VTT

Trend report 2023

by VTT Business Intelligence

VTT's trend report 2023 features global megatrends & industry disrupting technologies

VTT's 2023 trend report covers some of the major development patterns of the macroenvironment, by presenting seven global megatrends of today. Our specialists in Business Intelligence have also picked out three areas where exciting technology-driven changes are now made: mobility, health and material technologies. Beside these, the report highlights seven cross-sectoral, disruptive technologies that touch countless of industries and areas of life.

The themes have been selected and scanned by going through hundreds of information sources, and by sparring and evaluating them with VTT's strategic partners Swanlake Strategy and Frost & Sullivan.

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Report contents

GLOBAL MEGATRENDS

1 **Unpredictable, multi-polar world**

2 **Challenged democracy**

3 **Shifting demographics**

4 **Profound sustainability**

5 **Accelerated energy transition**

6 **Digitally enhanced economies**

7 **New societal norms**
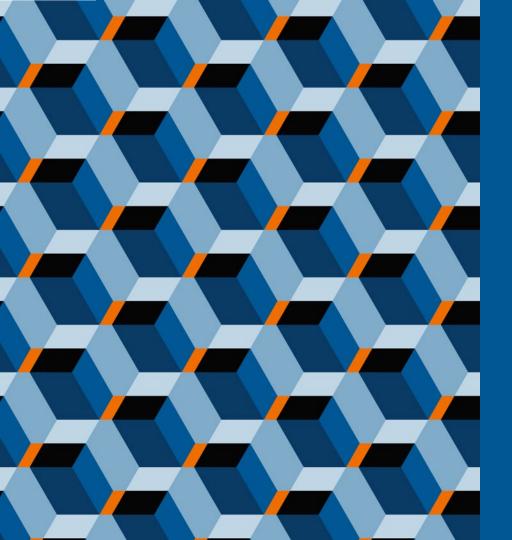
TECHNOLOGY TRENDS*

Transformative trends

A. Mobility technologies
B. Health technologies
C. Material technologies

Highlighted disruptive technologies

A. Human-like artificial intelligence
B. Cyber security technologies
C. 3D printing
D. Metaverse & new realities
E. Quantum computing
F. Hydrogen
G. Carbon capture

Executive summary & areas for action

Executive summary

VTT has systematically done trend reports for years. What has changed from the previous report?

Trend report 2022	Trend report 2023	Change from 2022 to 2023
1 Unpredictable & Regionalised World Economy	**1** Unpredictable multi-polar world	Global pandemics, inflation and geopolitical tensions emphasise that there is uncertainty at all fronts.
2 Unstable multi-polar world	**2** Challenged democracy	Democracy is something we continuously need to rediscover and protect.
3 Confident superpower China challenges USA	**3** Shifting demographics	The shifts in demographics create opportunities. → *Health technologies* added as a new section.
4 Demographic changes: world growing old	**4** Profound sustainability	The Zero Concept World will transform economics. → *Material technologies* added as a new section.
5 Towards sustainable world	**5** Accelerated energy transition	The peak for fossil fuels' demand is in sight → *Mobility technologies* added as a new section.
6 Digitally connected world	**6** Digitally enhanced economies	Digital transition affects all parts of the society, the future is defined by real-time connectivity.
7 Energy transition	**7** New societal norms	The boundaries that define our lives are shifting radically, people increasingly live in separate realities.
8 Time and place independent work	**NEW** Transformative trends	Highlighted areas with exciting technology-driven changes, selected cross-sectoral technology advancements.
9 Disruptive living and society	**+** Highlighted disruptive technologies	
10 Technological disruptions		

Act on each of the megatrends

Trend report 2023

1	**Unpredictable multi-polar world**

- Decentralised global supply chains are digitally integrated: advance geopolitical positions through technology.
- Reshape alliances: self-sufficiency and availability of critical raw materials are determining the trajectory.

2	**Challenged democracy**

- Create new opportunities with digital platforms.
- Take into account the transfer of investments and intellectual property, the access to foreign markets, possible boycotts and protectionist domestic agendas.

3	**Shifting demographics**

- Understand Gen Z which is bypassing as the largest market, with new values and interests: mental health, empowering work cultures, social justice, gender-fluid concepts, conscious brands, distrust beyond politics.

4	**Profound sustainability**

- Grasp the opportunities of the Zero Concept World.
- Be prepared for the growing complexity of sustainability: ESG-action & reporting are increasingly expected and required from all organisations.

5	**Accelerated energy transition**

- Invest in future energy systems that are a combination of clean electricity and hydrogen. End-use sectors are increasingly electrified, while cleaner (synthetic) fuels are adopted in areas where electrification is difficult.

6	**Digitally enhanced economies**

- Invest in real-time connectivity: the nature of innovations is changing towards customer experience, while intangible resources become crucial for growth.

7	**New societal norms**

- Consider behavioural analytics that form central part of today's business environment: technologies with long-term disruption potential emphasise both human and planetary-impact.

NEW	**Transformative trends**

- Create scenarios to envision how disruptive technologies impact on your business, create your preferred future and think of the next best actions to tap into opportunities.
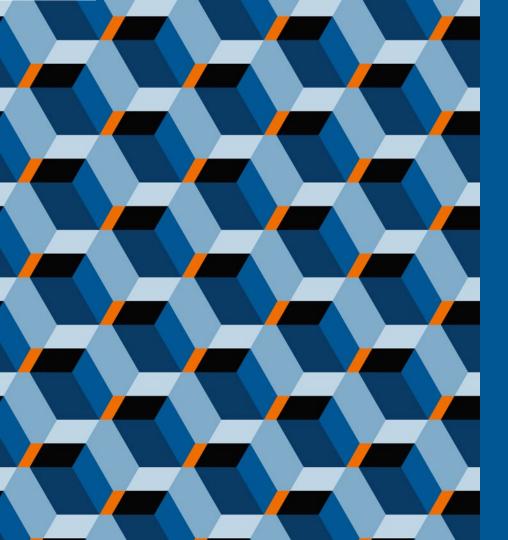
+	**Highlighted disruptive technologies**

Global megatrends

1. Unpredictable, multi-polar world
2. Challenged democracy
3. Shifting demographics
4. Profound sustainability
5. Accelerated energy transition
6. Digitally enhanced economies
7. New societal norms

1. Unpredictable, multi-polar world

With global pandemics, inflation and geopolitical tension, uncertainty in everything is rising. Protectionism is growing as disrupted trade, energy & food crises, and weakening of the global co-operation underline self-reliance and existence of hard geopolitics. World's multi-polarity increases while individual countries strive for economic clout. Tactical alliances & partnerships change trade paradigms and create spheres of influence. The geography of production and distribution has started to change radically, as regionalism tries to supplant globalism: reshoring and nearshoring are increasing when long-distance links are severed or disturbed. The risk landscape for businesses is now more complex than ever.

Things to consider

- The extremely high level of public debt could lead to an economic crisis & social unrest.

- Geopolitical tension increases risk aversion among many investors.

- Nationalism & protectionism can undermine EU's unity and ability to act.

- Asia is expected to continue leading the global market growth.

Take action

- Decentralised global supply chains are digitally integrated by technology: technological frontrunners advance their geopolitical positions.

- Self-sufficiency & availability of critical raw materials are determining the trajectory. Reshaped alliances are gaining momentum.

Key themes: shifting geopolitics, nearshoring, protectionism, regionalism, fragmenting co-operation & tactical alignments, self-sufficiency, critical resources, VUCA, (cyber)warfare, decoupling, inequality, interconnectedness of global crises.

Picture: VTT Material Bank

2. Challenged democracy

As social and environmental challenges build up, the trust in democracy is being tested. Restriction of individual rights during the COVID-19 pandemic, political instability, abuse of power, and the hampered decision making in modern-day VUCA-worlds have all raised questions about legitimacy and functionality of liberal open societies. With populist interventions becoming more frequent and democratic processes weakening, pluralistic civil society is striving to make its voice heard.

Things to consider

- 39% of the global population today live in *Non-Free* countries (highest since 1997): more countries are developing towards authoritarianism than democracy.

- Only in 20% of countries there is electoral democracy, citizens are equal before the law and the actions of the executive are constrained by the legislative and the courts.

- Growing inequalities intensify challenges for democracy locally and sustainability globally.

Take action

- Global governance chaos & multitude of divergent political ideologies keep rising. Digital platforms are creating new opportunities for influencing, and power abuse.

- Changing social systems require companies to take into account the transfer of investments & intellectual property, the access to foreign markets, possible boycotts and protectionist domestic agendas.

Key themes: battle of social systems, endangered human rights & equality, information warfare, humanitarianism, weakening of international organisations, democratic short-sightedness, (social) media provocation, rogue states.

Picture: Unsplash

3. Shifting demographics

The world's population growth continues, but the pace is slowing down. The 8 billion mark was met mid-November 2022. Despite a decline in overall fertility and mortality, as well as increased emigration, population trends vary greatly around the world. Many of the world's 46 least developed countries are projected to double their population by 2050, while high-income countries may be solely growing through international migration. The amplified concentration of the working age population creates opportunities for enhanced economic growth.

Things to consider

- India has already surpassed China as the most populous country. Sub-Saharan Africa may contribute over 50% the global population growth through 2050.

- The share and number of over 65-year-olds is increasing globally, with women outnumbering men at older ages.

- Generation Alpha (2010-2024) is expected to be the largest generation yet.

Take action

- Understand Gen Z that is taking over as decision-makers and largest market, with new values and interests: conscious brands, empowering work cultures, social justice, mental health, gender-fluid concepts.

- Contribute to the social safety net: Europe is estimated to have the largest aging population in the world.

- Anticipate the unforeseen shortage & competition on workforce.

Key themes: multi-diversity, changing workforce composition, responsible migration, social security, universal health care & long-term care systems, wealth differences, demographic dividend, human capital, sustainability, data collection, urbanisation, mega cities, heterogenous society, complex needs.

4. Profound sustainability

Climate change keeps having fast-growing socioeconomic impacts on natural capital, liveability, food systems, physical assets, and infrastructure services. The swift biodiversity loss, climate issues and exploding waste all endanger growth and stress the need for fundamental sustainability of the society. Initiatives for sustainability have skyrocketed in the past decade, but achieving the needed global, collective climate goals has fallen short: tackling climate change requires major business, economic and social changes.

Things to consider

- Environmental issues exacerbate systems-level disruption to customers, investors, and communities: over 50% of the global GDP is directly dependent on nature.

- More than 90% of all materials extracted are wasted: the world is only 8.6% circular.

Take action

- Sustainability's complexity is growing: consistent, comparable and transparent ESG-action & reporting are increasingly expected, and required, from all organisations.

- The Zero Concept World will be one of the biggest economic transformations ever: innovative sustainability technologies & business models are developed across industries.

- Social enterprises with environmental preservation & customer satisfaction symbiosis are rising.

Key themes: low-emission clean energy, circular & sharing economy, digitally optimised (material) efficiency, new & alternative resources, W2E, water & food management, Re-everything, Finland's forest economy, carbon-tech, electrification of everything.

5. Accelerated energy transition

Climate change mitigation depends on effective emissions reduction and electrification of the society, both requiring huge amounts of clean energy. The ongoing global energy crisis has reshaped the world energy order, and for the first time ever the peak for fossil fuels' demand is in sight. With the vulnerable energy markets, more sustainable, secure, low-priced and efficient energy options are actively sought after. Long-term structural changes are made, as US Inflation Reduction Act, RePowerEU, and Japan's Green Transformation (GX) program show example of. Yet, stronger policies to drive the crucial investments are still needed.

Things to consider

- In Finland electricity consumption is expected to double by 2030, triple by 2040.

- "High point for global emissions is reached in 2025" (IEA 10/2022).

- Adoption of digital technologies within the total power sector will increase and accelerate intelligent, flexible energy management, but also engage energy users as part of the dynamic energy systems.

Take action

- End-use sectors are increasingly electrified, while cleaner (synthetic) fuels are adopted in areas where electrification is difficult.

- Future energy systems will be a combination of clean electricity and hydrogen.

Key themes: renewables, hydrogen, advanced biofuels, power-to-liquids, system integration, geo-energy, innovative storage, adequacy of minerals, electrified society infrastructure (i.e. smart district heating, modular nuclear power plants, microgrids).

Picture: Unsplash

6. Digitally enhanced economies

Globalisation, rapid technological development and connectivity keep driving digitalisation across the world. Combined, convergent and interdependent technologies are now utilised across industries, and the rising interconnectivity is speeding up disruption. New environments, markets and business models keep on emerging. Digital transition affects all parts of the society and is progressively shaking the very foundations of cyber security: data collection reaches almost all aspects of the modern life, and data management is becoming ever more important.

Things to consider

- Disruptive digital economy technologies could deliver additional global economic activity of about USD 13 trillion by 2030.

- Countries are increasingly prioritising high performance digital infrastructures: the EU is investing billions in digitisation and digital economy.

- Digital infrastructures create several new opportunities & threats: enhanced use of resources, faster development and economic growth, also inequality and high energy demand.

Take action

- The nature of innovations is changing towards customer experience, while intangible resources become crucial for growth: the future is defined by real-time connectivity.

Key themes: *smart cities, digital & autonomous material development, e-government, Internet of Things, generative-AI, machine learning, open-source tech, quantum computing, cyber security, connectivity (5G/6G), Big Data, blockchain, Industry 5.0, robotics, fintech, networks & clouds, zero latency.*

Picture: Unsplash

7. New societal norms

The boundaries that define our lives are shifting radically, and people are increasingly living in separate realities. The progress of technology is changing work, leisure, retirement and lifelong learning. Work has become increasingly time-place independent, while remote practices have created new business models. The importance of digital capabilities is growing exponentially: smart homes, clothes, wearables, services and experiences, virtuality and automation all illustrate today's connected living, nature and society.

Things to consider

- Consumption & value chains are changing: conspicuous consumption is increasingly questioned, broad spectrum of business models drive on customer engagement.

- Reshaped role of paid work: new approaches to talent and workplace impact urban economies, transportation & consumer spending.

- Old gender assumptions & stereotypes are fading: women manage 70% of the global consumer trade, minority empowerment is increasingly important.
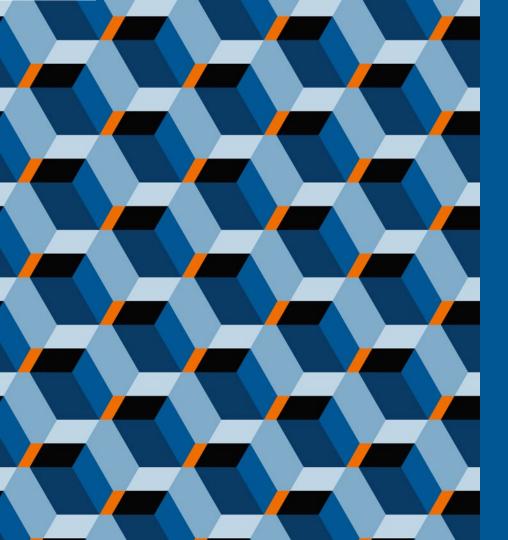
Take action

- Behavioural analytics & design form a central part of today's business environment. Technologies with long-term disruption potential emphasise both the human and planetary-impact.

Key themes: flexible employment, human clouds, AI, Metaverse, VR/AR/MR/XR, deepfakes, autonomous & integrated mobility, eHealth, eCommerce, digital-physical services, remote product development, sharing economy, 3D/4D printing, virtual cultures, behaviour analytics, personalisation communality, she-economies, LGBTQIA+, transhumanism, wearables, crypto currencies.

Transformative trends

In the section below we cover three examples of areas that are rapidly transforming due to technological advancements and the megatrends' drive. Each of the following snapshots includes a short description of the transformative megatrends, as well as examples of the recent disruptive developments.

A. Mobility technologies

Transformative megatrends

- The transition pace from fossil-fuel-based automotive powertrains to low- or zero-emission powertrains is increasing rapidly.
- Manufacturers are exploring alternative energy sources (e.g. hydrogen) for overall economic sustainability.
- Faster transitions are a major economic goal for several countries to achieve a cleaner and safer environment as soon as possible.
- Today's major technology trends in mobility and transport include electrification, automation, connectivity, and as-a-service.

Mobility trends

- Autonomous vehicles, robotaxis, delivery robots, glydways
- Wireless electric vehicle charging and electric roads
- Electrification of heavy-duty road and off-highway vehicles
- Fleet platooning
- Biofuels and fuel cells
- Micromobility for hyperlocal delivery and urban e-scooters
- Mobility-as-a-service
- Urban rail traffic

Maritime shipping trends

- Autonomous and electric ships
- Port automation, digital ports
- Sustainability including alternative fuels

Aviation trends

- Autonomous robots and drones
- Electric aircrafts and helicopters
- Flying taxis, electric vertical take-off and landing (eVTOL) aircrafts
- Smart airports, self-service and biometrics
- Supersonic aircraft technologies
- Sustainable aviation fuel (SAF)

Digitalisation of mobility industry

- Utilisation of data and learning models
- Vehicle-to-vehicle communications
- Digital Twins
- Cyber security

B. Health technologies

Transformative megatrends

- COVID-19 accelerated various health technologies, especially in relation to mobile health, health equity, healthcare resilience and sustainability.
- The rapidly evolving digital & e-health is both a consequence of and a driver for consumers' remote care preferences.
- In response to the growing healthcare challenges, the focus areas of the sector today include preparedness, equal & accessible care, digital upskilling, healthcare costs & staffing, and medical innovation.

Healthcare trends

- Mobile & Telehealth: virtual primary care, health communities
- Point-of-Care diagnostics
- Internet of Medical Things: data management, (multi)wireless interfaces.
- Personalised Health: precision medicine, connected patient
- Edge wearables with internal processors
- Robotics: transportation materials & equipment, diagnostics, operation
- Artificial Intelligence: medical imagery (early warning signs), analytical care (detecting & treating), clerical work (medical record keeping)

Drug discovery & diagnostics trends

- AI in pattern recognition & outcome prediction
- DNA sequencing & synthesis, next-gen gene therapies
- Cell therapy 2.0, biometrics & bioinformatics
- Genomics & genome engineering
- mRNA medicines & therapeutics
- Nano- and biomaterials & sensors (non-invasive testing)

Wellness trends

- Smart equipment, wellness platforms & apps
- Wearables for physical & mental health monitoring
- Behavioural health
- Personalised supplements
- At-home testing kits
- Wellness metaverse, gamified exercise
- Retail healthcare (blood tests, vaccinations, check-ups)

C. Material technologies

Transformative megatrends

- The need for new, sustainable materials keeps growing along with the increasing waste and emissions, and the lack of raw materials.
- Producers and constructors are now focusing on reducing material usage and losses, incorporating sustainable alternatives to their new and existing outputs, and complying with the ever stricter regulation of materials.
- Scale-up of sustainable materials is vital, and the pressure for large-scale industrial production & cost effectiveness is growing: real impact is made only if the old, unsustainable ways of production are replaced.
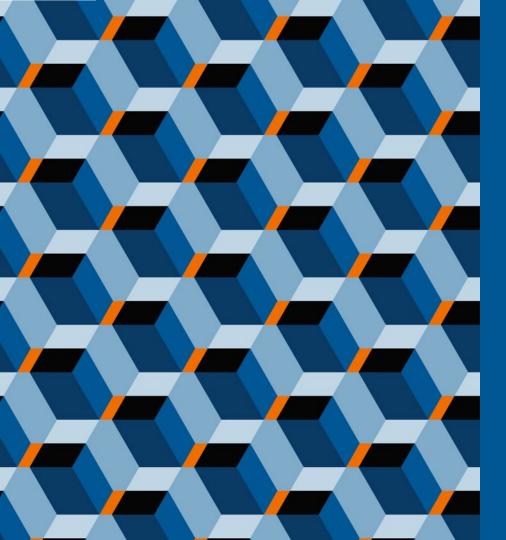
Materials industry trends

- Sustainability & circularity
- Feedstock innovation, critical raw material recovery
- Limitation of energy, water & raw materials, energy storage
- Lightweighting, durability
- Smart, functional & responsive materials
- Additive manufacturing, advanced composites
- Material informatics & digitisation
- Materials management 4.0

Key materials

- Biomaterials & biomimicry
- Industrial sidestreams & by-products
- (Organic) waste materials
- Alternative materials (sand, CO_2 negative concrete)
- Nanomaterials
- Graphene & 2D materials

Material technology trends

- AI for material exploration & development
- Digital twins for design iterations
- 3D printing (i.e. mycelium)
- Synthetic biology
- Nanotechnology
- Surface engineering
- Polymerisation
- Carbon capture and storage (CCUS)

Highlighted disruptive technologies

In this final section of the report we highlight a few of the most disruptive technologies that touch countless industries and areas of life. Some of these technologies already have a central part in our everyday living, while others are just about to change the norms. Each of the pages below includes a short description of the disruptive phenomena, a few application examples and a future outlook for the technologies.

A. Human-like AI

Phenomena: *Artificial Intelligence* (AI) can be defined as the ability of machines to mimic and simulate the human problem-solving and decision-making capabilities. Today AI is demonstrated particularly in intelligent computer systems and machine learning, but there is an increasing attempt to make AI present human-like, general intelligence. This would mean for AI to construct & continue a train of thought, maintain & leverage long-term memory, learn from feedback, and even develop a conscience.

Applications & use-case examples

- Expert systems, machine vision & reactive machines
- Natural language processing, voice & image recognition (Generative AI)
- Deep learning & decision-making (programming, science, art, games)
- DeepMind's AI-programs can save 30% of the energy used to cool-down data centres, diagnose eye diseases like the greatest doctors, and predict complex 3D shapes of proteins.
- Meta's game-playing AI makes and breaks alliances like a human.
- OpenAI's open-source Point-E paves the way for AI-breakthroughs with tools that produce 3D models in seconds. Earlier the company has broken headlines with its AI image generator DALL-E and the intelligent chatbot ChatGPT that recently even co-authored a research article.

Segments most impacted

- Information technology, data security
- Healthcare, diagnosis, therapeutics, virtual assistants, precision medicine, wearables.
- Marketing, customer interaction, tailored processes
- Transport, automated fleets, traffic security
- Industry maintenance, energy efficiency, automation
- Finance, insurance, fraud detection, algorithmic trading

Future outlook

- According to McKinsey (2022) the adoption of AI has more than doubled since 2017, with companies extending their AI capabilities and investments.
- The potential contribution of AI to the global economy has been estimated to reach USD 15.7 trillion by 2030.
- Despite the economic downturn and massive layoffs in tech companies, there has been no signs of AI winter: the field's research continues to take big leaps, while the pressure keeps growing.

B. Cyber security technologies

Phenomena: Cyber security is the process of protecting internet-connected systems from cyber attacks. The advances in technologies including cloud computing, the internet of things (IoT) and artificial intelligence (AI) have increased the threat of cyber attacks and other internet-based threats. Furthermore, the shift to remote and hybrid work as well as spread of IoT devices has increased the importance of cyber security.

Applications & use-case examples

- AI and automation programs enable faster identification and containment of data breaches, resulting in an average of USD 3 million savings in costs for organisations using these tools, according to IBM.
- Emerging cyber security solutions include cyber security training platforms and authentication solutions such as passwordless logins.
- Remote and hybrid work has also brough opportunities for companies, such as Talon Cyber Security, which has developed an enterprise browser to enable secure work regardless of location, device type or operating system.
- Metaverse is facing multiple security challenges including user authentication, privacy, network security, ransomware and financial fraud.

Segments most impacted

- Defence and intelligence
- Banking, Financial Services and Institutions (BFSI)
- Telecommunication and IT
- Government
- Healthcare
- Retail and eCommerce
- IoT verticals: Health care, Smart homes & Consumers, Infrastructure & Cities, Transport & Urban mobility, Industrial systems & Sensors

Future outlook

- The global cyber security market is expected to reach USD 266 billion in 2027 with a CARG of 8.9% between 2023 and 2027.
- Drivers: adoption of cloud-based solutions and wireless communication, increased targeted cyber attacks.
- Restrains: Lack of budget and expertise.

C. 3D printing

Phenomena: 3D printing, or additive manufacturing (AM), is the process of making a 3D object from a digital model by depositing successive layers of material in different shapes. Many different materials including organic, ceramic, polymeric and metallic materials are used in industrial manufacturing and creating prototypes. In addition, 3D bioprinting, which is a relatively new technology, has huge potential to benefit several industries including personalised medicine, drug discovery and cosmetics.

Applications & use-case examples

- Concept modelling and rapid prototyping as well as pilot production of low-volume components, especially with complex geometries, light components and spare parts. For example, BMW uses AM components in its iX5, which is a sports activity vehicle powered by hydrogen fuel cells and Saab has used AM to repair damaged Gripen fighter jets.

- Chilean Copper3D designed a face mask made from antimicrobial copper-based filament in the middle of the COVID-19 crisis.

- Polish 3D printing company Sygnis provided printers and raw material to Ukraine to print protective equipment, tourniquets and drones.

- Bioprinting and bio-ink: UPM's GrowInks offer hydrogels, which mimic the *in vivo* environment and CELLINK provides tools for researchers to develop alternatives to animal models and 3D printed organs.

Segments most impacted

- Automotive
- Industrial manufacturing
- Consumer products
- Aerospace and Defence
- Medical and Dental
- Construction and Architecture
- Bioprinting: Personalised medicine, cell cultured food, drug discovery, regenerative medicine, cosmetics

Future outlook

- By 2027, the global AM market will generate USD 37.25 billion in revenue with a 20.4% CARG between 2021-2026.

- Drivers include AM & supply chains, flexibility, demand driven production, mass customisation, novel materials including metals and sustainable materials and applications in nuclear and space.

- The main challenge is the inability to compete on cost with traditional manufacturing on economies on scale.

D. Metaverse & new realities

Phenomena: *Metaverse* is often described as the next iteration of the Internet. As a shared platform, an immersive, persistent, 3D virtual space, it gives people the opportunity to experience life in ways not necessarily possible in the physical world. Technologies such as *augmented reality* (AR) glasses and *virtual reality* (VR) headsets are considered the precursors or primary interfaces to access the virtual worlds, however the future Metaverse-solutions remains to be seen.

Applications & use-case examples

- Selling goods & services that only exist digitally (i.e. non-fungible tokens)
- Arranging concerts and other events in virtual universes
- AR and digital twins are for operational improvement
- Brand presence in VR settings (Hyundai) and own Metaverses (Disney).
- Decentraland (2020): first blockchain-powered place in the metaverse. The 3D virtual world enables users to buy, create & explore NFT-based plots of land through its own cryptocurrency.
- Sandbox (2021): platform that allows users to purchase land, collect cryptocurrency tokens, and participate in play-to-earn games.
- Nvidia Omniverse: platform for developing, creating and operating 3D pipelines and metaverse applications.

Segments most impacted

- Online experiences, games, services & entertainment
- eCommerce, branding & digital marketing
- Connectivity, social networks & -media, content creation
- Virtual work & meetings, data management
- Healthcare & rehabilitation
- Education, training, testing & inspection

Future outlook

- Gen Z is expected to be Metaverse's primary audience, but many of its future use-cases are still unknown.
- Valuations of the Metaverse market vary distinctively, yet showing the huge potential for disruption.
- Metaverse may be USD 800 billion market, next tech platform (Bloomberg Intelligence 2021)
- Goldman Sachs Sees the Metaverse as USD 8 Trillion Opportunity (2022)
- Despite the optimistic projections, various views have been presented as to why Metaverse would likely fail.

E. Quantum computing

Phenomena: By using the laws of quantum mechanics, *quantum computing* is producing exponentially high performance of calculations and solving problems significantly fast, beyond today's computers. Because of this, quantum computers are expected to disrupt breakthroughs in various industries, and help us overcome some of the biggest challenges of today.

Applications & use-case examples

- Complex problem-solving & calculation
- Optimisation & simulation (digital twins)
- Risk modelling, defence, finite difference analysis
- D-Wave is selling quantum-annealed computer for USD 20 million.
- IBM, IonQ, and Rigetti are selling small prototypes
- Currently, one of the main business areas for quantum computers lies in the growth of cloud-based quantum services (by Google, Microsoft, Alibaba, recently Amazon).
- The Quantum as a Service (QaaS) clouds give customers access to quantum computing through online platforms.
- Developing more effective and easier ways of programming noisy quantum devices is another focus area of quantum businesses today.

Segments most impacted

- Energy management, net-zero, logistics optimisation
- Healthcare, drug development, predictive models
- Finance, market projections, probability analysis
- Material & chemical compound discovery

Future outlook

- Funding of quantum technology start-ups was more than doubled from 2020 to USD 1.4 billion in 2021.
- Estimations for global quantum computing market are educated guesses at best. Some of the leading industry commentators estimate the market's size to rise between USD 1 billion and USD 5 billion by 2025, McKinsey (2022) projecting the market to reach nearly USD 700 billion in 2035.
- Despite the massive disruption potential, quantum computers are also expected to pose many threats and cyber security risks, even break all existing data encryption.
- It is still unclear when the technology will reach commercial-scale, but i.e. GlobalData predicts it to be by 2027.

F. Hydrogen

Phenomena: Urbanisation, electrification, asset autonomy, and increasing digitalisation & sustainability are accelerating investments in low-carbon technologies, mainly hydrogen. Especially the emission-free, electrolysis-based green hydrogen is in high demand, as industries and the power sector rush to decarbonise. The transition to green hydrogen has been advanced by the 70% increase in the natural gas-based blue and grey hydrogen production costs by the Russo-Ukrainian War, but many of the hydrogen projects still remain in their pilot stages.

Applications & use-case examples

- Power to gas (P2G), renewables integration, grid balancing
- Decarbonisation of industrial sectors, substitution of fossil fuels
- Ammonia as a carrier for hydrogen
- More than 50% of the total hydrogen consumption in EU, EFTA, and UK take place in Germany, Poland, Netherlands & Spain.
- Around dozen electrolyser demonstration projects are investigating the use of nuclear power for H2 production.
- NASA's spaceships fuelled with hydrogen create water for the astronauts to drink.

Segments most impacted

- Energy production, transport, long-term storage, fuels
- Industrial production, especially steel and chemicals

Future outlook

- In the next 5-10 years, hydrogen industry will see massive transformation on regulatory frameworks, technological innovations & decarbonisation, which will drive the market.
- The global demand for hydrogen is projected to more than double by 2030.The market for green hydrogen is expected to reach USD 89 billion by 2030 (CAGR of 51% from 2021).
- Despite the capital intensity of blue hydrogen in terms of CO capturing, it is expected to dominate for the next 8-10 years.
- In 2020, 99.3% of hydrogen was produced by polluting methods.
- The global installed electrolyser capacity could reach 54 GW by 2030. PEM electrolysers are expected to witness a higher growth-rate than alkaline electrolysers.
- It is expected that the decarbonisation with hydrogen will require over USD 15 trillion 2022 - 2050.

G. Carbon capture

Phenomena: Carbon capture refers to a variety of technologies that capture CO_2 from diverse large point sources, power plants and industrial facilities, or directly from the atmosphere. Carbon capture, utilisation and storage (CCUS) technologies allow to use the captured CO_2 on-site, inject it into deep geological formations for permanent storage, or compress and transport it for various application areas. These technologies enable to use carbon as a productive feedstock but also provide the foundation for negative emissions through carbon removal.

Applications & use-case examples

- Industrial processes (emission cuts)
- Power generation & storage
- Production (i.e. cement, iron, steel, chemicals)
- Fuel transformation (i.e. clean aviation fuels)
- The biggest carbon capture systems today include pre-combustion, oxy-fuel combustion and post-combustion capture.
- Today there are 30 CCS-projects in operation, and 164 in development or under construction, North America leading the deployment.
- In 2022 the CO_2 capture capacity of all facilities under development increased by 44%, with 61 new facilities added to the pipeline.
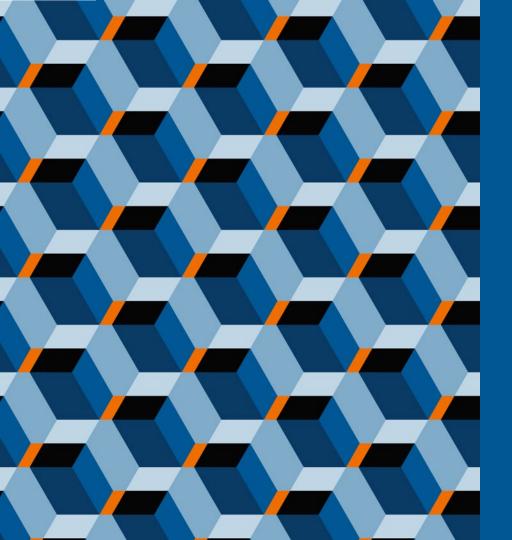
Segments most impacted

- Energy production, transport & storage
- Manufacturing, emission cuts, CO_2 as a feedstock
- Construction, zero-emission building aggregates

Future outlook

- The deployment of CCUS-technologies has not yet lived up to its promises, but its momentum has grown strong.
- The global market for CCUS is expected to grow from USD 2.6 billion in 2021 to USD 5.2 billion by 2026 (CAGR of 15.0%), with European CCUS technologies growing at 24.5%.
- Carbon capture can play a critical role in sustainable transformation but according to McKinsey (2022), the global CCUS uptake would need to grow 120 times by 2050, to achieve the net-zero commitments.
- To enhance CCUS adoption, its energy consumption and costs must still be decreased, efficiency to be technologically improved, and CO_2 storages' time- and cost effectiveness to be demonstrated.

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The themes covered in this report present some of the major development patterns of the macroenvironment and a few trending technologies, selected and scanned by VTT Business Intelligence with Swanlake Strategy and Frost & Sullivan. The methodology behind the report includes reviewing and analysing hundreds of information sources and reports, using both open source and subscribed material.
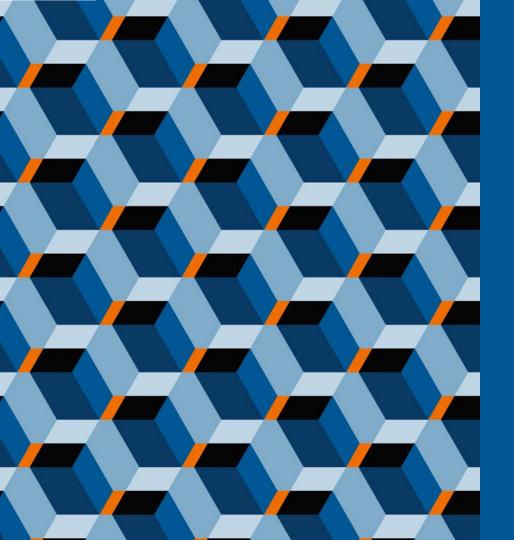
The report does not list all the impactful trends of today, leaving out various exciting topics regarding food, energy, biotech, blockchain, connectivity, the Internet of Things and Industry 5.0. As opinions on technology are often polarised, and the separation of hype from real impact can be tricky, we have also tried to challenge some of the technologies' future perspectives. We hope you find our selected themes attention-grabbing and challenge our views.

The **megatrends** presented have been chosen by reviewing different reports from, i.e. GlobalData, McKinsey, Sitra and Frost & Sullivan, and by combining views on the dominating global powers. Please note the Western perspective of this report and the fact that megatrends can be defined differently in other parts of the world.

In the **transformative trends** -section, we have selected three examples of areas where exciting technology-driven changes have been made. These sectors have been chosen in consideration of VTT's areas of interest.

The **highlighted disruptive technologies** point out a few transformative, cross-sectoral technology advancements. In this section, we have partly differed from the VTT's larger areas of focus and presented technologies that are not necessarily connected to any specific industry.

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Read more: Global megatrends

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- International IDEA, 2022: Global Democracy Weakens in 2022. Read 02/2023.

2. Challenged democracy

- Freedom House, 2022: The Global Expansion of Authoritarian Rule. Read 02/2023.
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3. Shifting demographics

- United Nations, Department of Economic and Social Affairs, 2022: World Population Prospects 2022. Read 02/2023.
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6. Digitally enhanced economies

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7. New societal norms

- Euromonitor International, 2022: Megatrends: Diversity and Inclusion. Read 02/2023.
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Transformative trends

A. Mobility technologies

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- Bernard Marr & Co., 2022: The 3 Biggest Future Trends In Transportation And Mobility. Read 02/2023.
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- Minna Takala, 2022: Innovative Material Trends 2022+. Read 02/2023.
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Highlighted disruptive technologies

A. Human-like artificial intelligence

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D. Metaverse & new realities

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