GO-Science Resilience Trend Cards

Long-term planning is notoriously complex, and increasingly so with our reliance on closely interconnected systems and the uncertainty of rapid global change. But it is essential for whole of society resilience so we can prepare in advance of and recover quickly following new or interacting challenges.

This Foresight project seeks to support a holistic and long-term approach to resilience and risk planning across government, answering the question 'how can government understand and prepare for longer-term trends and build its resilience to them?'.

The first output of the project is an evidence base on 17 long-term trends, identified by reviewing similar existing products (e.g. from POST, DCDC, FCDO etc) and asking a group of expert stakeholders 'which trends will be most important for the UK's prosperity and security out to 2050?'.

This deck summarises the evidence base we have assembled on these trends as well as expert views on plausible trajectories to 2050.

The 17 long-term trends

GOVERNANCE	Increasing uncertainty and challenges to the international order and international trade system.	Widening reach of global technology companies over the services and information provided by nation states.	Increasing political disengagement and polarisation.	
ECONOMY	Increased need to reskill the workforce as new sectors and emerging technologies disrupt the labour market.	Drivers of growth and prosperity rising more rapidly in Asia.	Financial transactions are increasingly mediated through new decentralised digital processes.	Increasing commitments from Government and business to meet net zero targets.
SOCIETY	The global population continues to grow, with a higher proportion of older people.	Climate change health risks, global infectious diseases and AMR are increasing global public health challenges.	Increasing income and wealth inequalities.	
TECHNOLOGY	Increasing use of artificial intelligence (AI) applications across multiple industries.	Increasing number of and changing nature of cyber-attacks.	Physical to virtual worlds as the next areas of innovation and social interaction.	Growth in applications of synthetic biology.
ENVIRONMENT	Competition for control of supply chains for scarce natural resources.	Global surface temperatures continue to increase, causing extreme weather events in every global region.	Ongoing biodiversity loss, leading to increasing financial risks.	

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International order and trade systems

Increasing uncertainty and challenges to international structures and systems

Rising powers are challenging international structures and systems, which align with liberal democratic values. Anti globalisation sentiment is leading to stronger regional integration and new trading blocs such as the Regional Comprehensive Economic Partnership of Asia-Pacific nations, covering a third of the world's population. The use of international sanctions has increased sharply over the last decade, creating trade and geopolitical uncertainty.

The number of autocratically governed states is growing. The potential consequences of this change include a widespread erosion of the international rule of law and civil liberties, growing economic inequality and an increasing failure among governments for multi-lateral policy making.

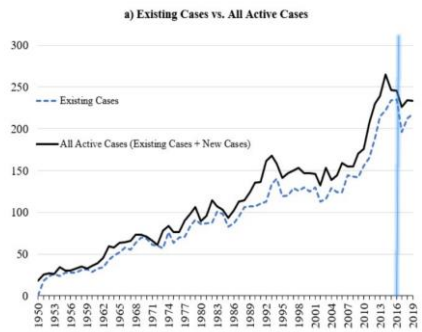
Within these shifts the United Nations system is trying to maintain international peace and security, global cooperation and stability through its funding programmes and institutions – trying to unite the world in the common delivery of priorities such as the 2030 Sustainable Development Goals and Framework Convention on Climate Change.

Strategic assumptions:

1. Globalisation and liberal democratic values persist for the foreseeable future.
2. Global power is shifting eastwards. By 2030 only three of the world's eight largest economies will be in Europe (including the UK) and by 2050 only Germany will remain.
3. International trade will remain strong, despite a rise in protectionism, as it benefits the global economy.

Sources: Kirilakha, Aleksandra & Felbermayr, Gabriel & Syropoulos, Constantinos & Yalcin, Erdal & Yotov, Yoto, 2021. "The Global Sanctions Data Base: An Update that Includes the Years of the Trump Presidency," School of Economics Working Paper Series 2021-10, LeBow College of Business, Drexel University, revised 15 Mar 2021.
BTI - collaboration analysing and comparing transformation processes towards democracy.
Global Trends to 2030: Challenges and choices for Europe
European Strategy and Policy Analysis System, April 2019

Evolution of sanctions 1950 – 2019, Global Sanctions Database



This figure illustrates: (a) the number of all active sanctions (solid line) and the number of all existing (i.e., previously imposed and still active) sanctions (dashed line) in each year of the sample coverage (1950-2019).

Wildcards:

- NATO no longer exists and nationalistic states form unstable alliances.
- Dissolution of a western regional trading bloc such as the EU or North American Free Trade Agreement.

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International order and trade systems

How is this trend playing out?

The international system is in flux as we move from the post Cold War unipolar world of the US as the only global superpower, to the ambitions of China to be the next global superpower. Even when China becomes the world's biggest economy (by 2028) and may rival the US in military power, it faces geopolitical and cultural challenges.

Although there has been political stability in China for a long time it doesn't have the same global acceptance, trust, cultural and language influences and powerful allies as the US, due to the closed nature of its society. This means its superpower status is likely to remain limited to economic and military strength. More uncertain is the nature of the historically strong relationship between China and Russia, following the Russian invasion of Ukraine, and trade tariffs between the US and China, particularly around competitive advantages in new technology.

Key uncertainty: Nature of global power

Alternative pathway one: Power determined by multilateral relationships

By 2050 power is not determined solely by measures such as a nation state population size, gross domestic product and military spending. A state's importance depends on its ability to deploy negotiating and diplomacy skills to influence the policy decisions of other states, rather than the raw capabilities it has at its disposal. In the future, no single state will be able to tackle major global challenges alone. The key determinants for state influence will be the number and quality of bi and multilateral (between at least three governments) relationships. Influence will be determined by trade and aid flows rather than economic power, and by arms and science and technology transfers rather than military spending. Membership of international organisations and alliances such as NATO increase in strength.

Alternative pathway two: Power determined by relational influences

By 2050 power is held by cities, regions, companies and transnational movements of money, human capital, goods and technology across borders. The connectivity, interdependence and pluralistic nature of the system, where power is dispersed beyond nation states, means the building blocks of the international system will be 'nodes': points where pathways relate to each other such as diplomacy, conflict resolution and, crucially, climate change rather than 'poles' (cohesive centres of power). Countries with superpower ambitions, such as the US and China, will have to contend with the pluralistic nature of global affairs and the increasingly virtual, digital and physically connected nature of the world, upon which many relational influences are built.

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Rise of global technology companies

US technology companies remain dominant. Regulation is increasing in China, Europe and the UK

Global technology companies provide billions of people with an increasing range of products and services, creating new markets and taking over existing ones. This allows them to shape access to information using personal data, enable nation state interference and alternative models for service delivery. As more people use smartphones and wearable devices the opportunity for technology companies to blend social and financial functionalities into platforms or virtual worlds such as the Metaverse is growing. The US remains home to most of the world's platforms and apps and leads in private investment in artificial intelligence (AI) research.

China has a strong regulatory tech regime with anti-trust fines, data privacy laws and a governance regime for AI. Under the EU Digital Markets Act giants such as Google and Apple will be forced to open up their services and platforms to other businesses and in the UK the Online Safety Bill allows Parliament to approve what types of 'legal but harmful' content platforms must tackle.

Strategic assumptions:

1. Tech companies will continue to diversify and compete with one another.
2. Social media, commerce and entertainment will merge, possibly into virtual worlds.
3. Regulation remains piecemeal and fragmented, decided by nation states or political and economic unions.
4. Increasing calls for micro-targeting - creating and conveying messages that reflect an individual's preferences and personality - to be banned for political campaigning.

Sources: Industrialised Disinformation 2020 Global Inventory of Organized Social Media Manipulation, University of Oxford
World-first online safety laws introduced in Parliament, DCMS, 17 March 2022
Fear of Chinese Competition Won't Preserve U.S. Tech Leadership, Carnegie Endowment for International Peace, April 2022

Apple, Microsoft, Alphabet, Amazon and Meta are amongst the top 20 largest companies in the world. At a market cap of more than $2.1 trillion, Apple's market capitalization is larger than 96% of country GDPs, a list that includes Italy, Brazil, Canada, and Russia.

Wildcards:

- Web3 a decentralised version of the internet, built on blockchain technology, where services are hosted by everyone.
- Regulation of social media algorithms

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Rise of global technology companies

How is this trend playing out?

The US technology companies remain dominant, but have to adapt their business models in response to public calls for better regulation, monitoring of content, especially around political misinformation, opening up services to other businesses and new digital taxes on revenue. China maintains the strongest regulatory regime with the US Congress (which makes the nation's laws) failing to progress federal privacy bills, security legislation and antitrust laws to address the power of the technology giants.

Debates continue over the best way to tax global technology companies, through digital levies on revenue or a global agreement on corporation tax. Stronger regulation of harmful online content has different emphases – actual content vs the dissemination and algorithmic amplification of content.

Key uncertainty: Regulation and taxation in the digital age

Alternative pathway one: Global corporation tax agreement

By 2050 the European Commission proposal for a directive introducing a digital levy, plus existing levies such as the UK's 2% digital services tax on gross revenue of technology companies, has long been phased out and replaced with a legally binding global tax agreement, brokered by the Organisation for Economic Co-operation and Development (OECD). This agreement is for a minimum of 15% corporation tax to be allocated to a company's revenue in the country where its customers are based, eliminating tax havens and shifting funds to countries where profits are earned. This brings in an extra $150bn of global tax a year. The global technology giants move their headquarters back to their home countries and adapt to the changes; the biggest impact is felt by start ups, who requires other tax incentives to enable them to compete.

Alternative pathway two: Nation state taxes on digital revenues

By 2050 the global technology companies continue to declare their profits and register their offices where they choose. Digital service taxes, enabled by new legislation, remain the preferred option for nation states to tax the revenue of technology companies, typically between 2-5%. These taxes, on primarily US based business, are unpopular with the US government and low tax jurisdictions like Ireland, but increased public support for regulation and the huge profits, from increased online activity, made by the technology companies in the coronavirus (COVID-19) pandemic force governments to act unilaterally. In China, the preferential tax incentives offered to companies like Alibaba, Tencent, Baidu, and Xiaomi are removed and the companies have to pay the standard corporate tax rate.

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Political disengagement and polarisation

Low levels of trust, political disengagement and issue polarisation

The UN suggests that high levels of public trust in institutions are found to improve public compliance with regulations and tax collection, as well as giving confidence to consumers and investors, crucial to creating jobs and functional economies. People who are economically insecure often lack political influence and the capacity to organise and lobby for their interests, compared with more economically secure groups. This disparity in influence tends to preserve or widen opportunity gaps, eroding trust in the ability of governments to address the needs of the majority. Disengagement matters as it affects the legitimacy of government and its policies. 2022 ONS figures show 35% of the UK population trusted the national government, lower than the OECD average (41%).

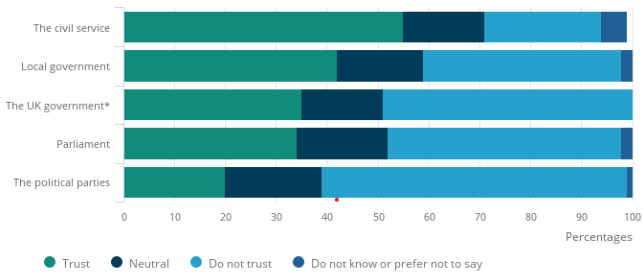
There are indications that politics is becoming more polarised worldwide, particularly in the US, but how far this applies to the UK and the consequences for political participation remain unclear. There has been a decrease in the number of people who strongly identify with a particular party in the UK and traditional left-right concerns have diminished in importance. Instead of political parties, people often align themselves to specific issues such as EU Exit or climate change.

Strategic assumptions:

1. In the UK, younger people, ethnic minority groups and unskilled workers/unemployed are less likely to vote but can still be politically engaged.
2. Youth activism on global issues is rising, e.g., climate change and Black Lives Matter.
3. The use of digital media in election campaigns, to target audiences, is increasing.
4. "Fake news," the dissemination of false information by social media has become a major threat to public trust in democracy and trust in established media.

Sources: Trust in public institutions: Trends and implications for economic security, UNDESA, July 2021
Political disengagement in the UK: who is disengaged? House of Commons Library Briefing, February 2021
Political polarisation and participation, POST, April 2021

Levels of trust in UK government vary by type of institution, March 2022



Source: Office for National Statistics - Trust in Government Survey, March 2022

Wildcards:

- The creation of false information is regulated with criminal sanctions imposed. Online anonymity is ended.
- Far-right extremism becomes the biggest terrorism threat.

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Political disengagement and polarisation

How is this trend playing out?

There continues to be a steady decline in voter engagement with traditional party politics, with a trend towards citizens feeling their political opinions are unrepresented. Most voters continue to see themselves as moderates, with the economy, justice, education and health remaining priorities.

Where policy fails to address public concerns there are flashpoints of political activism on both national and global issues – activism spreads from one country to others. It is hard to pinpoint what these issues might be, other that an increase in climate activism as climate change impacts increase. Although political misinformation has been around for as long as politics itself the amplification and targeting of messages through social media fuels issue polarisation, anxiety and societal behaviours.

Key uncertainty: Impact of polarising issues on politics

Alternative pathway one: Single issue political party in power

By 2050 a single issue political party is in power as successive governments and international agreements have failed to address the worst impacts of socio-economic issues such as wealth inequality, or environmental issues like climate change. The young political activists of the 2020s and 2030s have reached voting age and gathered enough support to form a major political party. They are supported by like-minded political parties across the world, forming a 'transnational political party'. Traditional political parties have found their own niche, supporting their voting base of older generations on health, social care, the economy and education but these policies are geared to enabling the transitions the single issue party is focused on, be it net zero or wealth distribution.

Alternative pathway two: Fragmentation into issue based political parties

By 2050 political party systems have fragmented into many smaller parties as electoral volatility has increased and voters align themselves to specific issues that matter to them at any one time. This makes it much more difficult for countries to legislate and govern themselves, leading to further alienation and distrust. Governance is through a coalition of parties, which takes a long time to put together after every election, leaving countries vulnerable and fragile for periods of time. Where coalitions fail, voters increasingly look to authoritarian leaders who promise to cut through the dysfunction of the political process.

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Competition for scarce natural resources

Increasing demand for scarce natural resources, particularly rare earth metals, creates competition for access and control of supply chains

The Covid-19 pandemic and recent military conflicts have highlighted our reliance on complex supply chain systems and global cooperation to access natural resources. This has led to price rises and a shift in awareness of supply chain vulnerabilities.

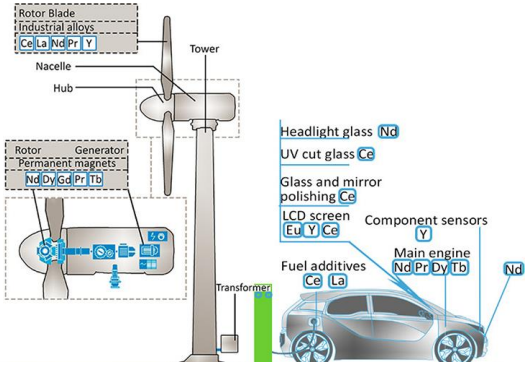
The transition to a low carbon economy, to meet Net Zero targets, is likely to increase demand for scarce natural resources used in low carbon technologies. These include cerium in electric vehicle (EV) production and neodymium required for wind turbines. This is exacerbated by innovation and demand from other growth areas, such as medical technologies. There is increasing competition to secure trade deals with politically stable regions but rising costs and demand for scarce resources could also increase illegal exploitation and workers' rights abuses.

By 2050 the demand for scarce natural resources could have shifted the geopolitical landscape, with more political power afforded to countries with mineral reserves, rather than oil and gas.

Strategic assumptions:

1. Increasing demand for low carbon technologies increases scarcity of key materials including cobalt and rare earth metals.
2. State and corporate actors will compete for supply chain rights on critical materials.
3. Conflict exacerbates inequalities in access to resource supply chains, driving global inequalities.
4. New geopolitical divisions and alliances based on scarce natural resources.

Sources: Department for Environment, Food and Rural Affairs (DEFRA) (2022) Global Mega Trends: 2022 annual revision (slide 23)
Future Agenda (2020) The UK in 2030: An Expert-Informed View on Some Key Trends
Saeed Rahimpour Golroudbary, Iryna Makarava, Andrzej Kraslawski, Eveliina Repo,"Global environmental cost of using rare earth elements in green energy technologies", Science of The Total Environment, Volume 832, 2022. https://doi.org/10.1016/j.scitotenv.2022.155022
Gilbert, Alex, Morgan Bazilian "The Era of commercial Space Mining Begins" Payne institute commentary series: viewpoint. (2020)



This figure shows the rare earth metals used in electric vehicles and wind energy production.

Wildcards:

- Advanced materials replace rare earth metals.
- Asteroid mining becomes a viable source of rare earth metals

Government Office for Science

Competition for scarce natural resources

How is this trend playing out?

Rare earth metals are increasingly critical to the high-technology and low-carbon economy. With a shift away from fossil fuel dependency, global demand for rare earth metals continues to rise, despite their uncertain supply chain and high environmental impact of production. This places pressure on existing supply chains, with nations that have access and control over rare earth metals gaining geopolitical power. To address supply chain resilience there is growing interest in advanced materials science (materials specifically engineered with properties that improve their performance relative to conventional materials) and the circular economy to reuse waste materials. The success of nation states, in developing advanced materials and material reuse, is dependent on leadership, research and development funding, skills and routes to commercialisation.

Key uncertainty: Use of rare earth metals in low carbon technologies

Alternative pathway one: Reuse via the circular economy

By 2050 China and, following some way behind, the US, Australia and Russia have effectively become rare earth metal monopolies, controlling the flow of materials and the rate at which countries can deliver low carbon economies. To build resilience, the UK salvages and reuses as many rare earth metals as possible by a circular economy approach. This has the benefit of reducing the environmental impacts of extraction, with mining areas restored to help meet Net Zero targets and benefit biodiversity. There are still some residual requirements for new rare earth metal sources, but their use is prioritised in low carbon technologies rather than consumer electronics. The transparency and sustainability reporting requirements, behind the supply chains for residual resource extraction, have become clearer as governments and businesses have to justify their reasons for using new sources of rare earth metals.

Alternative pathway two: Rare earth metals alternatives

By 2050 advanced materials, such as graphene, have provided many alternatives to rare earth metals for low carbon technologies. This has led to a significant decrease in the use of rare earth metals, reducing the geopolitical power associated with their access and control. However, a small number of countries, rich in rare earth metals, have sought to protect the economic benefits of their resources and investment from mining companies by continuing to develop low carbon technologies which rely on rare earth metals. This has enabled the transition to the use of advanced materials to meet Net Zero targets, but there is now a 'dual track' of competing low carbon technologies based on different materials.

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Global surface temperatures increases

'Locked in' global temperature rise, due to climate change, increasing the frequency and severity of extreme weather events

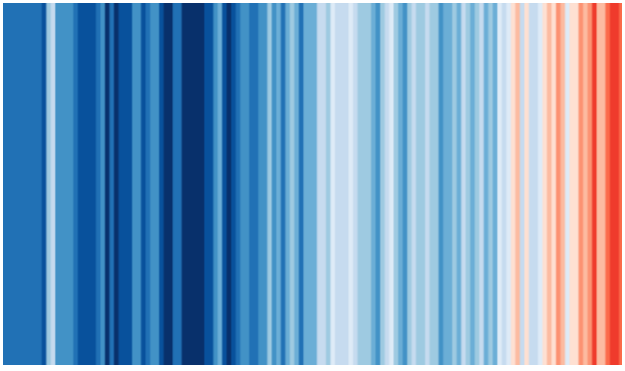
There has been roughly a 1 degrees Celsius increase in global average surface temperature since the pre-industrial era (1880-1900) and locked-in temperature change is predicted to top 1.5 degrees Celsius by 2030. Increased temperatures are driving regional and seasonal temperature extremes, reducing snow cover and sea ice, intensifying heavy rainfall and changing habitat ranges for plants and animals. Temperature increases are not consistent across the world, the north and south poles are warming faster, as ice melt has increased the amount of sun absorbed. This differential warming influences the flow of migrants around the world in response to localised climate change effects.

As well as the direct impacts of extreme weather disasters, droughts, floods and heatwaves are putting added pressure on food production in many regions of the world. Parts of Africa and Central and South America are already experiencing increased, sometimes acute, food insecurity and malnutrition due to floods and droughts. Other projected impacts include soil erosion, increased plant and animal disease and a weakening of ecosystem services, such as pollination.

Strategic assumptions:

1. Even with significant reductions in greenhouse gas emissions some level of warming is locked-in.
2. Increasing frequency and severity of climate change related weather events.
3. Increase in climate migration of vulnerable populations away from the worst affected areas.
4. Continued disagreement on climate finance and tension between countries on how targets should be met.
5. Increasing pressure on food supply chains, access to clean water and health services.

Sources: Department for Environment, Food and Rural Affairs (DEFRA) (2022) Global Mega Trends: 2022 annual revision (slide 19)
United Nations (UN) (2019) Let's Talk about Climate Migrants, Not Climate Refugees
International Pannal on Climate Change (IPCC) (2022) IPCC Sixth Assessment Report, working group 2 report
UN Stats report Sustainable Development Goal 13.



The figure of #showyourstripes shows global temperature 1850-2021, with climate attributed rise in recent years that will continue (Reading University: data source Met Office)

Wildcards:

1. Widespread adoption of a net zero lifestyles means temperatures remain below 1.5^{0}C of warming from 1990 levels.
2. Tipping points are reached earlier than anticipated, causing chain reactions that lead to warming to exceed 4^{0}C

Government Office for Science

Global surface temperatures increases

How is this trend playing out?

If current trends continue, the UN Office for Disaster Risk Reduction projects that medium to large scale extreme weather disaster events could reach 560 a year by 2030, a 40% increase from 2015. Climate change is affecting everyone, but the most vulnerable are hardest hit. The Sixth Assessment report from the IPCC estimates that 3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change. Hotspots of high human vulnerability are concentrated in small island developing States, the Arctic, Southern Asia, Central and South America, and much of sub-Saharan Africa. Poverty, limited access to basic services, conflict and weak governance limit adaptability to climate change, resulting in humanitarian crises that could displace millions from their homes. By 2030, an estimated 700 million people could be at risk of displacement by drought alone.

Key uncertainty: Responses to more rapid warming than models predicted

Alternative pathway one: Rapid warming leading to rapid societal change

By 2050 it has become apparent that temperatures are rising higher than previously anticipated, and the 4 degrees warming scenario is looking ever more certain for 2100. The increase in extreme weather events, and gradual changes to the availability of food and water, has led to hotspots of internal and cross border climate migration. Over 200 million people have left their homes which has led to conflict and an increasing number of refugees. There has been a societal shift towards personal responsibility to lead a net zero lifestyle, given the perceived failure of governments, and concerns the 'climate migrant crisis' will only get worse. Climate activist groups grow and popularise 'living within your means' from a planetary perspective, reducing emissions from heating homes, only travelling when essential, cutting waste and changing to plant based diets.

Alternative pathway two: Rapid warming leading to geoengineering

By 2050 more rapid warming than predicted has led to a loss of trust in climate modelling. The uncertainty this causes has spurred a response in geoengineering projects, intervening in the Earth's natural systems, to tackle the direct causes of climate change. Richer countries have taken 'big bets' on technologies such as direct air carbon capture or modification of weather systems. The latter has caused serious consequences for some other nation states or regions within a country where rainfall patterns have been altered, leading to internal and cross border climate migration. Solar geoengineering projects are also being tested by both public and private players, despite concerns over unknown risks, ethical implications and a lack of global governance.

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Increasing impacts of biodiversity loss

Biodiversity loss directly impacts on the economy and human wellbeing

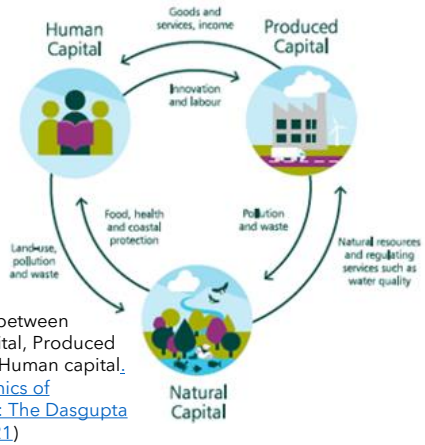
There is increasing awareness of the value of natural capital (the world's stock of natural assets) and the goods and services it provides to people. Research by the World Economic Forum has estimated that $44 trillion of economic value generation – more than half of the world's total GDP – is moderately or highly dependent on nature or its services, and is therefore exposed to biodiversity loss. Industries that are highly dependent on nature generate 15% of global GDP ($13 trillion), while moderately dependent industries generate 37% ($31 trillion). This is also evidence that access to nature for wellbeing is important, with potential for the NHS to save approx. £2.1 billion every year in treatment costs if everyone in England had access to high quality green space.

Human-caused environmental degradation has been attributed to a current mass extinction event, with three-quarters of ice-free land and two-thirds of marine environments severely altered. One million species are at risk of extinction in the coming decades. Latin America and the Caribbean have seen a decline of 94% in the animal population since 1970. This is linked to habitat loss driven by global consumption patterns, over-exploitation of species and, increasingly, climate change.

Strategic assumptions:

1. Nature's worth to society continues to not be reflected in markets or current economic models.
2. Nature remains important for physical and mental health and wellbeing.
3. Biodiversity loss, driven by over-consumption will continue, exacerbated by climate change.
4. There are limits to what nature can provide and unknown impacts from continued biodiversity loss.
5. Biodiversity-related risk is a liability that is currently poorly understood by investors and is omitted from most financial institutions' balance sheets.

Sources: Department for Environment, Food and Rural Affairs (2022) Global Mega Trends: 2022 annual revision (slides 10, 19, 21, 23)
Future Agenda (2020) The UK in 2030: An Expert-Informed View on Some Key Trends
HM Treasury (2021) The Economics of Biodiversity: The Dasgupta Review
Amigo, Ignacio (2022) When will the Amazon hit a tipping Point Nature 578, 505-507, doi: https://doi.org/10.1038/d41586-020-00508-4
Nature Risk Rising, World Economic Forum (2020)
Investing in nature is an investment in the NHS, Environment Agency (2020)
Ceballos, Gerardo, et al., (2017) Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. PNAS
UNCCD "Land Degradation Neutrality: Overview"



Interaction between Natural capital, Produced capital and Human capital. The economics of biodiversity: The Dasgupta Review (2021)

Wildcards:

1. Animal-centric arguments and rights for nature drive significant action to prevent biodiversity loss.
2. Agriculture and energy production systems are transformed away from land and ocean based activities.

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Increasing impacts of biodiversity loss

How is this trend playing out?

The health of ecosystems continues to deteriorate rapidly, eroding the foundations of economies, livelihoods, food security, health and quality of life worldwide. This is driven by ongoing land use change, over-exploitation of species, climate change, pollution and alien invasive species. Transformative change is needed to meet the global target of protecting 30% of land and marine environments by 2030. Meeting such targets requires more than global biodiversity goals. Conservation funding, new protections, industrial agriculture and the global energy industry, amongst other things, need to be transformed. The UN convention to combat desertification state that 90% of land will bear human imprint by 2050.

Key uncertainty: Interplay between biodiversity loss and financial risk management

Alternative pathway one: Biodiversity related risks incorporated into financial risk management

By 2050 the scale of nature-related systemic crises, has transformed laws and regulation governing environmental liabilities. For example, the COVID-19 pandemic, has led to the integration of national biodiversity targets into domestic policy, recognising that sectors across the entire economy are highly exposed to nature-related risks, primarily through their supply chains. Financial institutions routinely incorporate nature-related risks into internal risk management processes and investment decisions. Understanding biodiversity risks is important as, with better monitoring and data, campaign groups can hold companies and government to account through legal challenges, particularly where environment and health issues intersect, building on the air and water pollution challenges of the 2020's.

Alternative pathway two: Biodiversity related risks manged through voluntary reporting

By 2050 nature related risks still sit on the periphery of financial risk management systems with little support for mandatory disclosures or reporting. Risks are recognised and addressed through voluntary reporting and standards set by industry bodies in tandem with nature conservation organisations but this does not lead to the transformative economic or institutional change needed to prevent widespread biodiversity loss. Within the UK, the natural capital accounts, published by the ONS, have been extended to cover more of the scale and complexity of the services provided by nature. This helps track change in natural assets but has limited ability to monitor the exposure of government, society or businesses to biodiversity related risks

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Growing and ageing populations

Populations are still growing, but at a slower rate, leading to an ageing population

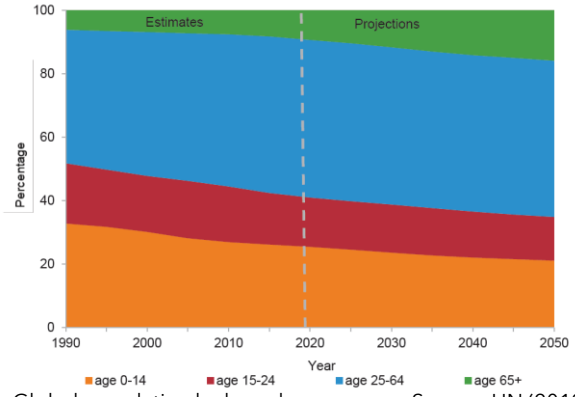
The global population is rising, but at a slower rate. Between now and 2050, 55 countries are projected to see a population decrease of 1% or more, with the number of people aged 65 years or over more than doubling. ONS projects that the population of the UK will increase by 3.2% from an estimated 67.1 million in mid-2020 to 69.2 million in mid-2030, driven by net migration of 2.2 million. This population is not just growing, but also ageing: by mid-2045, 3.1 million, or 4.3% of the total UK population is expected to be aged 85 or over, due in part to increases in life expectancy.

Healthy life expectancy, the average number of years that an individual is expected to live in a state of self-assessed good or very good health, has remained stable, while life expectancy has risen slowly. This means more years are spent in poorer health, driving demand for health and social care services.

Strategic assumptions:

1. There is little change from projected immigration levels.
2. Fertility levels either stay the same or fall.
3. Life expectancy continues to rise or stay the same.
4. Advancements in medicine do not drastically change quality of life for older people.
5. Demand for social care and healthcare increases with age.

Sources :King's Fund (2021) What is happening to life expectancy in England; Migration Observatory (2020). Migrants in the UK: An Overview; National Audit Office, (2021) The adult social care market in England; ONS (2018) Living longer: how our population is changing and why it it matters; ONS (2020) Migration Statistics Quarterly Report: August 2020; Trend Deck; UN (2019a). World Population Ageing; UN (2019b) UN Department of Economic and Social Affairs. ONS population projections, Jan 2022.



Global population by broad age groups. Source: UN (2019)

Wildcards:

1. Humanitarian crisis leads to mass immigration, including permanent residency.
2. Pandemic leads to mass mortality event of younger people.
3. Breakthrough in care for cognitive decline reduces overall costs of aging.

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Growing and ageing populations

How is this trend playing out?

The global population is expected to virtually stop growing by the end of this century, largely due to falling global fertility rates. Only Africa is expected to have strong population growth to the end of the century, providing a demographic dividend of a large working age population.
The world continues to age and by 2073, there are projected to be more people aged 65 and older than under age 15. Life expectancy increases with medical advances, but years spent in good health play out along existing lines of social and economic inequality. Reduced entitlement to care, combined with growing demand for adult social care, puts pressure on the informal care sector (e.g., care undertaken by family networks). The Health Foundation estimates an increase of 55% in social care workers will be needed in the England over the next decade.

Key uncertainty: **Advances in medicine and impact on healthy life expectancy**

Alternative pathway one: Healthy ageing

By 2050 the population has continued to age but significant advancements in medicine, such as personalised medicine, biomarker technology and disease modifying drugs mean that the onset of conditions such as dementia have been delayed. As healthy life expectancy has risen, people work longer, aided by assistive technologies and digital services, and pensioner poverty rates have fallen. Rapidly developing (and rapidly ageing) countries have learnt the importance of preventative healthcare, investing in risk management programmes for alcohol and tobacco consumption, the reduction of risk factors for diabetes and hypertension, and the provision of primary healthcare services that prevent non-communicable diseases and chronic conditions.

Alternative pathway two: Surging demand for social care

By 2050 slow progress in early treatment and detection of conditions like dementia and lack of investment in preventative healthcare means healthy life expectancy has not improved but populations continue to age. Medicine and treatment focus on managing the symptoms of older adult patients. Moves towards extending working life have been slow, even with the rise of the state pension age, due to the poor health of many older adults. Health inequalities are compounded by those with the ability to pay for private health and receive treatments more rapidly than those who rely on state services. These demand increases will put pressure on health service costs and could lead to longer waiting lists, a review of eligibility criteria for care, or more working age adults trying to balance jobs with care needs'

Government Office for Science

Global public health challenges

Global infectious diseases, anti-microbial resistance (AMR), and the wider effects of climate change are increasing global public health challenges

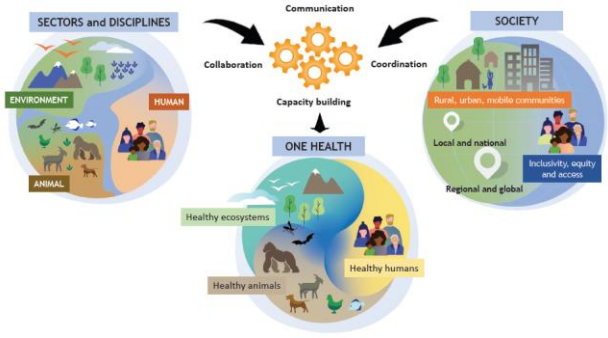
The increasing global impacts of infectious diseases, partially attributed to AMR, are an ongoing challenge. Globally, AMR causes 700,000 deaths, which is expected to rise to 10 million by 2050 if no action is taken. Though the UK has reduced the use of antibiotics in humans, it is still a high user relative to other European nations. The UK aims to have AMR controlled by 2040. Additionally, climate change also influences health through injury from extreme weather events, by exacerbating respiratory and cardiovascular disease, and by shifting the spread of vector-borne diseases. Impacts are unevenly distributed across populations - those who are older, poorer and marginalised are the most vulnerable.

Countries with weak health systems are less able to cope with emerging health risks; responding to pandemics further constrains their ability to deliver services to treat non-communicable diseases. Governments (including the UK) are adopting a One Health approach, which takes a holistic approach to health, recognizing the interconnection between people, animals, plants, and their shared environment.

Strategic assumptions:

1. Even with mitigation and adaptation, climate change will have negative health impacts, particularly on vulnerable people.
2. New infectious diseases continue to emerge and spread globally.
3. Antibiotic resistance will continue to grow.

Sources: Ahmed, M.H., 2020. Black and minority ethnic (BAME) alliance against COVID-19: one step forward. *Journal of racial and ethnic health disparities*, *7*(5), pp.822-828; DHSC (2019) Contained and controlled: the UK's 20-year vision for antimicrobial resistance; Patel, J.A., Nielsen, F.B.H., Badiani, A.A., Assi, S., Unadkat, V.A., Patel, B., Ravindrane, R. and Wardle, H., 2020. Poverty, inequality and COVID-19: the forgotten vulnerable. *Public health*, *183*, p.110; PHE (2020) New antibiotic-resistant infections rise to 178 per day in England; The Climate Coalition (2021). This report comes with a health warning;



The One Health Concept

Wildcards:

1. New classes of antibiotics are developed that mitigate against AMR.
2. Collapse of ecosystems opens up niches and pathways for the spread of new pathogenic diseases.

Foresight

Global public health challenges

How is this trend playing out?

Due to changes in the climate, population, food systems and supply chains, novel disease outbreaks at the scale of COVID-19 are only getting more likely. A failure to tackle the climate and biodiversity crises together also reduces the options to develop alternatives to current anti microbials, which could be inspired by agents found in in the natural world. The scale of future impacts depends on the lessons we have learnt – trusting science and tackling misinformation, investing in data and predictive modelling, focussing on hyperlocal communities and using diverse approaches and community ambassadors for public health messaging. Between 2030 and 2050, the World Health Organisation expects climate change to cause approximately 250,000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress.

Key uncertainty: Interplay between inequality and health risks

Alternative pathway one: Health risks closely tied to vulnerable groups

By 2050, close international collaboration on climate change and biodiversity targets and following a One Health approach has been successful in containing AMR and reducing the number of outbreaks of global infectious diseases. However, there are still groups vulnerable to infection because of social determinants such as poor housing, poor working conditions and low incomes. These reservoirs of infection have led to new variants of disease, which cause localised outbreaks. Local communities have recognised the value of social connections in times of crisis. These connections are often tech enabled. Countries which have invested in internet connectivity and digital skills have reduced both the physical and mental health impacts on vulnerable groups.

Alternative pathway two: Improved public health outcomes for all

By 2050 there has been action across a range of public policy areas, with policies to tackle economic and social inequalities alongside actions with a specific focus on disadvantaged groups and deprived areas. This has reduced the vulnerability of previously marginalised groups, with health risks and emerging infectious diseases having an equal impact across society. New diagnostic tools for early pathogen detection, such as nano sensors and wastewater analysis, are regularly used but there are still infectious disease outbreaks where countries do not have the resources to access and use these new technologies.

Government Office for Science

Income and wealth inequalities

Increasing income and wealth inequalities, exacerbated by COVID-19

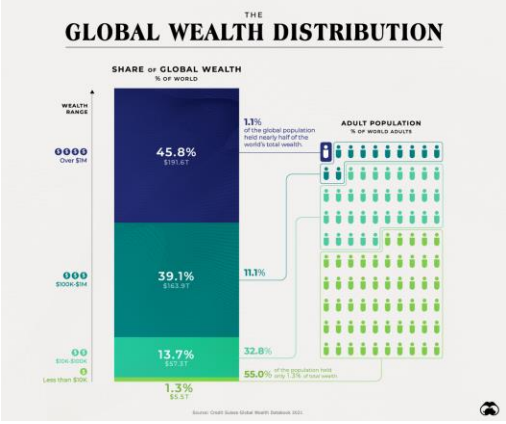
The richest 10% of the global population currently receives 52% of global income, while global wealth inequalities are even more pronounced. Deregulation and liberalisation have decreased the share of wealth held by public actors, making it close to zero or negative in developed countries. In the wake of the COVID-19 pandemic, global debt has surged. 58% of the world's poorest countries are in debt distress or at high risk of it, limiting investment in education, health and infrastructure.

The UK has a high level of income inequality, compared to other developed countries, and wealth is even more unequally divided. Inequalities have been exacerbated by the COVID-19 pandemic, affecting young people and the lowest paid, as well as women, single parents, those with disabilities and Black and Minority Ethnic (BAME) groups. The UK government's levelling up mission is for pay, employment and productivity to have risen in every area of the UK by 2030.

Strategic assumptions:

1. Economic growth – as measured by GDP – continues.
2. Wealth, by current definitions, will continue to be concentrated in the hands of a small number of individuals.
3. Inequalities are avoidable with the right policy interventions.

Sources:Department for Levelling Up, Housing and Communities (2022) Levelling Up the United Kingdom; ONS (2021) Household income inequality, UK: financial year ending 2020; POST (2021) Economic inequality and recovery; Resolution Foundation (2022). The Living Standards Outlook 2022; The Equality Trust. (nd) The scale of economic inequality in the UK; World Income Inequality Database (2021) United Nations University; World Inequality Report (2022)
When the debt crises hit, don't simply blame the pandemic, World Bank blog, June 2022; Inequalities in education, skills, and incomes in the UK: The implications of the COVID-19 pandemic Institute for Fiscal Studies, March 2021; The Economy 2030 Enquiry, Resolution Foundation



Credit: Visual Capitalist

Wildcards:

1. Organised cybercrime redistributes wealth from the rich to the poor.
2. Policies target new societal success metrics related to reducing inequality, with less focus on GDP

Foresight

Income and wealth inequalities

How is this trend playing out?

Work by the Institute for Fiscal Studies shows three particular inequalities are likely to have risen because of the pandemic crisis: income inequalities between richer and poorer households, socio-economic inequalities in education and skills, and intergenerational inequalities between older and younger people. The Russian invasion of Ukraine is likely to increase economic inequalities further. This is playing out as a cost of living crisis due to high inflation and rising energy bills. In the UK, areas with poorly-insulated homes and heavy reliance on cars are particularly vulnerable to rising costs. The Resolution Foundation's Economy 2030 report, suggests that policies that close the inequality gap to that of our peers such as Australia, Canada, France and the Netherlands could increase incomes by over 40 per cent among the poorest fifth of the UK population.

Key uncertainty: Whether national inequalities rise or fall

Alternative pathway one: Increasing inequality driven by economic downturn

By 2050 downturns in the economy following COVID-19 and the cost of living crisis have translated into increasing income and wealth inequalities, which correspond with other inequalities. The rich are best able to weather the turbulent economic conditions, holding on to safe assets and cutting discretionary spending. Continued international mobility of the rich and their assets has made it harder for national government to redistribute income and wealth. Technological developments have delivered increasing economic returns to those with existing assets, particularly data and Intellectual Property. People with the lowest incomes have their employment options squeezed by automation, with the remainder being mostly the next generation of gig economy jobs.

Alternative pathway two: Stability and investment decreases inequalities

By 2050, several periods of stability and investment have helped to decrease inequalities. Economic stability emerged following turbulent years in the 2020s, alongside renewed investment in skills, infrastructure and innovation by both the public and private sectors. This investment has also been more evenly spread across the regions of the UK. Over time, this has helped to create more well-paid jobs and a workforce with the skills to undertake them. Technological developments have been more decentralised and open than in the past, creating more scope for anyone to create new valuable assets with negligible cost barriers. Automation has improved productivity and reduced the need for low-paid work.

Government Office for Science

Re-skilling the workforce

Increased need to reskill the workforce as new sectors and emerging technologies disrupt labour markets

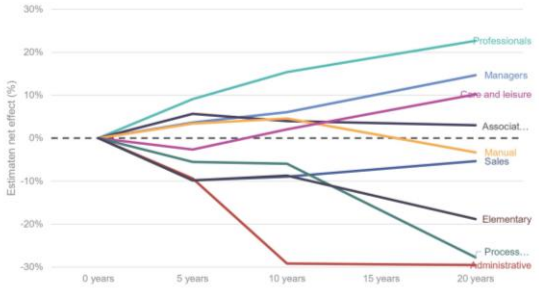
UK job vacancies reached almost 1.3 million in 2022, with shortages in roles such as farming, sales and hospitality impacting on key supply chains. By 2030, the move to online retail and automation may eliminate significant numbers of jobs in services and manufacturing, with 1.5 million jobs in England at high risk of some of their duties and tasks being automated. By 2050, the skills required to exploit advanced technologies will likely require fundamental changes in the education system, including deployment of education technologies (EdTech), and an increased focus on employability and transferable skills in Higher Education (HE).

The Government has set a target to create 250,000 jobs in green industries, whilst 400,000 jobs will need to be filled in the energy sector between now and 2050. By 2030, growth in new and emerging jobs sectors like the green economy, digital sectors, and services will spur increased demand for educational programmes in green finance, Artificial Intelligence (AI) and Financial Technologies (FinTech). Demographic changes in the population will lead to an older workforce, who will remain in work for longer, necessitating lifelong learning and retraining.

Strategic assumptions:

- A higher ratio of people of retirement age to people of working age.
- The pursuit of science and technology will be linked with strategic advantage.
- Technology in developed economies will be increasingly pervasive
- Continued commitment to Net Zero target.

Sources: DEFRA (2022) Global Mega Trends: 2022 annual revision
ONS (2022) Vacancies and jobs in the UK: April 2022
ONS (2019) Which occupations are at highest risk of being automated?
POST (2016) Automation and the workforce
GOV.UK (2022) Future opportunities for education technology in England
Advance HE (2018) Building Higher Education Curricula Fit for the Future
Beatty, C and Fothergill, S (2020) The Long Shadow of Job Loss: Britain's Older Industrial Towns in the 21st Century
GOV.UK (2020) Ten Point Plan for a Green Industrial Revolution for 250,000 jobs
National Grid (2020) Building the Net Zero energy workforce
ONS (2021) Economic labour market status of individuals aged 50 and over, trends over time: September 2021
BEIS (2021) Estimated net effects of AI by broad occupational category



Source: PwC analysis of OECD PIAAC and ONS APS data

Estimated net employment effects of AI by broad occupational category - The Potential Impact of Artificial Intelligence on UK Employment and the Demand for Skills, BEIS, 2021

Wildcards:

- Political or public resistance prevents the widespread automation of jobs.
- Continuing to work into your 70's or even 80's becomes increasingly common.

Government Office for Science

Re-skilling the workforce

How is this trend playing out?

Artificial Intelligence (AI), Machine Learning (ML) and automation technologies have progressed rapidly, but have not yet led to a wholesale reorganisation of the workforce. The susceptibility of job roles to automation varies greatly, with lower paid and low-skilled workers at most risk of seeing their roles disappear. Patterns of work and economic migration are in flux, with worker shortages coming up against political resistance to immigration, real wage cuts linked to the cost of living and the gig economy all impacting on public service delivery and service sectors such as childcare and hospitality. The demand for reskilling has not yet translated through to corresponding uptake of further education, skills and training where participation has been decreasing, although there has been a significant increase in interest in online learning courses following the COVID-19 pandemic.

Key uncertainty: People's role in the future economy

Alternative pathway one: AI-enhanced economy

By 2050 the widescale deployment of AI and ML has created new jobs in digital services, green technologies and the creative industries. Distributed learning has reduced the barriers to knowledge, and enabled a large section of the workforce to retrain and participate in the new knowledge economy. While a significant fraction of the workforce benefit from this expansion, inequalities have not gone away entirely, with some workers continuing to rely on AI-supported gig economy jobs. Higher Education provision has changed significantly to compete with other sources of training, and focuses strongly on the provision of Science, Technology, Engineering and Mathematics (STEM) learning, at the expense of the humanities and other creative subjects.

Alternative pathway two: The AI hourglass

By 2050 automation has created an 'hourglass' economy by eroding traditional middle-class jobs in education, construction and manufacturing, whilst creating only small numbers of very well paid AI related jobs in sectors such as robotics and ML engineering. This has increased the number of people in precarious employment, and further expanded the gig economy. Despite the availability of online and distributed learning opportunities for people to retrain, skilled well paid roles are limited. Education systems are increasingly outpaced by developments in technology, and Higher Education has retrenched to become a reserve of the knowledge elite.

Government Office for Science

Rise in prosperity in Asia

The drivers of growth and prosperity rise more rapidly in East and South-East Asia

Research and Development (R&D) spending is dominated by the established economies in the US, Europe and East and South East Asia, driving their economic success and prosperity. By 2030 the fastest growing cities in terms of population, GDP growth and R&D intensity will likely be located in Brazil, India and China. China's R&D spend is planned to increase by 7% per year between 2021 and 2025.

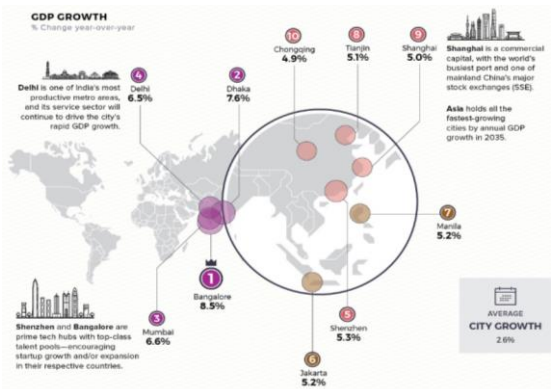
China is predicted to have four cities in the top 10 by GDP by 2035, though economic sanctions, linked to alleged human rights abuses, and reductions in international cooperation over Taiwan may impact China's continued growth. Competition may come from the African continent, which is estimated to have a workforce of 1 billion by 2040, with 500 million new middle-class consumers.

The UK is strengthening ties with East and Southeast Asia to help create green jobs, reinforce security cooperation, promote technology and science partnerships, and safeguard key pillars of international law like the UN Convention on the Law of the Sea.

Strategic assumptions:

1. Investment in science and technology is linked with strategic advantage.
2. Global economic growth will re-establish, following the pandemic.
3. Economic growth will centre around East and South-East Asia.
4. A resurgence of superpower competition between the EU, US, China and Russia.

Sources: DEFRA (2022) Global Mega Trends: 2022 annual revision
CNBC (2021) 'China spending on research and development to rise 7% per year in push for major tech breakthroughs' *4 March 2021*
World Economic Forum (2019) These will be the most important cities by 2035
Future Agenda (2022) Africa Growth
EY Global (2020) Why Africa is becoming a bigger player in the global economy
Deloitte (2022) Sizzling food prices are leading to global heartburn
European Bank for Reconstruction and Development (EBRD) (2022) EBRD sees war on Ukraine causing major growth slowdown
Visual Capitalist (2019) Mapped: The World's Top 10 Cities in 2035
UK announces agreement to strengthen ties with Southeast Asia, August 2022



Projected GDP growth in 2035 – Mapped: The world's top 10 cities in 2035, The Visual Capitalist, 2019

Wildcards:

- China becomes a democracy.
- The African continent becomes an economic superpower.

Government
Office for Science

Rise in prosperity in Asia

How is this trend playing out?

Whilst the global economy slows or levels off, the emerging economies of East and South-East Asia are still predicted to grow, with increases in GDP, R&D spend and the population of key cities. The economic opportunity this represents will draw interest from developed economies and global companies, who will seek to take advantage of new and expanding consumer markets, labour pools, and opportunities for investment. The African continent's expanding workforce and growing middle class may spur accelerated growth, providing more influence in the global economy, rather than being dominated by the US and China. However, political and environmental instability threaten global growth, with climate change likely to disproportionately affect poorer and emerging economies in the global South, whilst conflict and great power competition may increase due to food and resource insecurity.

Key uncertainty: Impact of political instability on growth

Alternative pathway one: Stable transformation from the old world order

By 2050 a new global order is in place, supported by the older developed economies advancing trade agreements, investment and exports towards markets in East and South-East Asia. Despite turbulence in the 2020s, geopolitics has remained stable enough for this shift to happen, although some tensions remain, particularly over critical natural resources. Living standards across East and South-East Asia have improved as technological development in the region has skipped many intermediate steps, with home-grown innovation taking advantage of imported knowledge and skills. The improvement in living standards helps to shore up regional political stability.

Alternative pathway two: The world order fragments

By 2050 the emerging economies of East and South-East Asia have rejected the investment and interests of the older developed economies, as the old geopolitical order has faded due to tensions over human rights and resource security. Political and economic sanctions and trade wars have continued. This fracturing means the 15-strong Regional and Comprehensive Economic Partnership (RCEP) of Asian-Pacific nations has gained strength and influence, not just for trade, but also by leading the way in its responses to pandemics and climate change. This has led to shifting global alliances as other nation states try to decide where their interests lie - with the old world order, or the strengthened power base of East and South-East Asia.

Government Office for Science

Decentralised finance (DeFi)

Financial transactions are increasingly mediated through new decentralised digital process

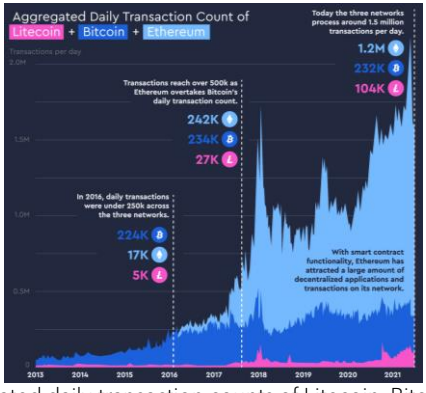
DeFi describes a collection of finance applications often built on Distributed Ledger Technology (DLT), a decentralised database managed by multiple participants, across multiple nodes. These include cryptocurrencies and digital currencies secured by cryptography. There are currently around 17,000 different cryptocurrencies in circulation. Daily transactions for the three biggest cryptocurrencies experienced a six-fold increase between 2016 and 2022. Traditional financial institutions are exploring the use of DLTs to simplify their processes. The Bank of England is considering the case for a UK Central Bank Digital Currency (CBDC), which would be a digital equivalent to cash. A shift toward sustainable DLTs may drive increased use, with new systems using three orders of magnitude less energy than current systems. By 2050, DLTs may also be used in government and legal services in the form of 'smart' contracts, and CBDCs may have replaced cash. However, unregulated DLT systems could enable avoidance of financial and legal oversight. The National Cyber Security Centre has raised concerns over the security of the technology and highlighted limitations that could hinder widespread uptake.

DeFi also includes mobile money services (financial services for those without bank access), peer to peer (P2P) and microlending. These are widely used in emerging economies, for example in Kenya transactions worth 60% of the country's GDP used the mobile money system in 2022. DeFi tools are being used to make the mobile money system interoperable with conventional financial services.

Strategic assumptions:

1. Nation states will attempt to regulate DeFi from a legal and environmental standpoint.
2. Cyber attacks have evolved and become more frequent.
3. Government services and processes are increasingly delivered digitally.
4. Cryptocurrencies remain volatile, unless backed by stable fiat currencies or assets.

Sources: MOD (2018) Global Strategic Trends: the future starts today
DEFRA (2022) Global Mega Trends: 2022 annual revision
GO-Science (2021) Trend deck 2021: Governance and Law and Technology
Bank of England (2021) Is 'crypto' a financial stability risk?
Bank of England (2022) Financial Stability in Focus: Cryptoassets and decentralised finance
Vox (2020) What Kenya can teach its neighbors about improving the lives of the "unbanked"
Bloomberg (2022) Kenyan Mobile Money Gets Boost in Shift to Seamless Payments
Bank of England (2022) UK central bank digital currency
GOV.UK (2022) Government sets out plan to make UK a global cryptoasset technology hub
M Platt *et al* (2021) The Energy Footprint of Blockchain Consensus Mechanisms Beyond Proof-of-Work
Washington Post (2022) Jack Dorsey is wrong. The dollar is still a global reserve currency.
World Economic Forum (2022) Cryptocurrency regulation: where are we now, and where are we going?
Visual Capitalist (2021) Visualizing the Rise of Cryptocurrency Transactions



Aggregated daily transaction counts of Litecoin, Bitcoin and Ethereum – Visualising the rise of cryptocurrency transactions, The Visual Capitalist, 2021

Wildcards:

- Quantum computing renders cryptography ineffective.
- International transactions are no longer conducted in US dollars.
- Banks cease to use cash and paper currency.

Decentralised finance (DeFi)

How is this trend playing out?

While cryptocurrencies are being used as a speculative asset, they have not yet achieved mainstream use. At the same time, DeFi is expanding to encompass an increasing variety of uses and applications. Both autocratic and democratic governments are looking to regulate cryptocurrencies, with the US and China seeking to implement varying levels of control on their use. Meanwhile, emerging economies are taking advantage of DeFi to extend financial services to those who would not otherwise have access to the financial system. The 'killer-app' for DLTs has yet to be found, though their suitability for establishing ownership and identity could revolutionise fields as diverse as real estate and government services. The environmental impact of some cryptocurrencies is high, but this could change if other versions of the technology win out.

Key uncertainty: Extent of DeFi regulation

Alternative pathway one: Regulation and control

By 2050 government regulation has curbed the worst excesses of cryptocurrency booms and busts, settling on stable cryptocurrencies backed by fiat currencies and stable assets. The delivery of government services has been enhanced by DLT smart contracts, which also determine the populations' eligibility to access services, acting as a form of social control. This widespread adoption has impacted digital inequality, with those unable or unwilling to use digital banking services and digital currencies largely excluded from accessing mainstream financial services. Those seeking to evade government control and taxation have developed new financial mechanisms to prop up a shadow economy of illicit finance and money laundering.

Alternative pathway two: Fragmentation and disorder

By 2050 the decentralised nature of cryptocurrencies and the efforts of crypto entrepreneurs have made it challenging for governments to impose control. The DeFi landscape is an unregulated landscape of tax avoidance, illicit transactions and frequent cyber attacks. Central banks have experimented with Central Bank Digital Currencies (CBDCs) but these struggle to gain traction as one of many competing alternatives. This makes it more challenging for central banks to maintain macro-economic stability. P2P lending and microfinance have grown, as a lack of confidence in the financial system leads people to seek more localised finance options.

Government
Office for Science

Commitment to Net Zero

Increasing commitments from Government and businesses to meet Net Zero targets

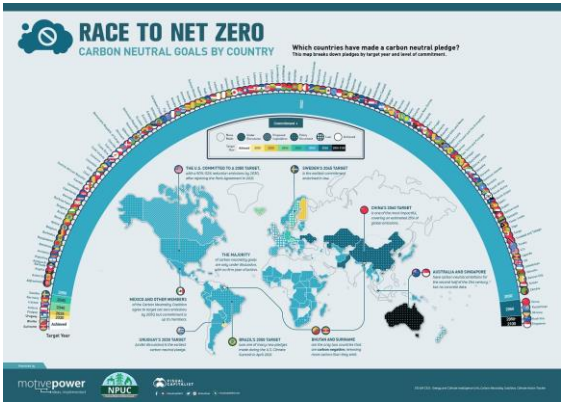
More than 70 countries have set Net Zero targets, covering about 76% of global emissions. By 2050, most major economies are likely to have lowered their carbon emissions but there are significant risks around Net Zero targets being met, depending on funding and policy shifts, and costs may fall unequally across countries and societies. Where commitments are not supported by clear action plans, legal challenges and activism are following. There are many environmental and sustainability corporate standards, including the Carbon Trust's Route to Net Zero Standard which uses science based targets. Ten large corporates have signed up as pathfinders for the standard.

Public behaviour change will be an important part of achieving Net Zero, with 65% of UK emissions reductions to 2035 requiring some form of public choice. The public's future dietary and transport preferences will influence the policy agenda, and shape business models. Global Environmental, Social and Governance (ESG) assets grew from $22.8Tn in 2016 to $35.3Tn in 2020 (36% of the global total) and their value could exceed $50 trillion by 2025.

Strategic assumptions:

1. The Paris Agreement target of keeping temperature increases under 1.5°C will not be met without further commitments that are translated into policies.
2. Continuing tension between countries about how to meet climate targets and who should pay.
3. Increasing international commitments on emission reductions and their translation into national legislation.
4. The cost of climate change impacts will increase over time and fall disproportionately on the poorest.

Sources: Department for Environment, Food and Rural Affairs (DEFRA) (2022) Global Mega Trends: 2022 annual revision
GO-Science (2021) Net Zero Society PESTLE drivers
Global Fossil Fuel Divestment Commitments Database (2021) Invest-Divest 2021: a decade of progress towards a just climate future
Climate Change Committee (2022)
Institute for Government (2021) Paying for net zero
World Bank (2021) When poverty meets climate change: A critical challenge that demands cross-cutting solutions
B-Corporation (2021) About B Corps
London School of Economics (2021) Public behaviour in the UK's Net Zero Strategy: the Government must work out how to bring people with it
Global Sustainable Investment Alliance (GSIA) (2021) Global Sustainable Investment Review 2020
Visual Capitalist (2021) Race to Net Zero: Carbon Neutral Goals by Country
Carbon Trust Net Zero Standard



Race to Net Zero: Carbon neutral goals by country – The Visual Capitalist, 2022

Wildcards:

- Net Zero targets are scrapped in some countries.
- Rapid temperature rises mean targets need to be more ambitious.
- Mass mortality event due to extreme temperatures.

Commitment to Net Zero

How is this trend playing out?

Extreme weather events have made carbon reduction a higher priority with more countries, cities and businesses adopting Net Zero targets. These targets play out over different timescales – some to 2030, others to 2050. Targets are being translated to action and policy packages at the national level, but more wide-reaching and longer-term measures are needed. There have been some successes, particularly in early government support for new technologies leading to private sector investment and rapidly falling costs, including for solar panels, wind turbines and electric vehicles. Other areas such as heavy industry and aviation remain challenging to decarbonise. Businesses are keen to display their Net Zero credentials but a plethora of standards and reporting practices means 'greenwashing' of certain business practices persists.

Key uncertainty: Future global co-operation

Alternative pathway one: Targets achieved with varied contributions

By 2050 climate change impacts have driven international co-operation and agreement to significantly reduce carbon emissions through a mixture of low carbon technologies, policy changes and financial incentives. This has helped to achieve Net Zero globally, but efforts have been varied with some countries racing ahead and becoming green economy leaders, while others have lagged and missed their targets. Climate finance initiatives help the worst-affected countries to meet costs and mitigate against large numbers of 'climate refugees' crossing national borders. Co-operation between international businesses and global citizen networks has increased with a Net Zero lifestyle becoming the norm for many citizens.

Alternative pathway two: Global turbulence leaves Net Zero off track

By 2050 climate change impacts have contributed to a rise in isolationism, as nation states try to adapt to protect their own national security and prosperity. This has caused global conflict as food and water security diminishes and critical materials for low carbon technologies are less equitably shared. A planned transition to Net Zero in many emerging economies is now just a pipe dream. Without access to these resources, and the constant crisis management needed in responding to extreme weather events, the transition to low carbon economies has stalled. There are further conflicts over geo-engineering projects, such as large-scale weather modification programmes, which have altered rainfall patterns over other states.

Government Office for Science

Increasing use of Artificial Intelligence (AI)

Growing AI capability is likely to change the nature of work over the coming decades.

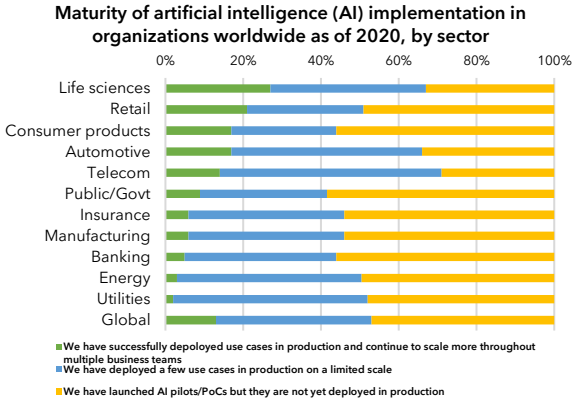
AI applications are developing rapidly to perform multiple tasks and automate routine processes. This has workforce implications as industries become more productive through the use of AI, as well as changing the nature of work. AI is currently most mature within the service sector and product development, but future applications are likely to be diverse, affecting both low-skilled and high-skilled occupations. This means that will be winners and losers in terms of AI integration into jobs, but there is some uncertainty in how this will develop within specific sectors. For example, health, science and technical services and education are *likely* to see a net increase in jobs, but manufacturing, transport and administrative roles are *potentially* set to see a net decrease.

There is also much uncertainty on when general AI (i.e., AI capable of many different tasks and/or rational decision-making) may be realised, with some experts predicting this could be as early as 2040-50, potentially leading to fundamental changes within this century. The National AI Strategy (2021) outlines steps for how the UK will begin its transition to an AI-enabled economy, the role of research and development in AI growth, and the governance structures that will be required to ensure citizens are protected.

Strategic assumptions:

1. Challenges around AI capability, robustness, reliability and trustworthiness are addressed.
2. AI develops alongside other enabling technologies (e.g., 6G, Internet of Things and Quantum).
3. AI continues to be incorporated into services, goods and processes.
4. AI augments jobs, changing job roles in several sectors, requiring reskilling.
5. AI will be used to drive the creation of entirely new jobs, industries and needs.

Sources: https://www.mckinsey.com/business-functions/quantumblack/our-insights/global-survey-the-state-of-ai-in-2021
https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/
https://www.gov.uk/government/publications/national-ai-strategy
Graph data obtained from:
https://www.statista.com/statistics/732992/worldwide-ai-deployment-at-scale-among-ai-implementers/



Wildcards:

- Computing power is insufficient to sustain AI capabilities.
- Large breakthrough in the use of general AI which transforms lifestyles.

Foresight

Government Office for Science

Increasing use of artificial intelligence (AI)

How is this trend playing out?

While the capabilities of AI are growing, there continues to be uncertainty surrounding the extent of its transformative impact, beyond its direct influence on jobs and skills (i.e., how AI will be used in specific industries and in what contexts). The future location of AI jobs is also uncertain as some companies, particularly start ups, are fully remote.

The speed at which AI is being applied in different sectors varies, as sector-specific applications are likely to mature at different paces. This could lead to unequal rates of adoption across different sectors, or result in AI only benefiting a select number of companies or early adopters, rather than have a wider impact on industry and society.

Key uncertainty: Distribution of investment in AI

Alternative pathway one: Uneven adoption in industry

By 2050, only the leading corporate giants have extensively adopted AI systems, making them more efficient and able to process much larger amounts of data in a shorter amount of time than their smaller competitors. This contributes to the failure of smaller companies, shrinking the competitive ecosystem and promoting monopolisation.

In the leading corporate giants, the use of AI has also led to a reduction in the availability of jobs for those early in their careers, and a much lower percentage being recruited. Young people are now considering different careers, shifting workforce and early talent to other sectors.

Alternative pathway two: Investment moves from US to Asia

By 2050, the top spot for AI investment has moved from the US to Singapore, with Japan and South Korea also becoming world leaders. China has AI as a priority but finds it hard to compete due to regulation that doesn't align to the rest of the world, and difficulty in attracting international talent. Recruiting international talent and developing local talent has been key to applying AI across sectors such as healthcare, sustainability, transparency and governance and service delivery to improve economic performance. Countries which under-invested in developing local talent in the 2020's and 2030's are now lagging behind.

Government Office for Science

Increasing number of cyber attacks

The increasing severity and complexity of cyber attacks will change how we understand cyber risks

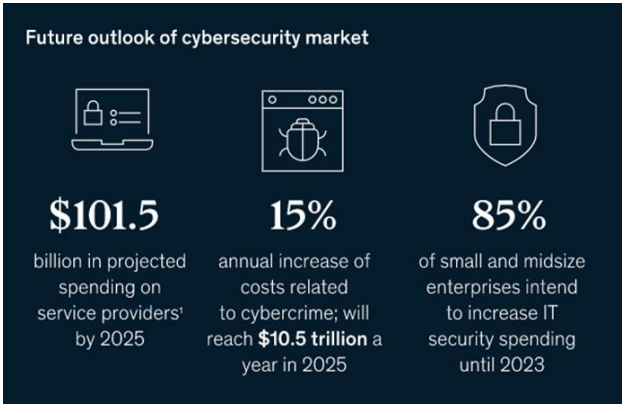
Digital technologies are diversifying, helping society to work remotely, enhance customer experience and optimise jobs. Data is also becoming more centralised in cloud-based services, shared amongst different online platforms to create unified digital experiences. This is changing the nature of cyber attacks - attempts to damage, disrupt or gain unauthorised access to computer systems, networks or devices. Attacks are increasing in number, scale and complexity, and can span across interconnected systems. Current breaches involve data exposure, disruption to critical systems and loss of system control. Other vulnerabilities, such as cyber attacks on extensive supply chains, are an increasing concern as our relationship with digital technologies continues to evolve.

It's estimated that global costs associated with cybercrime will reach $10.5 trillion by 2025, and cybercrime involving novel technologies, such as the Internet of Things, has doubled over the past year. The UK's National Cyber Strategy (2022) outlines government commitments to build understanding of our evolving cyber risks by 2025 and risk reduction measures.

Strategic assumptions:

1. Consumers expect their personal data to be available on demand, increasing data vulnerability.
2. Attacks become more sophisticated, incorporating the use of emerging technologies.
3. Increased connectivity between services/facilities creates broader risks.
4. Malware/ransomware becomes more accessible and common.

Sources: https://cybersecurityventures.com/cybercrime-damage-costs-10-trillion-by-2025/
https://www.iottechnews.com/news/2021/sep/07/kaspersky-attacks-on-iot-devices-double-in-a-year/.
https://www.gov.uk/government/publications/national-cyber-strategy-2022/national-cyber-security-strategy-2022
Image reference: https://www.mckinsey.com/business-functions/risk-and-resilience/our-insights/cybersecurity/cybersecurity-trends-looking-over-the-horizon



Wildcards:

- Rise in 'cryptojacking' – covert criminal use of a victim's computer to mine cryptocurrency.
- Citizens move away from digital systems for sensitive data, following breaches.
- States or collectives increasingly adopt cyberwarfare as an offensive strategy.

Foresight

Government
Office for Science

Increasing number of cyber attacks

How is this trend playing out?

The value of digital systems in our everyday life in increasing. This has led to malicious actors disrupting digital systems as a primary means to achieve political or criminal aims. This is extending from social media into more extensive systems such as smart devices, traffic systems and virtual medical services. Advancing technology gives offenders new tools to commit cyber crime or fraud from anywhere in the world, communicating covertly through encrypted services and moving illicit finances at speed. In response, governments have started to allocate greater funding for the protection of national digital systems, and to encourage innovation in related digital technologies, such as Artificial Intelligence, to build resilience to cyber attacks.

Key uncertainty: Impact of cyber attacks on digital systems

Alternative pathway one: Interconnectivity opens up vulnerabilities

By 2050, digital services are highly interconnected to improve user experience. User data has become widely shared across different systems. This has inadvertently opened up some critical vulnerabilities. Recently, a state-sponsored hacktivist group has used such vulnerabilities to break into a popular digital smart devices platform, giving the group control over connected household and personal goods, and the data they generate, including household appliances, thermostats, and lights. Such methods can be used to target individuals in other countries, leveraging control in order to extort money, exert influence over citizens, and put pressure on governments.

Alternative pathway two: People lose trust in digital systems

By 2050, significant cyber attacks against online financial systems and large businesses have become incredibly common, exposing the sensitive data of millions of individuals, As a result, consumers have begun to lose trust in all digital systems, preferring instead to handle their day-to-day affairs via in person services. This has begun to limit or even reverse some long-term digital trends, such as online banking, cashless payments and online shopping. Some citizens are even beginning to pressure governments to return the services which handle personally sensitive information back to non-digital systems for example, paper based medical records.

Government Office for Science

Physical to virtual worlds for innovation and social interaction

Diverse uses of virtual (VR), augmented (AR) and mixed (MR) reality platforms are increasing

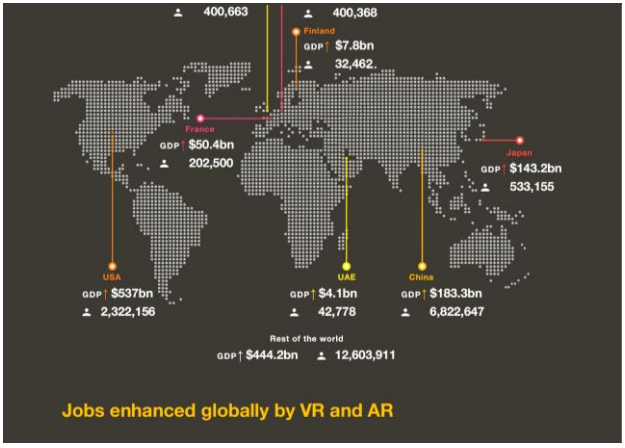
The uptake of these platforms, together known as XR (extended reality), is currently driven by recreational uses (e.g., gaming and socialisation). XR is starting to diversify – companies are using XR to advertise or sell products, and integration of XR into existing occupations is becoming more common, including healthcare, education and product development. Growing interest in the metaverse concept (a single, universal, immersive virtual world) has accelerated the uptake of XR, and is starting to provide a larger and more diverse platform for interactions. The use of XR might in future be integral to daily life, much like smartphones, and virtual assets may be valued in a similar way to physical assets.

PwC predict that over 400,000 UK jobs could be enhanced by XR by 2030, boosting GDP by £69 billion. By 2030, it's possible that XR will have introduced new ways of communication, fundamentally changing how we socialise and interact, and even possibly changing how we see ourselves and our identity.

Strategic assumptions:

1. XR capability develops at its current pace, technology remains accessible.
2. XR incorporates other technologies, offering unified experiences, e.g., social media, non-fungible tokens, digital twins.
3. XR is integrated into a range of workplaces where this helps people do their jobs more effectively.
4. XR platforms allow companies and organisations to offer virtual services at same or lower cost than in-person services, prompting uptake.

Sources: https://tcglobal.com/extended-reality-an-in-depth-look/
https://home.kpmg/au/en/home/insights/2022/02/future-of-extended-reality-xr-metaverse.html
https://www.pwc.com/seeingisbelieving
Image reference https://www.pwc.com/seeingisbelieving



Wildcards:

- XR is not publicly accepted due to privacy concerns or issues with user experience.
- Open data initiatives for developing XR content are limited by lawsuits or paywalls.
- Unforeseen health effects of long term XR use limits consumer buy in.

Foresight

Government Office for Science

Physical to virtual worlds for innovation and social interaction

How is this trend playing out?

XR has made rapid progress toward mainstream adoption and, just like the introduction of the personal computer and smartphones before them, broad consumer adoption of XR headsets could revolutionize human digital experiences and provide the entry points to the metaverse. If XR does become widely used, society will become even more reliant on digital connectivity to communicate and share information with others. XR is also likely to make it easier for us to connect internationally, and in new and creative ways, for example, the ability to have immersive international collaborations without the need to travel, and the ability to disseminate knowledge. However, increasing immersion is leading to safety concerns - harassment, assaults, bullying and hate speech are already common in virtual reality games that are part of the metaverse, and there are few procedures in place to report misconduct.

Key uncertainty: Scale of adoption of XR tech

Alternative pathway one: Sector and location based adoption of XR

By 2050, technology solutions can deliver widespread XR applications, but the move to digital worlds has stalled as people realise its limitations and lack of regulation or procedures to deal with safety concerns. The rise in online manipulation has led to more frequent psychological harm, and a greater hesitancy over data privacy and the physical impacts of wearable devices. XR adoption has grown within specific use cases, such as gaming, virtual tourism experiences and education. A continuing lack of worldwide fast internet connectivity also means mainstream XR is only available to a small segment of the global population, who have fast connectivity and can afford the latest headsets.

Alternative pathway two: Widespread adoption of XR

By 2050, XR is the medium through which most people live at least part of their lives. Costs have come down significantly with a new generation of XR headsets. People are introduced to XR from an early age by education, and use it regularly to meet friends and family rather than travel long distances. These shifts are compounded by other changes that limit face to face interactions, such as increasing travel costs. Business meetings, events and conferences nearly all take place in the virtual world as knowledge workers predominantly work from home. VR headsets and other wearable devices are more common than smartphones, with devices integrating to create seamless digital experiences.

Government
Office for Science

Increasing biosecurity risks from engineered organisms

Techniques which modify genetic material, can be used to create engineered organisms

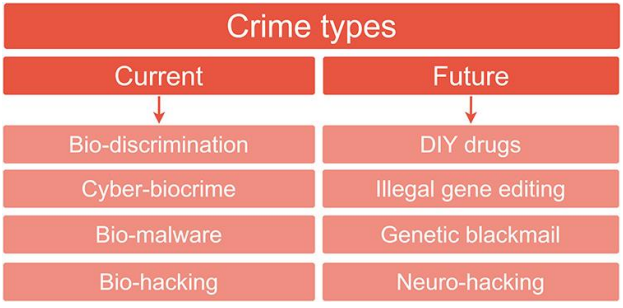
The use of biotechnologies in research and industry is rapidly increasing. Research with the potential to be misused for illicit purposes is said to be 'dual use.' It is already possible to engineer genetically modified organisms, and to create short strands of synthetic DNA. The first synthetic species of bacteria was created in 2016 and many genome-modified plants are already available worldwide.

These biotechnologies could help us tackle diverse challenges and ambitions including Net Zero, the production of complex pharmaceuticals, antibiotic resistance, personalised medicine and crop resilience. These same underpinning biotechnologies could also cause harm – either unintentionally, through the accidental release of biologically modified organisms, but also on purpose such as through state-sponsored biowarfare or the intentional leaking of harmful materials. Longer term, these biotechnologies could even enable novel crime types, such as illegal gene editing.

Strategic assumptions:

1. The speed, efficiency, accessibility and capability of genetic tools will continue to improve.
2. Long term, stable funding is maintained for technology R&D.
3. Public perception of genetic technologies and their impacts remain positive.
4. Increasing application and use of genetic tools.
5. Biosecurity and surveillance measures, for DNA synthesis companies keep improving.
6. Malicious actors could seek to design organisms that create risks on release (either accidental or non-accidental).

Sources: https://www.science.org/content/article/synthetic-microbe-lives-fewer-500-genes
https://www.fda.gov/food/agricultural-biotechnology/gmo-crops-animal-food-and-beyond
https://www.gov.uk/government/publications/genomics-beyond-health
https://www.gov.uk/government/news/genetic-technology-bill-enabling-innovation-to-boost-food-security
Image reference: https://www.frontiersin.org/articles/10.3389/fbioe.2020.571672/full



Wildcards:

- Leak of a novel pathogen from a lab or bioterrorism attack.
- Mitigation strategies are developed to selectively target engineered risks (e.g., ensuring organisms only grow under certain requirements).
- DIY genetic engineering of a pathogen.

Foresight

Government Office for Science

Increasing biosecurity risks from engineered organisms

How is this trend playing out?

The use of genomic manipulation to alter crops is becoming commonplace in the UK, leading to the creation of varieties which are suited to specific climates, resistance to diseases, improved flavours, nutritional content or reduced waste. The success of modified foods has begun to drive wider-scale shifts across other sectors, with industry beginning to seek biological solutions to non-biological problems. This is largely pioneered in the fuel industry, where leading companies are developing biofuels based on engineered algae, and by the textiles industry, where bacterial proteins are being used for renewable materials. However, as gene editing tools become more commonplace, they also start to be exploited by rogue nations, terrorist groups or individuals. There are fears that bioterrorism strategies could move beyond the use of known biological agents (e.g. anthrax) to novel gene-engineered pathogens, with catastrophic consequences.

Key uncertainty: Consumer acceptance of gene-edited goods

Alternative pathway one: Gene editing loses popularity

By 2050, consumers are wary of genetically altered food, particularly animal-based editing, seeing it as a welfare issue. This has been compounded by patchy regulation, different labelling schemes and scare stories and conspiracies circulating online. The negative image of gene edited produce has reflected on the appeal of gene editing itself – consumers begin to reject other gene-edited products, such as textiles, medicines, materials and fuels, and innovation in this area slows. This has led to the secondary effect of companies investing further in conventional products, including fossil fuels and other non-renewable resources. Nevertheless, a lack of popularity in and slowing innovation of gene editing tools does work to reduce the risk of harm from their use or effects.

consumers are still wary of genetically altered food, particularly animal based, seeing it as an animal welfare issue. This has been compounded by patchy regulation, a raft of different labelling schemes and scare stories and conspiracies circulating online. Even with some genetic manipulation, food production is suffering with scorching hot temperatures, and crops are regularly wiped out by wildfires. The result has been a shift to factory-based food production using hydroponics and vertical/underground farming and fungi-based cultured proteins. Although the biosecurity risks associated with genetically altered foods have declined the food safety risks of cell based protein production are a big concern, particularly microbial, toxin and allergen risks.

Alternative pathway two: Adoption of altered foods

By 2050, the use of genetic tools has become routine across health, agriculture, manufacturing, and energy. Consumers first accepted these technologies in the food supply chain, which then encouraged wider adoption across more sectors. However, as these technologies have become more fundamental to many critical processes and they increase in visibility, hostile nation states, terrorists and collectives begin to target technology end users to meet their goals. A particular target is the agricultural sector – as companies accumulate sensitive data on species varieties, hostile actors increasingly try to manipulate the data to sabotage cultivars and cause food chain disruption or contamination. As a result, companies begin to enhance their cyber/biosecurity measures, and become secretive in their research and development programmes.

ecology. As consumers have accepted these technologies in the food supply chain, agri-businesses have begun to accumulate sensitive data on species varieties as part of their research and development. If this data gets into the wrong hands it could be manipulated to cause food chain disruption or contamination. As a result, companies begin to enhanced their cyberbiosecurity measures to prevent disruption to their genetic engineering processes. Science-based regulation, transparency, ethics and labelling have been key to consumer confidence and in reducing the influence of anti GMO activists.