low-carbon economy. UHVDC can increase the attractiveness of renewables by addressing their apparent lack of reliability – by transferring electricity from areas with a surplus or high production capacity to other areas across interconnected systems, operators can adjust supply and demand efficiently.³⁷³ This is possible thanks to innovative sensors and controls that allow minute-by-minute variances in the direction and magnitude of flow. In addition, the reduced need to ship energy resources will help lower emissions from the transport industry.

368. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

369. Global Connectivity Outlook to 2030 (World Bank, 2019)

370. Global Connectivity Outlook to 2030 (World Bank, 2019)

371. Global Connectivity Outlook to 2030 (World Bank, 2019)

372. Global Connectivity Outlook to 2030 (World Bank, 2019)

373. Global Connectivity Outlook to 2030 (World Bank, 2019)



Finally, UHVDC can also connect more people to the energy supply system. While the IEA reports that over 750 million people still do not have access to electricity, access is increasing rapidly.³⁷⁴ New transmission technologies could accelerate the spread of access to electricity and even lead developing countries to leapfrog in the energy sector³⁷⁵ – over the next 30 years, many countries in Africa are expected to potentially skip development phases that older economies have transitioned through, and move straight into digital and sustainable infrastructure. As a region where a majority of the population does not have access to electricity, this is expected to dramatically change the power dynamics in the energy sector. It is also an opportunity for African countries rich in natural resources to combine the development goal of access to electricity with resilient, low-carbon development.³⁷⁶

The future of distribution: From state-based centralized systems to regional and local solutions

Regional solutions: sub-national interconnected energy networks

In the context established above, countries currently face a choice between pursuing electrification and distribution through a national agenda, or through an approach of energy interdependence at regional or local levels.^{377,378}

Considering the commercial cost of investment in new transmission lines and other energy technologies, as well as resource limitations in any single country, cooperation and energy trade between countries yields many benefits. It can minimize energy-production costs and increase regional surplus through sharing infrastructure and resources, and taking advantage of the different renewable-energy profiles of participating countries in order to adjust supply and demand efficiently.³⁷⁹ “In sub-Saharan Africa, where the cost of energy supply is amongst the highest in the world, regional trade may reduce costs by an average of 40%.”³⁸⁰ Latin America can serve as an example, as countries have largely invested in regional energy systems to reduce energy costs, improve reliability and diversify

374. [Access to electricity](#) (International Energy Agency, 2020)

375. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

376. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)

377. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

378. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)

379. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

380. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)



the region's energy sources (see, for example, the Central American Electrical Interconnection System (SIEPAC), and the Andean Electrical Interconnection System).³⁸¹

However, this regional approach is not without significant challenges, including those related to cooperation across multiple jurisdictions and countries, with varied infrastructures and legislation and the fact that existing electricity grid facilities in both developing and developed countries will need to be updated to accommodate renewable-energy sources, which are different from the infrastructure used for fossil fuels.³⁸²

Local solutions: beyond the grid

An alternative to mega-grids is the development of local and small-scale distributed, energy systems that do not require power-grid connection (microgrids). With such innovations, homes, cities, and local equipment could act as tools for electricity production, storage, and distribution, thereby removing local communities' reliance on centralized and state-based grids.³⁸³ This can lead to more resilient communities, with increased security of energy supplies for remote communities that have a reduced access to the grid, or in the event of natural disasters. It could also provide opportunities to generate income.³⁸⁴ However, with more actors involved, the complexity of the energy system would increase, and with it, the risk of failures.³⁸⁵

381. Latin America and the Caribbean 2030. Future scenarios (Inter-American Development Bank, 2016)

382. Global Connectivity Outlook to 2030 (World Bank, 2019)

383. Global trends. Paradox of progress (US National Intelligence Council, 2017)

384. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

385. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)



Relevant ISO technical committees and standards

- ISO/TC 301, *Energy management and energy savings*
 - ISO 50001:2018, *Energy management systems – Requirements with guidance for use*
- ISO/TC 197, *Hydrogen technologies*
 - ISO 17268:2020, *Gaseous hydrogen land vehicle refuelling connection devices*
 - ISO 22734:2019, *Hydrogen generators using water electrolysis – Industrial, commercial, and residential applications*
- ISO/TC 205, *Building environment design*
 - ISO 13153:2012, *Framework of the design process for energy-saving single-family residential and small commercial buildings*
 - ISO/TR 16822:2016, *Building environment design – List of test procedures for heating, ventilating, air-conditioning and domestic hot water equipment related to energy efficiency*



Relevant ISO news stories

- ISO - Affordable and Clean Energy
- ISO - Zero-energy buildings
- ISO - On the road to net zero
- ISO - Helping the world reach net-zero emissions
- ISO - The rise of energy efficiency



Environmental degradation

Natural resources scarcity | Threatened ecosystems

The natural world has been irreversibly changed by human actions and this has led to long-term trends towards increasing environmental degradation and scarcity of natural resources. Both of these trends are closely interlinked and will pose significant challenges over the next few decades, requiring large-scale, international action to avoid the worst-case scenario.

Human activities have resulted in air pollution, habitat destruction, soil erosion, desertification, ocean acidification and many other changes that are causing significant stress to ecosystems. With a growing global population, demand for fresh water and arable land for agriculture are expected to increase in the future. The development of new technologies (such as smart farming) will be essential to overcome some of these challenges. However, many such technologies, including clean energy technologies, require critical minerals that are also in short supply. Substantial efforts in terms of both mitigation (reduction of carbon emissions) and adaptation (changing behaviours, consumption patterns, resource management and more) will be required to maintain a level of ecosystem services needed for human wellbeing.

Natural resources scarcity

As the effects of climate change continue to impact the globe, precious, natural resources like fresh water, arable land and minerals are expected to become increasingly scarce, with significant implications for agriculture and food security, as well as the production of many new innovative technologies. According to the US National Intelligence Council, “nearly all of the Earth’s systems are undergoing natural and human-induced stresses outpacing national and international environmental protection efforts.”³⁸⁶ The World Economic Forum identifies

386. Global trends. Paradox of progress (US National Intelligence Council, 2017)



Related trends: Energy sources, Energy storage and distribution, Increased migration, Rise of the middle class, Sustainable production, Threatened ecosystems

human over-exploitation and/or mismanagement as key drivers of the scarcity of natural resources.³⁸⁷ Resource scarcity, whether of water, land or minerals, may also be a driver of conflict, particularly where economic and political issues create barriers to access to natural resources.^{388,389}

Water, land, and consequences for food production

Water is already scarce and is likely to become even more scarce in future. Only 3% of the world's water is freshwater, and much of this is not readily accessible due to factors that include remote location, political boundaries, economics, and purity. The UN Food and Agricultural Organization (FAO) estimates that 1.8 billion people worldwide will face water scarcity by 2025 and 5.2 billion are expected to face water stress. By 2050, the FAO estimates that only 60% of the water needed will be available.³⁹⁰ Although climate change may promote glacier melting that could lead to increased flows of water, higher temperatures are also expected to increase

water loss due to evaporation.³⁹¹ An increasing demand for water will make the extraction and production (e.g. through desalination) of fresh water more energy intensive, and is likely to drive up costs for access to water.³⁹² Industrial water pollution, inadequate water management, and non-compliance with water sharing agreements and treaty provisions may lead to tensions over access to water sources.³⁹³

The same forces that are expected to impact water scarcity (climate change, population growth, '[Urbanization](#)', economic development, and poor management) will also impact the availability of arable land for farming. This is a serious challenge when projections estimate that average levels of food production will have to increase by around 50% by 2050 (from a 2012 baseline) to meet the needs of the world's population.³⁹⁴ Indeed, it is impossible to separate out the issues of water and land scarcity as each affects the other in a significant way. For example, around 70% of global water consumption goes to agriculture, agriculture will be responsible for a

387. [The Global Risks Report 2021](#) (World Economic Forum, 2021)

388. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

389. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

390. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)

391. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

392. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

393. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)

394. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)



large part of the increased demand for water in future³⁹⁵, and current intensive farming techniques are linked to water pollution, along with air pollution, soil degradation and pest resistance.³⁹⁶ Water scarcity and other consequences of climate change, such as volatile weather events and sea-level rise, will, on the one hand, reduce the amount of land available for developing new agricultural areas and, on the other hand, lead to reduced agricultural production. The resulting food insecurity is predicted to have a disproportionate effect on developing countries, with some predicting that "Africa could face a near double-digit reduction in crop yields and production volumes over the next decade, as well as rising food prices by similar margins."³⁹⁷

Technology will need to play a major role in overcoming natural resource scarcity and improving agricultural productivity.³⁹⁸ 'Smart farming' and techniques such as hydroponics and vertical farming will be key. Smart farming involves the use of digital technologies – e.g. unmanned machinery, robots, sensors, drones, big data, and advanced analytics – to be able to analyse the individual needs of specific fields, crops, or animals.³⁹⁹ This kind of precision agriculture

is more environmentally benign, minimizes water and electricity use, while maximizing the productivity of the land. Hydroponics (growing plants in mineral solutions instead of soil) and vertical farming (growing crops in vertically stacked layers) both reduce the need for land to grow certain crops and make it more practical to farm them in urban environments.⁴⁰⁰

Critical minerals and consequences for emerging technologies and the energy transition

Scarcity issues also apply to lesser-known natural resources like critical minerals – rare metals such as lithium, tellurium and rare earth metals that are used for batteries, solar panels, and various electronic devices. Demand for these product types will only increase in the coming decades as more people join the middle class and purchase consumer electronics such as smartphones. In addition, as the global community steps up efforts to cut GHG emissions, and transition to cleaner sources of energy such as electric vehicles (which require a lot of lithium) and solar power, this will increase the demand for these rare metals. As this demand grows, pressure on these limited resources will be significant.

395. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)

396. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

397. [Foresight Africa. Top priorities for the continent 2020-2030](#) (Brookings Institution, 2020)

398. [Global strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

399. [Future technology for prosperity. Horizon scanning by Europe's technology leaders](#) (EU Commission, 2019)

400. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)



With the bulk of known critical mineral deposits in a small number of countries, political and supply chain issues could cause significant challenges in the future.⁴⁰¹

Scarcity of water, land or minerals will provide both challenges and opportunities for businesses, who may have less readily available resources for production, but who may see potential market opportunities develop for sustainable and eco-friendly production.⁴⁰²

Relevant ISO technical committees and standards

- ⇒ ISO/TC 207, *Environmental management*
 - ISO 14001:2015, *Environmental management systems – Requirements with guidance for use*
 - ISO 14046:2014, *Environmental management – Water footprint – Principles, requirements and guidelines*
- ⇒ ISO/TC 23, *Tractors and machinery for agriculture and forestry (and its subcommittees)*
 - ISO 17989-1:2015, *Tractors and machinery for agriculture and forestry – Sustainability – Part 1: Principles*
- ⇒ ISO/TC 224, *Drinking water, wastewater and stormwater systems and services*
 - ISO 46001:2019, *Water efficiency management systems – Requirements with guidance for use*
- ⇒ ISO/TC 282, *Water reuse*
 - ISO 22519:2019, *Purified water and water for injection pretreatment and production systems*
- ⇒ ISO/TC 287, *Sustainable processes for wood and wood-based products*
 - ISO 38200:2018, *Chain of custody of wood and wood-based products*

Relevant ISO news stories

- ISO - Farming fit, farming smart
- ISO - Calculating the value of the environment with new ISO standard
- ISO - A standard for water reuse brings hope for water scarcity
- ISO - Managing a precious resource
- ISO - Precision farming takes off
- ISO - Putting waste to good use

401. [Critical minerals scarcity could threaten renewable energy future](#) (Stanford University, 2018)

402. [Global Trends 2020. Understanding Complexity](#) (Ipsos, 2020)



- ISO/TC 298, Rare earth
 - ISO 22450:2020, Recycling of rare earth elements – Requirements for providing information on industrial waste and end-of-life products
 - ISO/TS 22451:2021, Recycling of rare earth elements – Methods for the measurement of rare earth elements in industrial waste and end-of-life products
 - ISO 22453:2021, Exchange of information on rare earth elements in industrial wastes and end-of-life cycled products
 - ISO 23664:2021, Traceability of rare earths in the supply chain from mine to separated products
- ISO/TC 323, Circular economy
 - ISO/AWI 59040, Circular Economy – Product Circularity Data Sheet
- ISO/TC 331, Biodiversity
 - ISO/AWI TS 13208-1, Biodiversity – Vocabulary – Part 1: General terms
- ISO/TC 333, Lithium
 - ISO/AWI 9287, Lithium sustainability across the value chain: concentration, extraction, separation, conversion, recycling, and reuse
- ISO/TMBG, Technical Management Board - groups
 - ISO/TMBG/SAG_CRM, ISO Strategic Advisory Group on Critical minerals
 - ISO/TMBG/SAG SF, Smart Farming



Threatened ecosystems

Ecosystems worldwide are at increasing risk of long-term changes and damage. Changes to plant life-cycles and animal behaviour are observed in both land and marine ecosystems.⁴⁰³ Threats from pollution, habitat destruction, deforestation, over-exploitation, changes in biodiversity, seabed mining and ocean acidification are all interfering with the natural functioning of the earth's ecosystems^{404,405} alongside the ongoing threat of global warming.⁴⁰⁶

Reducing emissions of CO₂ and other GHGs is a critical response to these threats, and, if ambitious emission-reduction targets are achieved, offers some hope for the world's ecosystems.⁴⁰⁷

Air pollution continues to increase, especially in rapidly growing cities, and will pose significant health risks into the future.⁴⁰⁸ By 2035, air pollution may be the top cause of environmentally-related deaths worldwide.⁴⁰⁹ Air quality is predicted to become "the most significant indicator with regards to quality of life, happiness and other indices."⁴¹⁰ As growing numbers of people live in urban areas, air pollution can be expected to increase and will especially impact on

Related trends: **Natural resource scarcity, Increased migration, Rise of the middle class, Sustainable production, Synthetic biology, Urbanization**

403. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

404. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

405. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

406. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

407. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

408. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)

409. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)

410. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)



urban populations.⁴¹¹ Already, more than 80% of people living in cities are exposed to air pollution that exceeds safe limits.⁴¹²

Signs of hope in relation to air pollution may appear in the form of increased public awareness, cleaner transport options, retrofitted buildings, and improved urban design.⁴¹³

Soil erosion and desertification will increasingly threaten agricultural and habitable land⁴¹⁴, particularly where deforestation and unsustainable farming practices continue.

Relevant ISO technical committees and standards

→ ISO/TC 207, Environmental management

- ISO 14055-1:2017, *Environmental management – Guidelines for establishing good practices for combatting land degradation and desertification – Part 1: Good practices framework*
- ISO TR 14055-2:2022, *Environmental management – Guidelines for establishing good practices for combatting land degradation and desertification – Part 2: Regional case studies*

→ ISO/TC 82/SC 7, Mine closure and reclamation management

- ISO 21795-1:2021, *Mine closure and reclamation planning – Part 1: Requirements*
- ISO 21795-2:2021, *Mine closure and reclamation planning – Part 2: Guidance*

Relevant ISO news stories

- ISO - Climate Action
- ISO - Ones to watch
- ISO - International Day of Forests
- ISO - Biodiversity high on standards agenda
- ISO - Putting sustainability at the heart of the standards agenda
- ISO - Food, feed, fibre
- ISO - Breathe easy with ISO standards on World Environment Day
- ISO - New ISO standard to combat land degradation

411. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

412. Global trends. Paradox of progress (US National Intelligence Council, 2017)

413. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

414. Asia Pacific Megatrends 2040 (Commonwealth Scientific and Industrial Research Organisation, 2019)



- ISO/TC 190, *Soil quality*
 - ISO 15175:2018, *Soil quality – characterization of contaminated soil related to groundwater protection*
 - ISO 19204:2017, *Soil quality – Procedure for site-specific ecological risk assessment of soil contamination*
- ISO/TC 234, *Fisheries and aquaculture*
 - ISO/PRF 5020, *Waste reduction and treatment on fishing vessels*
 - ISO 22948:2020, *Carbon footprint for seafood – Product category rules (CFP-PCR) for finfish*
- ISO/TC 265, *Carbon dioxide capture, transportation, and geological storage*
 - ISO 27919-1:2018, *Carbon dioxide capture – Part 1: Performance evaluation methods for post-combustion CO₂ capture integrated with a power plant*
 - ISO 27919-2:2021, *Carbon dioxide capture – Part 2: Evaluation procedure to assure and maintain stable performance of post-combustion CO₂ capture plant integrated with a power plant*
- ISO/TR 27923:2022, *Carbon dioxide capture, transportation and geological storage – Injection operations, infrastructure and monitoring*
- ISO/TC 287, *Sustainable processes for wood and wood-based products*
 - ISO 38200:2018, *Chain of custody of wood and wood-based products*
- ISO/TC 331, *Biodiversity*
 - ISO/AWI TS 13208-1, *Biodiversity – Vocabulary – Part 1: General terms*
- ISO/TMBG, *Technical Management Board - groups*
 - ISO/TMBG/CCCC, *Climate Change Coordination Committee*
 - ISO Guide 82:2019, *Guidelines for addressing sustainability in standards*
 - ISO Guide 84:2020, *Guidelines for addressing climate change in standards*



Economy

Trade

Changing trade patterns | New business models

Trade has been increasingly globalized in recent decades, but this trend is now slowing, and the future may see an increasing fragmentation and a shift towards regionalization and localization. Drivers of these changing trade patterns will include shifting consumption patterns (with, for example, goods produced in China increasingly being consumed in Southeast Asia), changes in the political environment (see 'Power transition'), changing consumer preferences (see 'Consumption'), and the growth of new business models that are made possible by new technologies (such as 'Blockchain' and 'Additive manufacturing').

Changing trade patterns

Regionalization / localization

Although digital globalization looks set to continue apace, trade globalization has been slowing down over the past 10 to 15 years as the number of bilateral and regional trade agreements proliferates, and countries increase their use of restrictive, trade policy measures.^{415,416}

Regional trade agreements may increase the intensity of trade between their signatory countries⁴¹⁷ while regional connectivity initiatives (for example, the Master Plan on The Association of Southeast Asian Nations [ASEAN] connectivity) will make intra-regional trade more efficient.⁴¹⁸ This may have particular impacts for developing economies – the African

415. Global Connectivity Outlook to 2030 (World Bank, 2019)

416. Global trends 2040. A more contested world (US National Intelligence Council, 2021)

417. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

418. Global Connectivity Outlook to 2030 (World Bank, 2019)



Related trends: **5G, Additive manufacturing, Customized products, Data privacy, Diversifying inequalities, Rise of the middle class, Services moving online, Spread of the Internet, Threatened ecosystems, Urbanization**

Continental Free Trade Agreement, for example, integrates a market of 1.2 billion people and may significantly stimulate the growth of African economies by considerably increasing intra-continental trade.⁴¹⁹ The potential downside is that regionalized trading could lead to disconnected markets and protectionism, particularly if there are conflicting technology standards between regions.⁴²⁰

Alongside this shift from international to intra-regional trade, there is also a shift from countries to cities, as the drivers of wealth creation and innovation (localization). Cities will increasingly “shape the dynamics of international trade”⁴²¹ over the next 30 years as more people move to urban areas because of better opportunities for work and education. Cities may even strengthen their position in the global economy to the extent that they “could replace countries as the most important economic entities” (see ‘Smart cities’).⁴²²

Increasing South-South trade

Trade between emerging economies (known as South-South trade) has increased significantly over the last 20 years and this trend is predicted to continue alongside economic growth in those countries. South-South Regional Trade Agreements (RTAs) already make up more than half the total number of RTAs in the world, with the majority in Asia.⁴²³ Further South-South trade growth will be driven by an increase in demand for consumer goods from a growing middle class (often goods that are produced in emerging economies), alongside better communications and easier customs arrangements.⁴²⁴

419. Foresight Africa. Top priorities for the continent 2020-2030 (Brookings Institution, 2020)

420. Global risks 2035 update. Decline or new renaissance? (Atlantic Council, 2019)

421. Global Connectivity Outlook to 2030 (World Bank, 2019)

422. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

423. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

424. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)



What and how we trade

The composition of trade flows and the means by which they are transported are evolving. In terms of *what* we trade, for several decades, international trade in services has grown at a much faster pace than trade in goods, and, despite being hit hard by the COVID-19 pandemic, global trade in a wide range of services (e.g. financial, communications, tourism) is expected to increase over the next 20 years.⁴²⁵ Trade in digital services (i.e. services provided over digital networks, such as computer network maintenance, entertainment, broadcasting, or financial management) is one area that has seen a huge growth recently (see '[Services moving online](#)'), and this has led to a massive increase in the amount of cross-border data flows.⁴²⁶ Such cross-border data flows are essential for digital services trade but must also be carefully managed due to privacy concerns. Countries must ensure they place adequate restrictions on cross-border data flows to protect personal data and national security, without these restrictions being so severe that they negatively affect the level of digital services trade.⁴²⁷ The importance of trade in digital services means that all countries will have to make

big investments in digital capacity and data infrastructure to keep up with this evolution of the global trading system.⁴²⁸ Countries less able to do so will be at a huge disadvantage in terms of economic and social development. The digital divide (related to levels of connectivity and access to the Internet) and data-related divide (related to the ability to capture, analyze and transform data into digital intelligence) between developed and developing countries is therefore a major challenge to overcome.⁴²⁹

In terms of *how* we trade, climate change, new technologies and shifting customer preferences are all contributing to reshaping the trade and logistics sectors. The potentially disruptive effects of climate change are causing companies to modify the way they operate to increase the resilience and reliability of their supply chains.⁴³⁰ In some cases, this means the shortening of supply chains, which is made possible by new digital technologies such as automation and '[5G](#)' (note: this contributes to the trend away from trade globalization).⁴³¹ Growth in the 3D-printing market (see '[Additive manufacturing](#)') also facilitates this, by allowing for what's called 're-shoring' or 'near-shoring' of production – where manufacturing

425. [Global trends 2040. A more contested world](#) (US National Intelligence Council, 2021)

426. [Digital Economy Report 2021. Cross-border data flows and development: For whom the data flow](#) (UN Conference on Trade and Development, 2021)

427. [World Development Report 2021. Data for Better Lives](#) (World Bank, 2021)

428. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

429. [Digital Economy Report 2021. Cross-border data flows and development: For whom the data flow](#) (UN Conference on Trade and Development, 2021)

430. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

431. [Asia Pacific Megatrends 2040](#) (Commonwealth Scientific and Industrial Research Organisation, 2019)



can be performed on demand and much closer to the end user.⁴³² While this may decrease the need for long-distance transport, it will not eliminate it and thus the long-distance transport sector is also evolving in the face of new technologies and the imperative to reduce carbon emissions. For example, driverless freight using autonomous trucks may become a reality in the next 10 to 15 years, improving delivery times, and reducing traffic congestion, operating costs and accidents.⁴³³ Meanwhile, in shipping, many companies are exploring low-carbon fuels, renewable energy, and new ship designs (e.g. hulls and propellers) to increase efficiency and reduce carbon footprints.⁴³⁴ These kinds of changes are also propelled by an increasing customer demand for more sustainable production and more customized products (see 'Consumption').

Relevant ISO technical committee and standards

→ ISO/PC 317, *Privacy by design*

- ISO/AWI TR 31700-2, *Consumer protection – Privacy by design for consumer goods and services – Part 2: Use cases*

Relevant ISO news stories

- ISO - Building a new consensus on trade

432. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

433. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

434. [Five future trends in the shipping industry](#) (MARINEi, 2021)



New business models

As digitalization has accelerated, so has economic connectedness, leading to the emergence of today's data-driven digital economy and, with it, some new business models.

Digital platforms

The use of digital platforms (e-commerce platforms) has allowed sellers to connect directly to buyers, to make more efficient exchanges, and to gain greater access to international markets (especially in the case of SMEs).⁴³⁵ The role of the 'middle-man' in the economy (e.g. distributors and physical retailers) has been transformed and may eventually become redundant.⁴³⁶ Advanced uptake of technologies such as 'Artificial intelligence' and 'Blockchain' are spurring this trend and the expansion and diversification of digital platforms is expected to steadily increase over the next ten years.⁴³⁷ Because these digital platforms have the ability to collect data at a massive scale, there is growing concern that large digital platforms are already creating monopolistic or undesirable market conditions and that better regulation and global data governance are needed to combat this.^{438,439}

Related trends: 5G, Blockchain, Customized products, Cyber-vulnerability, Data privacy, Diversifying inequalities, Rise of the middle class, Services moving online, Spread of the Internet, Sustainable production, Urbanization

435. Global trends 2040. A more contested world (US National Intelligence Council, 2021)

436. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

437. Digital megatrends. A perspective on the coming decade of digital disruption (Commonwealth Scientific and Industrial Research Organisation, 2019)

438. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

439. Digital Economy Report 2021. Cross-border data flows and development: For whom the data flow (UN Conference on Trade and Development, 2021)



Sharing economy

One notable new business model that has been made possible by digital platforms is the sharing economy (also called the 'gig' or 'peer-to-peer, P2P' economy), which refers to a model of collaborative consumption where people can use or consume a product or service without taking full ownership (i.e. the owner of that resource shares it), allowing people to redistribute and make use of excess capacity of goods or services in the economy.⁴⁴⁰ Transactions are usually facilitated by a digital platform – Uber, the ride-sharing app, and Airbnb, the online marketplace for accommodation, are some well-known examples. The sharing economy is expected to grow significantly over the next ten years (with a predicted 35% growth per year in Europe)⁴⁴¹ and this growth is driven by societal and environmental trends such as '[Urbanization](#)', consumer demand for '[Sustainable production](#)' and '[Consumption](#)', and '[Natural resource scarcity](#)'.^{442,443}

Digital currencies

Alongside changes in how people buy and sell goods and services, the emergence of digital currencies is changing the way people pay for them. Digital currencies include cryptocurrencies, virtual currencies and central bank digital currencies (CBDC). Today, the most popular digital currencies are cryptocurrencies like Bitcoin, which use '[Blockchain](#)' technology to verify transactions (in a very energy-intensive manner).⁴⁴⁴ However, it is predicted that digital currencies will gain wider acceptance over the next 20 years as more central banks begin to issue them to supplement or replace fiat (physical) currencies.⁴⁴⁵ Developing countries, particularly in Africa, have already shown a huge interest in digital currencies, driven by the high use of mobile-banking services and young consumers. Nigeria launched Africa's first CBDC, the eNaira, in October 2021.⁴⁴⁶ China, South Africa and Sweden are amongst 14 countries piloting a CBDC and, as of January 2022, 87 countries (making up over 90% of global GDP) are exploring a CDCC (up from only 35 countries in May 2020).⁴⁴⁷

440. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)

441. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

442. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs and the Future, 2017)

443. [Beyond the Noise. The Megatrends of Tomorrow's World](#) (Deloitte, 2017)

444. [Bitcoin Uses More Electricity Than Many Countries. How Is That Possible?](#) (New York Times, 2021)

445. [Global trends 2040. A more contested world](#) (US National Intelligence Council, 2021)

446. [Widespread m-payment adoption in Africa inspires growing interest in crypto currencies](#) (Nielsen, 2021)

447. [Central Bank Digital Currency Tracker](#) (Atlantic Council, 2022)



The advantages of digital currencies include that they are cheaper to administrate than fiat currency and allow faster and lower-cost transactions (by cutting out intermediaries). Their disadvantages include that they could enable the shadow economy by facilitating the movement of funds by criminal organizations, they are vulnerable to hacking, and can be volatile in value.^{448,449} Strong regulation will therefore be needed to control the impacts of digital currencies.

Relevant ISO technical committees and standards

- ISO/TC 68/AG 5, *Digital currencies*
- ISO/TC 68/SC 2, *Financial Services, security*
 - ISO 23195:2021, *Security objectives of information systems of third-party payment services*
- ISO/TC 68/SC 8, *Reference data for financial services*
 - ISO 24165-1:2021, *Digital token identifier (DTI) – Registration, assignment and structure – Part 1: Method for registration and assignment*
 - ISO 24165-2:2021, *Digital token identifier (DTI) – Registration, assignment and structure – Part 2: Data elements for registration*
- ISO/TC 321, *Transaction assurance in E-commerce*
 - ISO/CD 32111.2, *Transaction assurance in E-commerce – Principles and Framework*
- ISO/TC 324, *Sharing economy*
 - ISO 42500:2021, *Sharing economy – General principles*

Relevant ISO news stories

- ISO - The sharing economy creates a more sustainable world
- ISO - A common language for digital currency
- ISO - The down-low on digital currency
- ISO - New ISO solution to support the sharing economy

448. Future Outlook. 100 Global Trends for 2050 (UAE Ministry of Cabinet Affairs and the Future, 2017)

449. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)



Politics



Power transition

Power transition

Multipolarity | Decline of multilateralism | Regionalization

As the world moves towards multipolarity, some predict a decline of multilateralism as international coordination becomes more difficult. Others see multipolarity as a potential driver of increased interstate cooperation, forcing countries to form alliances to counteract fragmentation. In either case, regional alliances are likely to become stronger and the regionalization that is already evident in trade statistics will probably continue.

Multipolarity

It is likely that, in the next 20 years, there will be no single state that can dominate all regions of the world or all domains of influence. The relative power of countries such as China and India is increasing with respect to existing powers such as Europe, the US and Russia. Alongside these, emerging powers such as Brazil, Indonesia, Mexico, Nigeria, Turkey and Vietnam, will also increasingly exert their influence at a regional and global level.⁴⁵⁰ The nature of the relationships between these countries will be key to determining the kind of international order that will emerge – if ideological differences and divisions over models of governance grow, then this could foster competition instead of cooperation and “the intensity of competition for global influence is likely to reach its highest level since the Cold War”.⁴⁵¹ But this global influence will not be decided primarily by military and economic power, but by trade flows, aid and technology transfers, plus the number and quality of bilateral relationships.⁴⁵² What this multipolarity means for global governance is not yet clear (see ‘Decline of multilateralism’).



Related trends: **Changing trade patterns, Decline of multilateralism, Urbanization**

450. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

451. Global Trends 2040. A more contested world (US National Intelligence Council, 2021)

452. Global Trends to 2030. Challenges and choices for Europe (EU Strategy and Policy Analysis System, 2019)

Decline of multilateralism

The multilateral system put in place after World War II was designed to foster cooperation between countries and improve their ability to pursue common goals and tackle global challenges. But these institutions may no longer be fit for purpose in a multipolar world and there are already serious signs of weaknesses in the system (as demonstrated by the response to the COVID-19 pandemic).⁴⁵³

As global power becomes more diffused, it may become even more difficult to reach agreement between countries within international institutions such as the United Nations. As a result, the universalist approach to international law and human rights could be challenged – “with competing local and regional understandings of international norms likely to prevail”.⁴⁵⁴ If international institutions are weakened or even collapse, responses to global challenges such as climate change, poverty or technology governance will become more uncertain.⁴⁵⁵ The rise in nationalism, protectionism and populism in some countries has been linked to this sense of increased uncertainty about multipolarity and its effects on multilateralism.⁴⁵⁶

Related trends:
**Multipolarity,
Changing
trade patterns**

453. [The Global Risks Report 2021](#) (World Economic Forum, 2021)

454. [Global Strategic Trends. The future starts today](#) (UK Ministry of Defence, 2018)

455. [The Global Risks Report 2021](#) (World Economic Forum, 2021)

456. [Global Trends to 2030. Challenges and choices for Europe](#) (EU Strategy and Policy Analysis System, 2019)



Nevertheless, there is a distinct lack of agreement on which way this trend will go – even if institutions are weakened, some argue that multilateralism will continue, potentially in a modified form involving companies, civil society, governments and international institutions (multi-stakeholder multilateralism). The majority of countries may continue to see value in international institutions and, even if their reform is challenging, these institutions could continue to exist and remain influential.⁴⁵⁷

Regionalization

If globalization has slowed or stalled, then it has arguably been replaced by regionalization – countries are trading more and becoming more interdependent with those in geographical proximity to them.⁴⁵⁸ Regional alliances are forming out of economic pragmatism, to strengthen security, and to increase regional resilience to global shocks or crises.⁴⁵⁹ However, there is a risk that as integration within regions increases, divisions between regions could grow, especially if nationalism continues to flourish and leads to more protectionist policies.⁴⁶⁰

Related trends: **Decline of multilateralism**

457. [Global trends. Paradox of progress](#) (US National Intelligence Council, 2017)

458. [Global Connectivity Outlook to 2030](#) (World Bank, 2019)

459. [Global Trends and the future of Latin America. Why and how Latin America should think about the future](#) (Inter-American Development Bank, Inter-American Dialogue, 2016)

460. [Future Outlook. 100 Global Trends for 2050](#) (UAE Ministry of Cabinet Affairs for the Future, 2017)



Science



Biotechnology

Biotechnology

Gene editing | Synthetic biology

Biotechnology uses living organisms and biological systems to create new products. Over the last 50 years, this field has developed rapidly because of advances in genetic engineering that allow scientists to make changes to organisms' DNA. New methods of genetic modification have led to rapid advances in gene editing and testing and have also become much more targeted, quicker, and cheaper. According to the US National Intelligence Council, "biotechnologies are at an inflection point [...] turning science fiction into reality."⁴⁶¹

Within the broad category of biotechnology, there are many emerging developments that are mentioned below (and many, many more that we do not have space to cover). Although it lies at the crossroads between the categories of science and technology, biotechnology is included in the 'Science' category here because its foundations are in scientific research and experimentation – and it overlaps with many other scientific fields such as molecular biology, biochemistry, and genomics. Nevertheless, a lot of the developments mentioned here have strong links to other trends in the technology category (e.g. 'Artificial intelligence').

While international standardization is no stranger to the field of biotechnology (ISO/TC 276, *Biotechnology*, was created back in 2013), the pace of development in this field and the breadth of its applications means that this is an area to watch for emerging-market needs.



461. Global trends. Paradox of progress (US National Intelligence Council, 2017)



Gene editing

Advances in gene editing could potentially lead to enormous breakthroughs in human health, agricultural and industrial productivity, and sustainability. Technologies such as clustered regularly interspaced short palindromic repeats (CRISPR) have transformed this field, by enabling extensive genome editing and allowing scientists to precisely edit DNA using a bacterial enzyme.⁴⁶²

Gene editing could lead to significant improvements in human health and medicine by eliminating hereditary diseases (by modifying or replacing illness-causing genes), providing more effective and targeted treatments for diseases such as cancer, and eliminating causes of disease (e.g. malarial carrying mosquitoes).^{463,464} As gene editing technologies become faster and cheaper, they will foster the shift towards personalized medicine.⁴⁶⁵ They could even allow the transplant of animal organs into humans – in October 2021, a significant step was made towards animal-to-human transplants as surgeons in the US tested the transplant of a genetically modified pig kidney on a deceased recipient.^{466,467}

Applying biotechnology such as gene editing to food production has the potential to significantly increase the sustainability of food production by boosting agricultural yields while reducing land and water use, increasing the nutritional content of food, and increasing crop

Related trends: Ageing population, Artificial intelligence, Ethics of technology, Synthetic biology

462. 2021 Tech trends report. Strategic trends that will influence business, government, education, media and society in the coming year (Future Today Institute, 2021)

463. 20 new technology trends we will see in the 2020s (BBC Science Focus Magazine, 2020)

464. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)

465. Global trends. Paradox of progress (US National Intelligence Council, 2017)

466. Global Trends 2020. Understanding Complexity (Ipsos, 2020)

467. Surgeons successfully test pig kidney transplant in human patient (The Guardian, 2021)



resilience (resistance to pests and severe weather). Even meat-eating could become sustainable if the use of CRISPR technology can make the process of growing meat in the lab much cheaper and more efficient.⁴⁶⁸ All these factors will be increasingly important to guarantee food security for populations dealing with the effects of climate change.⁴⁶⁹

Broader sustainability impacts could result from the application of gene editing technologies to create microbes that can produce biofuels, new construction materials, biodegradable plastics and more.⁴⁷⁰ For example, cities of the future could potentially be lit up (at no cost and with no emissions) by bioluminescent algae, or plants that have been engineered to glow through the addition of genes for fluorescent proteins from these algae or jellyfish.

Nevertheless, there are moral and ethical questions that will arise as gene editing technologies become more advanced and where it may be difficult to find international consensus.⁴⁷¹ Human augmentation (enhancing human physical or cognitive abilities), the safety of genetically modified food or animals, the large-scale collection and storage of genetic data, and the possibility that gene editing technologies could be used to create targeted biological weapons – these are all issues likely to raise divisive political debates.

468. Memphis meats uses crispr to create real meat from animal cells (Trendhunter, 2019)

469. Global trends. Paradox of progress (US National Intelligence Council, 2017)

470. Future technology for prosperity. Horizon scanning by Europe's technology leaders (European Commission, 2019)

471. Global Strategic Trends. The future starts today (UK Ministry of Defence, 2018)



Relevant ISO technical committees and standards

→ ISO/TC 276, Biotechnology

- ISO 5058-1:2021, *Biotechnology – Genome editing – Part 1: Vocabulary*
- ISO 20387:2018, *Biotechnology – biobanking – General requirements for biobanking*
- ISO/TR 22758:2020, *Biotechnology – biobanking – Implementation guide for ISO 20387*

→ ISO/TC 34/SC 16, Horizontal methods for molecular biomarker analysis

- IWA 32:2019, *Screening of genetically modified organisms (GMOs) in cotton and textiles*

→ ISO/TC 215/SC 1, Genomics informatics

- ISO/TS 22693:2021, *Genomics informatics – Structured clinical gene fusion report in electronic health records*

Relevant ISO news stories

- ISO - Injecting quality into biobanks
- ISO - The new dawn of disease control



Synthetic Biology

Synthetic biology refers to the use of certain tools and approaches within biotechnology to create new biological parts or systems, for a specific purpose. These tools may include gene editing and there is certainly overlap and blurred lines between these two trends. However, the scale of DNA changes introduced in synthetic biology is generally larger, and synthetic biology also incorporates the fields of engineering, design, and computer science. A consensus definition drafted by a group of European experts defined synthetic biology as follows: Synthetic biology is the engineering of biology: the synthesis of complex, biologically based (or inspired) systems, which display functions that do not exist in nature. This engineering perspective may be applied at all levels of the hierarchy of biological structures – from individual molecules to whole cells, tissues, and organisms. In essence, synthetic biology will enable the design of biological systems in a rational and systematic way.⁴⁷²

The emerging global market for synthetic biology was estimated to be worth USD 11 billion in 2018 and to grow by 24% by 2025.⁴⁷³ Several notable trends in synthetic biology include⁴⁷⁴:

- **mRNA vaccines:** Instead of using bits of a live or dead virus, these vaccines introduce mRNA molecules that cause the body's own cells to produce a protein, which then elicits an immune response. The mRNA vaccines for COVID-19 approved in December 2020 (Pfizer and Moderna) were the first ever mRNA vaccines to be marketed. In addition this type of vaccine has huge promise because it is quicker to design and test and can be made synthetically, without cultured cell-lines.

Related trends: Artificial intelligence, Ethics of technology, Gene editing, Threatened ecosystems

472. Synthetic Biology. Applying Engineering to Biology: Report of a NEST high-level expert group (European Commission, 2005)

473. Future possibilities report 2020 (UAE Government, 2020)

474. 2021 Tech trends report. Strategic trends that will influence business, government, education, media and society in the coming year (Future Today Institute, 2021)



- **Organoids and organs-on-chips:** Organoids are tiny *in vitro* organs grown from human stem-cells. These allow scientists to study how human tissue responds to drugs, viruses, and other stimuli *in vitro*. Organs-on-chips (or micro-physiological systems) are used for the same purpose but are engineered systems where cells from organs are grown on a chip (instead of *in culture*), which allows for a much more precise control of the cells and their micro-environment. This can lead to the development of much more advanced *in vitro* models of human systems.
- **DNA memory:** In 2018, scientists discovered how to create random access memory (RAM) on DNA at scale. In 2020, Chinese scientists at Tianjin University stored 445 kB of data in a cell on the *E. coli* bacterium. Current magnetic or optical data-storage systems require huge amounts of space and energy. Using DNA as a medium for storing data could potentially solve future data-storage problems, as DNA data storage is durable and hundreds of terabytes of capacity could be stored in a pill-sized container.

Relevant ISO technical committees and standards

→ ISO/TC 276, Biotechnology

- ISO 20688-1:2020, *Biotechnology – Nucleic acid synthesis – Part 1: Requirements for the production and quality control of synthesized oligonucleotides*
- ISO/TS 23565:2021, *Biotechnology – Bioprocessing – General requirements and considerations for equipment systems used in the manufacturing of cells for therapeutic use*

→ ISO/TC 34/SC 16, Horizontal methods for molecular biomarker analysis

- ISO 20688-1:2020, *Biotechnology – Nucleic acid synthesis – Part 1: Requirements for the production and quality control of synthesized oligonucleotides*



Where to from here?

The purpose of this report is to get you thinking about the trends that will shape the future. We have provided a high-level overview of how the world is changing and how the future is emerging, linking this to the work currently underway in ISO's technical committees. The trends we have covered are diverse, and yet, the number of interlinkages between them demonstrates that they are all connected. What is clear is that we cannot understand the future by thinking in silos; it is the interactions between these drivers of change that will shape the world in the years to come and that will provide both challenges and opportunities for standardization.



The future doesn't stand still: Continuation of environmental scanning

Because the trends presented in this report are high-level and long-term driving forces, they do have some degree of longevity. But they are nevertheless in continual evolution and will no doubt interact in unpredictable ways, leading to changing trajectories.

The environmental scanning phase of the ISO Foresight Framework therefore does not end with this report. The ISO/CS R&I Unit will continue to review new trend reports and analyze as they are published, with a view to updating this trend report and publishing a new edition, as necessary.





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