WWW.OEAW.AC.AT

ÖAW AUSTRIAN ACADEMY OF SCIENCES

REPORT

VIENNA, JUNE/2025
ITA-2025-03
WWW.OEAW.AC.AT/ITA

FORESIGHT AND TECHNOLOGY ASSESSMENT: MONITORING FUTURE ISSUES FOR THE AUSTRIAN PARLIAMENT

MAY 2023 – MAY 2025

itas

ITA

ITA – INSTITUTE OF TECHNOLOGY ASSESSMENT

FORESIGHT AND TECHNOLOGY ASSESSMENT: MONITORING FUTURE ISSUES FOR THE AUSTRIAN PARLIAMENT

MAY 2023 – MAY 2025

Institute of Technology Assessment (ITA)
of the Austrian Academy of Sciences

In cooperation with:
Institute for Technology Assessment and Systems Analysis (ITAS)
at the Karlsruhe Institute of Technology

Project lead: *Michael Nentwich* (ITA)
Authors: *Manuel Baumann* [MB] (ITAS)
Christian Büscher [CB] (ITAS)
Fabian Fischer [FF] (ITA)
Felix Gnisa [FG] (ITAS)
Niklas Gudowsky-Blatakes [NG] (ITA)
Dirk Hommrich [DH] *(ITAS)*
Christoph Kehl [CK] (ITAS)
Harald König [HK] (ITAS)
Jaro Krieger-Lamina [JKL] (ITA)
Michael Nentwich [MN] (ITA)
Walter Peissl [WP] (ITA)
Pauline Riousset [PR] (ITAS)
Christine Rösch [CR] (ITAS)
Nora Weinberger [NW] (ITAS)
Marcel Weil [MW] (ITAS)

A report commissioned by the Austrian Parliament
Vienna, June/2025

NOTE

This report is an English translation of a collection of five individual reports published between May 2023 and May 2025 to make the original German texts accessible to an international audience.

PLEASE CITE AS

ITA-ITAS (2025) Foresight and Technology Assessment: Monitoring Future Issues for the Austrian Parliament, May 2023 – May 2025. (p. 202). Vienna. epub.oeaw.ac.at/ita/ita-project-reports/ITA-2025-03.pdf

IMPRINT

Media owner:
Austrian Academy of Sciences
Legal entity under public law (Federal Law Gazette 569/1921 as amended by Federal Law Gazette I 31/2018)
Dr. Ignaz Seipel-Platz 2, A-1010 Vienna

Publisher:
Institute for Technology Assessment (ITA)
Bäckerstraße 13, A-1010 Vienna
www.oeaw.ac.at/ita

The ITA project reports appear irregularly and serve to publish
the research results of the Institute of Technology Assessment.
The reports are published in small print runs and are made available to the public via the
The reports are published in small print runs and made available to the public via the "epub.oeaw" Internet portal:
epub.oeaw.ac.at/ita/ita-projektberichte

Cover picture: © Parlamentsdirektion/Bildagentur Zolles KG/Martin Steiger

Report no.: ITA-2025-03 (Vienna, June/2025)
ISSN: 1819-1320
ISSN-online: 1818-6556
epub.oeaw.ac.at/ita/ita-project-reports/ ITA-2025-03.pdf

This report is licensed under the Creative Commons Attribution 4.0 International License:*creativecommons.org/licenses/by/4.0/*

CONTENTS

SUMMARY

In the five reports published from May 2023 to May 2025 the following 30 new socio-technical topics were identified as particularly relevant for Austria and the Austrian Parliament:

Smart implants

Smart neurotechnological implants facilitate direct interaction between the nervous system and technology, integrating energy self-sufficiency, bidirectional communication, and adaptive control. They enhance established therapies, such as deep brain or vagus nerve stimulation, and offer potential for new applications in orthopaedics, prosthetics, and the treatment of chronic diseases. Technical challenges include long-term stability and autonomous control; ethical challenges relate to autonomy, identity, and data protection. Market development is characterised by high regulatory hurdles and economic risks, particularly for start-ups. With the further development and proliferation of advanced implants, human enhancement and neuroabandonment — i.e., the discontinuation of the supply of implanted medical technology by manufacturers (e.g., due to insolvency) — could present increasingly significant risks. A broad public debate on the benefits and risks of smart implants is advisable.

Non-military drone defence

The rapid development of drone technology has led to civilian applications across various fields, including research, logistics, and security. Unmanned aerial vehicles (UAVs) are also being increasingly utilised in agriculture, logistics, and leisure activities. However, they also play a crucial role in modern warfare. This proliferation raises security concerns, as drones can be misused for espionage and terrorist activities. Technologies for detecting and neutralising drones are vital for mitigating these risks. In Austria, civilian drone operations are regulated by EU directives and overseen by several government agencies. Ongoing monitoring of technological developments is essential for addressing the continually evolving challenges of UAV technology.

Humanoid robots

Until now, humanoid robot applications have primarily held a prominent position in science fiction but have yet to establish a significant market presence. However, they could now be on the brink of a breakthrough. This is partly due to advancements in artificial intelligence, specifically through multimodal language models that can process image data, voice data, and sensor data. Despite ongoing challenges in development and production, humanoid robots possess considerable potential for use in various areas of human life, including military operations, industry, rescue missions, healthcare, education, personal assistance, entertainment, and agriculture. The increasing utilisation of humanoid robots raises legal and ethical questions regarding liability, data protection, and potential job displacement.

Hybrid work

During the COVID-19 pandemic, there was a sudden and sharp increase in the use of home office to avoid contracting infections. Current studies indicate that the frequency of working from home has decreased since the end of the pandemic but remains above pre-pandemic levels. In addition to working from home, the term 'hybrid working' also encompasses mobile working. Depending on its

specific form, hybrid working offers advantages on individual (time savings, work-life balance) and social levels (reduction in traffic, attractiveness of peripheral regions), but disadvantages remain: on an individual level, risks such as constant accessibility, ergonomics, and high productivity pressure arise. At a societal level, the possibility of hybrid work is unevenly distributed, depending on the sector and role within the company, and reliance on non-European technology companies may increase.

AI agents

AI agents build upon recent developments in generative AI, focusing on performing actions in the digital or physical world rather than generating content. Through contextual understanding, the use of tools, and the ability to plan, AI agents can tackle complex tasks and pursue goals without close human supervision. In advanced deployment scenarios, multiple specialised AI agents collaborate effectively. However, from the technological foundation of large language models, AI agents also inherit their disadvantages, such as unreliability and a lack of reasoning skills. In many of the advertised scenarios, such as automatic vacation planning and booking, there are specific concerns regarding liability and the safeguarding of highly sensitive data.

Plastics and human health

Micro- and nanoplastics are ubiquitous and are primarily ingested by humans through respiration and food consumption. The research field concerning their health effects on humans is relatively nascent, presenting several methodological challenges. Nonetheless, increasing evidence suggests that there are significant health impacts. While most microplastic particles are excreted, some enter the bloodstream via the intestines or lungs and accumulate in blood vessels, the brain, and other organs. These accumulations can cause inflammation and are associated with an elevated risk of heart attack, stroke, or death. Microplastics are linked to cancer, asthma, neurological disorders, intestinal diseases, and immune reactions that may promote autoimmune diseases.

Brain organoids

In recent years, the creation of three-dimensional structures from human stem cells that currently only partially form structures and functional characteristics of the brain - so-called brain organoids - has made new model systems for researching brain development and neurological diseases possible. However, ethical problems are also being discussed that could arise, in particular, from the development of consciousness and pain perception of such organoids in tissue culture or after their transplantation into the brains of animals. Due to the lack of complexity of current brain organoids and those that can be produced shortly, these problems are unlikely to become relevant in the foreseeable future or lead to a need for legislative action. Regarding possible transplants in prenatal stages—and the associated potential for further development and functional integration of human cells into the animal brain—it seems advisable to examine whether the current regulations for assessing and conducting such research are adequate.

Superbatteries

Global demand for batteries will increase significantly by 2030. This is mainly due to the expansion of renewable energies and electromobility. This market will become a strategic area for new business models, technologies and raw materials globally. Lithium-ion batteries currently dominate this market. The increased use of batteries poses challenges regarding environmental impact, supply chains and the use of critical resources such as cobalt, lithium, nickel and natural graphite. Post-lithium technologies such as sodium-ion batteries are being researched to reduce the use of rare and expensive materials. Common standards and transparent supply chains are needed to promote the development of new technologies and establish a sustainable, circular battery industry. A comprehensive TA study is proposed to identify potentials and strategies for research, production and recycling of batteries.

Protein transition

Some European countries have already developed strategies to implement the protein transition, which aims to gradually reduce the consumption of animal protein and increase the consumption of alternative, mainly plant-based proteins. Such measures are also highly relevant for Austria. Agriculture accounts for around ten percent of greenhouse gas emissions in Austria and is heavily affected by the effects of climate change. In Europe, around 70 percent of agricultural emissions are attributable to livestock farming. The protein transition could be an essential step towards reducing emissions, and reducing Austria's very high meat and milk consumption would also have positive health effects.

Forest fires

On average, there are more than 200 forest fires in Austria annually, most of which are caused directly or indirectly by humans. Forest fires have high ecological, economic, and social costs. As a result of climate change, the number of fires has already increased significantly in recent decades, and a further increase in the risk of fire is very likely in the future due to more extended periods of drought and heatwaves. Fifty percent of Austria's forests are made up of spruce trees, which are particularly vulnerable to fire. Technological advances in fire prediction and suppression and broader public awareness of the issue can help reduce the risk of forest fires. The recolonisation of burnt areas is a highly dynamic process; other species, more deciduous trees, and modified reforestation strategies will be needed.

Health & digitalization

Cell phones today are predominantly smartphones, with children receiving their first device at an increasingly younger age. The majority of children possess their smartphone from Year 3 onwards. These devices capture the attention of young people in particular (though adults are affected too); their presence and the necessity of focusing on them disrupt nearly every other activity. There are findings of manifest physical and, above all, psychological difficulties and even illnesses that can be caused by using smartphones too often and/or for too long. Empowering children to use digital media competently by integrating these resources beneficially into their education and training is essential.

Cobots

Robots play an essential role in the automation of industrial production. Until now, most of them have been installed in their safety zones not to endanger employees. The further development of collaborative robots (cobots) is intended to combine the advantages of robots with the skills of humans. Although cobots are generally somewhat less potent than everyday industrial robots, they also cost less, are more flexible and easier to program, which makes them interesting for SMEs. Designing human-friendly working environments is the central challenge regarding cooperation between man and machine. This complex system of man, machine, and production requires explicit guidelines, an appropriate research budget, training for all those involved, and, last but not least, a comprehensive ethical assessment of the overall system.

Intelligent social agents against loneliness?

Increasingly, digital applications are emerging to offer people emotional support and guidance in their daily lives. Digital social agents are AI-supported chatbots that produce textual and visual content for conversations with users. On the one hand, such applications can strengthen users' mental and emotional health, make it easier for poorer population groups to access psychological support, and, if necessary, support psychological treatments in everyday life. On the other hand, there is a risk of dependency, a long-term increase in loneliness, and a loss of interpersonal skills. Whether a dialogue-oriented AI chatbot is more likely to enhance the user's ability to build relationships with other people or increase loneliness depends largely on the design and discourse on AI.

Phages for therapy and biocontrol

Particularly concerning the problem of antibiotic resistance for human, animal, and environmental health, phages, i.e. viruses that infect bacteria, have the potential to make an essential contribution to solving the problem. However, under the current framework conditions in the European Union, it is unlikely that phages will be developed or used more widely for medical purposes or for biocontrol in agriculture and the food industry. This would require adjusting or flexibilization of the regulations, which have focused mainly on chemicals, creating effective economic incentive structures and, if necessary, reimbursement models, e.g. for genuinely new antimicrobial drugs, and targeted support for R&D activities. Therefore, political initiatives are mainly required to review the regulation and framework conditions in all application areas and to develop them further by adding flexible and innovative regulations.

Self-driving labs

Self-Driving Labs (SDL) are laboratories that can carry out fully automated test series. Roughly speaking, there are three steps: An experimental setup is designed using artificial intelligence (AI). In the next step, the experiment uses robots without human intervention. The result of the experiment is then evaluated automatically and provides the basis for the following experiments. In this way, an enormous acceleration can be achieved: On the one hand, the absence of laboratory technicians means that experiments can be carried out around the clock; on the other hand, intelligent control of the series of experiments allows a more targeted search for new substances, molecules and proteins. Furthermore, SDLs allow supra-regional access, although this also entails the risk of cyberattacks. Other hurdles stand in the way of realizing the potential of SDLs, including the poor data situation, lack of interoperability of instruments, inadequate availability of suitable software and high investment costs.

Textile recycling

The textile industry is characterized by overproduction and overconsumption ("fast fashion"), which leads to immense amounts of textile waste. The linear production method pollutes the environment through high water consumption, chemical pollution, CO_2 emissions and microplastics. Three-quarters of the textile waste produced in Austria is incinerated. Transitioning to a circular textile economy focusing on reuse, repair, and recycling is necessary. Mechanical recycling is widespread but only suitable for single-origin textiles, not synthetic fibres. Chemical recycling enables the reuse of mixed materials but is only available to a limited extent. According to the EU, all textiles on the European market should be recyclable by 2030. Austria can potentially play a pioneering role in this area and benefit from the economic and environmental advantages.

Green concrete

Conventional cement production, the main concrete component, causes around 8% of global CO_2 emissions and consumes immense amounts of natural resources. Given the increasing demand for concrete, finding more sustainable alternatives for concrete production is vital. Green concrete encompasses various approaches to producing more environmentally friendly concrete. These include: Replacing conventional cement with industrial waste such as fly ash or granulated blast furnace slag, using recycled materials in concrete, or energy-efficient manufacturing processes. Other innovations to make concrete construction more environmentally friendly include self-healing, 3D-printed or photocatalytic concrete, electrified machines and carbon capture, utilization and storage. The biggest challenges currently lie in the availability of alternative materials and technologies, the cost of renewable energy and recycled materials and the lack of incentives and subsidies for the use of green concrete.

Digital patient twins

The concept of digital twins describes a representation of a real object in the virtual world and can be understood as a further development of existing modelling that makes it possible to monitor the state of the real object in real-time and, if necessary, intervene to control it. In addition, the effects of changes to the real object can be tested on digital twins. There are already many applications in laboratories, urban and traffic planning, and logistics. While digital twins have been in use in these areas for several years at an early stage of development, their application is now increasingly being researched for medical purposes. Digital twins of specific organs, such as the heart or liver, have existed for some time. However, the vision for the future involves modelling the entire human organism.

Artificial womb

Techniques to enable the development of embryos or foetuses (including humans) outside the body in artificial systems (ectogenesis) have developed considerably in recent years. In addition to these advances, recent ground-breaking experiments on the creation of embryos without egg or sperm cells, so-called "synthetic embryos", as well as their in vitro cultivation, have made it possible to decipher fundamental processes of embryo (self-) organisation and development. Such embryo models are already raising profound legal questions. In the short to medium term, developments in the creation and cultivation of embryos will likely require a social discussion of the opportunities and ethical challenges to develop and use new knowledge and potential biomedical applications responsibly.

Medication against obesity

Obesity is a serious global health problem that can cause diabetes, cardiovascular disease and cancer. It is estimated that over 4 billion people could be affected by obesity by 2035. Recently, there appears to be a serious pharmaceutical treatment option based on the active ingredient semaglutide, which is being touted as a milestone in the fight against obesity. The European Union has also approved the active ingredient. So far, there have been no studies on the long-term effects. In addition to questions about safety and efficacy, the use of the drugs also raises profound questions about the social consequences of drug treatment options, which require a broad discussion of the opportunities, social and ethical challenges and possible risks. The socio-economic and cultural factors of obesity should not be lost sight of here.

Generative AI and democracy

Since ChatGPT was published in November 2022, generative AI systems have been causing a stir and old dreams, hopes and fears regarding artificial intelligence (AI) performance are being rekindled. Generative AI promises enormous simplification of work and unrestricted access to information. However, a closer look reveals many unresolved difficulties that make it inadvisable in most professional environments. In addition, experts see a significant security problem facing society, as generative AI systems could be used, for example, to write slightly varying malicious code thousands of times or to launch individually tailored fraud attempts on millions of citizens.

Large heat pumps

Heat pumps are central to the necessary heating transition and corresponding phase-out strategy. Until now, however, they have mainly been used in new builds and single-party households. With the development of large heat pumps with outputs of several megawatts, it is possible to use a large number of (waste) heat sources from the industry as well as ambient heat from geothermal energy and bodies of water and thus also use heat pumps in existing buildings and heating networks. Research is needed to qualitatively and quantitatively assess the potential uses in Austria and stable framework conditions that ensure investment security and social cushioning during the transition.

Environmental impacts of space travel

There are already over 5,500 active satellites in orbit, and this figure is set to rise to 58,000 by 2030 - a development that is being driven primarily by commercial space travel. In the foreseeable future, there will also be rocket launches to planned space stations and for exploration missions to the moon and Mars, space tourism, mining in space, anti-satellite weapons and solar power plants. The effects of these activities are manifold. Satellites provide essential services but have problematic environmental impacts that have so far received little attention due to the relatively low launch density: These include ozone-depleting emissions (aluminum, chlorine) in the upper atmosphere; enormous quantities of fuel with greenhouse gas emissions (CO_2, water vapor, soot particles), including near the ground during launch; space debris, with risk of collision and emissions during re-entry; hazards from re-entering rocket parts/broken satellites; impairment of astronomy. Although international agreements for outer space exist, they do not cover these emissions more than environmental agreements (e.g. Montreal Protocol).

Drought resilience

Rain-spoiled regions such as Austria are little prepared for droughts. However, droughts in Austria now cause more damage than all other natural disasters combined. Drought damage is expected to quadruple by 2050. It is no longer just agriculture that is affected by low rainfall, falling groundwater levels, and river levels; it is also drinking water, industry, energy production, and transportation. Every further drought reveals competing uses and conflicting goals. There is relatively little historical experience with drought, so the existing plans are only partially fit for the future. Monitoring systems are in place, but adaptation and coping strategies must be improved. Research and development of drought resilience and a national water strategy is urgent.

Resilient fertiliser supply

Mineral nitrogen, phosphorus, and potash fertilisers are both a blessing and a curse. They increase agricultural productivity but simultaneously cause climate and environmental problems and make food security dependent on a few countries and fossil fuels. Research and application of alternative approaches and technologies are necessary for a resilient, decarbonized, sustainable nutrient supply. Examples of this include the development of new processes for nitrogen production, the use of secondary phosphorus sources, in particular sewage sludge and polyhalite as a substitute for chloride-containing potash salts, but also the breeding of new plant varieties that can mobilize nutrients from the soil, the use of biochar and efficient nutrient fertilization through AI and precision agriculture. The coherent combination of the various approaches requires a context-specific assessment of the nutrient supply technologies and measures suitable for Austria and a national strategy for a resilient, climate-neutral and efficient nutrient supply.

Emotion-recognizing AI

AI is increasingly used to recognize patterns in faces, speech, texts, body signals and behaviour and to create analyses and predictions about people's emotional states, preferences and personality traits. The systems can be used in various areas - for example, by security authorities at borders and in public spaces, for therapeutic care in medicine, to support pupils in education, in personalised marketing or for personnel development in the world of work. However, the reliability of the systems must be critically assessed due to the underlying models and psychological assumptions. In addition, there are many challenges in terms of discrimination, data protection, ethical responsibility for particularly vulnerable groups, structural change in political public spheres and the exacerbation of social inequality in the world of work.

Solar storms and space weather

Space weather phenomena such as solar storms have the potential to severely affect human life on Earth for weeks or months due to our dependence on critical infrastructure that is vulnerable in this respect. In particular, the networks for electricity and communication, known as cross-sectional infrastructure, which form the basis for the functioning of all other areas of critical infrastructure, would be severely affected. The research field has been gaining relevance for several years due to the increasing dependence on these technologies. What problems can be expected, and what can be done to ensure a higher resilience in Austria?

Biocomputers

The human brain has unique abilities that technology can only partially imitate. However, the structure of today's AI software, known as neural networks, is based on the functioning of neuronal structures. Attempts are also being made to reproduce the brain's physical architecture in hardware (neuromorphic engineering). Biological systems, such as brain organoids produced from human stem cells or bacterial cells, can already be instrumentalized for computing power, while DNA is a long-term storage medium. Biocomputers could be an opportunity to replace resource- and energy-intensive conventional computing systems in the long term, as just a few grams of cells can provide high parallel computing power. However, developments are still in their infancy, even though impressive progress has been made in recent years.

Negative emission technologies

Even if measures to reduce greenhouse gases are prioritised, supplementary measures to remove CO_2 (negative emission technologies, NET) will probably be increasingly essential to limit global warming to below 2°C. However, their use must be strictly aligned with sustainability principles. However, their use must be strictly aligned with sustainability principles. Even if some approaches have the potential to sequester large amounts of carbon in the long term, detailed adaptation to local conditions is crucial to their implementation to ensure that they work at all and do not have the opposite effect. In addition to land-based processes such as afforestation or biochar, the focus is on various carbon capture and storage/utilization processes. Most NETs are land-intensive, which makes scaling difficult, while others require large amounts of energy and resources. Other environmental risks must be considered, such as effects on biodiversity, the possible reversibility of storage, and the interaction between different technologies.

A non-English AI large language model

The publication of ChatGPT and other language models (Large Language Models – LLMs) created hype and high hopes for positive disruptions in business and society. The models are primarily based on training data in US English. This has technical implications for the quality of other languages and cultural influences because the language logics in English and German, for example, are different. In addition, there are legal problems with the application (e.g., data protection compliance). There are also economic issues regarding the confidentiality of business secrets. The political dimension is an even greater dependence on global corporations and a further reduction in digital sovereignty. Therefore, the objective could be to develop an open language model based on German, with Austria and Switzerland participating in the development to exploit its potential fully.

Current studies by other parliamentary TA institutions

In addition, the analysis of the reports completed by member institutions of the European Parliamentary Technology Assessment (EPTA) network[1] since 2022 revealed that the following topics appear to be of particular interest to the Austrian Parliament:

- Reducing emissions in the raw materials industry
- Artificial intelligence and climate change
- Biometrics: use and misuse
- Cybersecurity in the food supply sector
- Deepfakes
- Cybersecurity of elections
- Meat and milk substitutes
- Food waste
- Digital estate
- Digitization and culture
- Climate-friendly air travel
- Plastic waste
- Metaverse
- Media restrictions and freedom of expression
- Alternative protein sources for food and animal feed
- AI modelling of extreme weather events
- Digital age discrimination
- Forensic technologies
- The future of horticulture
- Privacy and generative AI
- Immersive technologies
- Outlook Materials Science
- Space weather

[1] *eptanetwork.org.*

- Improving recycling
- The future of fertiliser use
- Use of AI in education
- Traffic resource planning
- AI: food production; healthcare sector
- Quantum computers: data security; impact assessment
- Automated biometrics; facial recognition
- Information technologies: energy consumption; rare earths
- Data centers
- Genome editing
- People analytics – technologies for analysing employee data
- Digital games in education
- Reform of the electricity market
- E-voting – alternative forms of voting and how to safeguard them
- Bicycle turnaround
- Indoor air quality
- Introduction of a horizontal European climate label for products
- Sustainable Cooling – sustainable cooling strategies
- New tobacco and nicotine products: Lift the smoking ban
- Energy planning at the local level: achieving net zero
- Technologies for online advertising and competition
- Biosecurity of plants in Great Britain
- Plastic recycling
- Social media
- Energy security
- Telecommunications
- Mental health and AI
- Bioprinting in medicine
- Heating and cooling
- Space debris
- Critical raw materials
- Speed limits
- Air taxis

Final reports on all these topics are available from TA institutions that are members of EPTA.

1 INTRODUCTION

Identification of central future topics for Austrian politics

Continuous monitoring of current or emerging international scientific and technological developments in the social context (socio-technical trends) is the basis for identifying key future issues for Austrian policy. Such a procedure also reveals essential scientific and technological drivers for change, which open up extended options for action and design for Parliament if considered early. Monitoring is, therefore, also the basis for in-depth studies in foresight and technology assessment (FTA). On this basis, it is possible for policymakers to locate specific and pressing issues that arise at a later date within broader future topics and to assess their relevance more quickly and with foresight. The results of monitoring thus not only support a forward-looking RTI policy but, with their TA component, also serve to maximise positive and, at the same time, minimise possible negative technological consequences and are thus also highly relevant for other policy fields. Potential fields of application for future technologies are associated with high expectations and diverse promises. During implementation, however, it often becomes apparent that these technologies are associated with not initially apparent effects. In contrast, the foresight component focuses on the designability of innovations: If the potential of future technologies is analysed early, the scope for shaping sustainable innovation paths opens up.

Support for RTI policy and dealing with the consequences of technology (opportunities and risks)

Responsible and future-oriented technology development focuses in particular on two dimensions, both of which can be addressed with foresight and TA:

Two dimensions of responsible and future-oriented technology development

- On the one hand, the scope for action and the conditions under which scientific and technological potentials become economically and socially relevant innovations;
- Second, the possible consequences of socio-technical developments in health, the environment, the economy, law, and society exist.

1.1 PROCESS

The monitoring process is carried out in the following steps:

Source evaluation

1. *Source evaluation:* Databases in TA, foresight, futurology, science and technology research and other relevant sources are evaluated qualitatively according to the usual scientific standards (see section 1.2). Data-based tools are also used to search for trends in extensive document collections (in particular. RS-Lynx and TIM/EU). The interim result in each case is a list of socio-technical developments on the international agenda or are currently receiving new attention.
2. *Topic selection:*

   Topic selection

   a. *Basic analysis:* The entries in the list from step 1 are analysed and evaluated by an interdisciplinary, international and inter-institutional team (consisting of scientists from the ITA-ÖAW and the ITAS-KIT). From a TA perspective, it is particularly relevant to identify those topics that could result in a need for political action. This applies particularly to socio-technical developments that have potentially problematic effects on health, the environment, the economy, law or society, and those whose promotion could lead to positive social effects. The interim result is a reduced list subject to the next steps.
   b. *Evaluation of the parliamentary agenda:* Monitoring and evaluating the agreed-upon and foreseeable parliamentary agenda for the next 6-18 months.
   c. *Relevance check: Against* the background of the medium-term parliamentary agenda (step b) and applying further criteria, in particular those relating to Austria (see section1.2), the identified topics are examined to determine whether and in what way they could become relevant for Parliament in the foreseeable future.
   d. *Determination of the topics to be addressed:* The interim result of step c is a further narrowed-down list of relevant socio-technical developments that could be included in the monitoring report. In an interdisciplinary workshop with the experts involved in the process, the list is evaluated from multiple perspectives, whereby the monitoring report's high relevance and thematic diversity play a role. A total of six topics are selected. The following play a role: the high relevance (Austria & Parliament); the provisionally identified potential need for action; the extent to which the topic already appears to have been investigated; whether the developments can be considered realistic; the existence or start of a scientific or public debate on the subject.
3. *Research and in-depth research*: The topics were selected based on preliminary research. In the next step, all chosen topics will be researched more deeply.
4. *Finalization of all* parts of the monitoring report in editorial and formal terms.

1.2 RELEVANCE CRITERIA

Monitoring aims to provide Austrian parliamentarians with an overview of relevant scientific and technical developments and related social developments. Relevance is central and is specified as follows:

1. *Relevance of content:* The future orientation and, thus, the anticipation of developments that have the potential to influence social development in the future significantly are central. In particular, those fields of technology that contribute to solving significant and complex social challenges are decisive for monitoring. A relevant development refers to a technology whose development options have an average time horizon of approximately a decade (shorter or longer, depending on the field). Basic research is considered necessary when there is a requirement for parliamentary action in the short to medium term. Technology is understood broadly, meaning it also encompasses new applications of existing technologies and service innovations and includes "social" innovations, which may even intentionally rely on less technology or alternatives. This clarification also refers to the social developments associated with these scientific and technical developments. The focus is, therefore, on the connection between social developments on the one hand and scientific and technical developments on the other. Both are mutually dependent on each other: Scientific and technical developments have a decisive influence on social developments, just as social developments have a decisive impact on scientific and technical developments. *Relevance of content*
2. *Relevance to Austria*: The second selection criterion is a specific reference to Austria, given the addressee, the Austrian parliament. A topic can be relevant because it ties in with particular competencies in Austria's R&D landscape and economy, or a concrete need for action in Austria can be foreseeable due to the local circumstances (social, economic, geographical, societal). *Relevance to Austria*
3. *Parliamentary work*: Thirdly, the aim is to highlight those developments that are directly relevant to the work of Parliament or will be of particular relevance in the future, especially about its responsibilities. Particular attention is also paid to those developments that cut across policy areas, i.e. that specifically affect several committees or Parliament. In addition to the topics on Parliament's short and medium-term agenda, topics are also classified as particularly relevant if there is already a concrete need for political action in the foreseeable future. Still, other stakeholders (administration, social partners, civil society) are not or not yet aware of this. *Parliamentary relevance*

1.3 BASIC SOURCES FOR THIS REPORT VERSION

This determination of parliamentary relevance determines the sources to be included in the monitoring and the methods used in the analysis. With the resources available, a primary survey of future scientific and technical developments (patent analysis, bibliographic methods, broad-based surveys of key players, etc.) is not feasible. For this reason, a secondary evaluation of previously scattered, relevant sources is carried out. Based on those mentioned above more precise definition of the subject matter, the following sources are therefore included in the evaluation: *Secondary evaluation*

A. *Selection of scientific journals*, in particular: Research Policy; Technological Forecasting and Social Change; Futures; foresight; Zeitschrift für Zukunftsforschung; proZukunft; European Journal of Futures Research; Futures Research Quarterly; World Futures Review; TATuP – Zeitschrift für

Technikfolgenabschätzung in Theorie und Praxis; Nature; Science; Scientific American; IEEE Spectrum.

B. *Proceedings of conferences of relevant scientific networks*, in particular: European Forum for Studies of Policies for Research and Innovation" (Eu-SPRI Forum); Future-Oriented Technology Analysis (FTA); European Association for the Study of Science and Technology (EASST); The Society for Social Studies of Science (4S); Netzwerk Technikfolgenabschätzung (NTA); European Parliamentary Technology Assessment (EPTA); European Academies Science Advisory Council (EASAC); International Network of Government Science Advice (INGSA); Swiss Association for Futures Studies (swissfuture); European Technology Assessment Conference (ETAC) and globalTA series.

C. *Future trends and megatrends publications by well-known international players*, in particular: Meta-Council on Emerging Technologies (World Economic Forum); OECD Science, Technology and Innovation Outlook; MetaScan3 Emerging Technologies; Office for Science UK: Technology and Innovation Futures; EC-JRC Megatrends; Standardization Opportunities from Horizon Scanning of the international Standardisation institutes.

D. *TA and foresight databases*, in particular: the project and publication database of the EPTA network; the publication database of the NTA openTA; the Open Repository Base on International Strategic Studies; the Knowlege4policy platform of the EU Competence Center for Foresight; Statista, ESPAS-Orbis (European Strategy and Policy Analysis System).

E. *Informal sources*, in particular: Perceptions and current discussions of team members in their relevant networks; experiences from team members' Horizon Scanning projects; blogs, websites, and newsletters (e.g., sciencemag.org, nature.com, SwissCognitive, OECD STI News, tech2b); observation of relevant media platforms (e.g., TED Talks, future zone, APA Science, VDI publications[2]); observation of EU calls for proposals Horizon Europe.

F. *Sources with a specific reference to Austria*, particularly: Research and Technology Report of the Federal Government; current BMVIT tenders (Climate and Energy Fund, Factory of the Future, etc.); Austrian Cooperative Research (ACR) Innovation Radar.

Method

Methodologically, the evaluation of the sources is based on systematic document analysis by relevant experts from ITA (ÖAW) and ITAS (KIT), as well as iterative, interdisciplinary discussions. In addition, semi-automated, AI-supported evaluations of digital sources are also used:

G. *AI-supported quantitative analysis of large amounts of text data*: In addition to qualitative source analysis, the RS-Lynx[3] software is used, which can detect trends based on large volumes of web-based information sources with the help of

[2] *vdi.de/about-us/press/publications*.

[3] *radiosphere.de/medienmonitoring-plattform-rs-lynx.*

artificial intelligence. The EU Commission's text mining platform TIM Open Access[4] is also used.

Sources specifically analysed for this report.

The following served as specific essential sources for this version of the report. Secondary sources:

- 10 Breakthrough Technologies 2024[5]
- 2023 Tech Trends Report (The Future Today Institute)[6]
  - A Horizon Scan to Support Chemical Pollution-Related Policymaking for Sustainable and Climate-Resilient Economies [7]
  - A Social Sciences and Humanities research agenda for transport and mobility in Europe: key themes and 100 research questions[8]
- acatech
  - Publications 2024[9]
  - Technology Radar 2023[10] and 2024[11]
- AI-Assisted Identification of Policy-Salient Research Priorities and Emerging Issues[12]
- CENELEC Standardization Opportunities from Horizon Scanning, Q3&Q4/22[13]
- Deloitte Tech Trends 2024[14]
- Dubai Future Opportunities Report – The Global 50 - 2024 Report[15]
- EDPS – Techsonar 2022-2023[16] and 2023-2024[17]
- European Innovation Council (EIC) Emerging Tech and Breakthrough Innovation report 2022[18]
- Emerging healthcare interventions: Patient-Centered Outcomes Research Institute's programmatic initiative[19]
- Federal Agency for Leapfrog Innovations 2022 (SRPIN-D)[20]

4 *knowledge4policy.ec.europa.eu/text-mining/tim_oa_en* Contents: OA publications/ Semantic Scholar, worldwide patent applications/Patstat, FP5 to Horizon projects (Cordis).
5 *technologyreview.com/2024/01/08/1085094/10-breakthrough-technologies-2024/*.
6 *futuretodayinstitute.com/trends/*.
7 *setac.onlinelibrary.wiley.com/doi/full/10.1002/etc.5620*.
8 *tandfonline.com/doi/full/10.1080/01441647.2023.2167887*.
9 *acatech.de/publication/*.
10 *acatech.de/publication/technikradar-2023/*.
11 *acatech.de/publication/technikradar-2024/*.
12 *papers.ssrn.com/sol3/papers.cfm?abstract_id=4502450*.
13 *cencenelec.eu*.
14 *www2.deloitte.com/at/de/seiten/enterprise-performance/articles/tech-trends.html*.
15 *dubaifuture.ae/wp-content/uploads/2024/03/The-Global-50-2024-Eng.pdf*.
16 *edps.europa.eu/data-protection/our-work/publications/reports/2022-11-10-techsonar-report-2022-2023_en*.
17 *edps.europa.eu/data-protection/our-work/publications/reports/2023-12-04-techsonar-report-2023-2024_en*.
18 *eic.ec.europa.eu/system/files/2022-02/EIC-Emerging-Tech-and-Breakthrough-Innov-report-2022-1502-final.pdf*.
19 *cambridge.org/core/journals/international-journal-of-technology-assessment-in-health-care/article/emerging-healthcare-interventions-patientcentered-outcomes-research-institutes-programmatic-initiative/F53E6CB249129967752117FD50BC49EC*.
20 *sprind.org/en/challenges/*.

- Future trends and potential uses of digital technologies in setting-based prevention and health promotion – a Delphi survey[21]
- Gartner
  - Top 10 Strategic Technology Trends 2024 [22]
  - Top 10 Strategic Technology Trends for 2023[23]
  - 10 most important strategic technology trends for 2024[24]
- GESDA: Geneva Science and Diplomacy Anticipators:
  - Science Breakthrough Radar 2022[25]
  - Science Breakthrough Radar 2023[26]
- GOV.UK foresight[27]
- Joint Research Centers of the EU Newsletter[28]
- KISTI – weak signals 2022-2023[29]
- LinkedIn: Big Ideas Technology and Innovation 2024[30]
- MIT 10 Breakthrough Technologies 2023[31]
- Policy Horizons Canada 2021-2023[32]
- PWC-Horizon scanning[33]
- Recent Trends, Developments, & Emerging Technologies towards Sustainable Intelligent Machining: A Critical Review, Perspectives & Future Directions[34]
- Resilience to Long-term Trends and Transitions to 2050[35]
- Top technology trends 2022+ (VDI)[36]
- WHO – 2023 Emerging technologies and scientific innovations[37]
- World Economic Forum
  - The Global Risks Report 2023[38]
  - Reports 2024, incl. Global Risks Report 2024[39]

---

21 *link.springer.com/article/10.1007/s00103-023-03669-5*.
22 *gartner.com/en/articles/gartner-top-10-strategic-technology-trends-for-2024*.
23 *gartner.com/en/articles/gartner-top-10-strategic-technology-trends-for-2023*.
24 *gartner.de/en/articles/the-10-most-important-strategic-technology-trends-from-gartner-for-2024*.
25 *radar.gesda.global*.
26 *radar.gesda.global/GESDA%202023%20Science%20Breakthrough%20Radar%2020231010.pdf*.
27 *gov.uk/government/publications/wireless-2030*.
28 *ec.europa.eu/newsroom/eusciencehubnews/newsletter-archives/view/service/169*.
29 *newswise.com/pdf_docs/167757135761191_(Attachment2)%20KISTI%20Data%20Insight%2024.pdf*.
30 *en.linkedin.com/pulse/big-ideas-2024-in-the-coming-year-will-be-important-linkedin-news-dach-8izyc?trk=public_post_feed-article-content*.
31 *technologyreview.com/2023/01/09/1066394/10-breakthrough-technologies-2023/*.
32 *horizons.gc.ca/en/our-work/*; *horizons.gc.ca/en/2023/02/22/exploring-change-in-social-connection/*.
33 *pwc.co.uk*.
34 *mdpi.com/2071-1050/15/10/8298*.
35 *gov.uk/government/publications/resilience-to-long-term-trends-and-transitions-to-2050*.
36 *vditz.de/fileadmin/Publications/2022-04-27_Flyer_TZ_VDI_Research_-_Top-Technology-Trends_2022_.pdf*.
37 *apps.who.int/iris/bitstream/handle/10665/370365/9789240073876-eng.pdf?sequence=1*.
38 *weforum.org/reports/global-risks-report-2023/*.
39 *weforum.org/publications/*.

  - Top 10 Emerging Technologies of 2023[40]
- HTA-Horizon Scans (Canada's Drug Agency, NIHR-Innovation Observatory UK)[41]
- Dubai Future Opportunities Report – The global 50 – 2024 Report[42]
- JRC: Eyes on the Future[43]
- GESDA – Science Breakthrough Radar 2024[44]
- NESTA – Weak signals 2025[45]
- Policy Horizons Canada[46]
- MIT 10 Breakthrough Technologies 2025[47]
- The Future Today Institute: 2024 Tech Trends Report[48]
- Deloitte Tech Trends 2025[49]
- EDPS – Techsonar 2025

40 *www3.weforum.org/docs/WEF_Top_10_Emerging_Technologies_of_2023.pdf*.
41 *cda-amc.ca*.
42 *dubaifuture.ae/wp-content/uploads/2024/03/The-Global-50-2024-Eng.pdf*.
43 *data.europa.eu/doi/10.2760/7083666*.
44 *radar.gesda.global/2024-edition*.
45 *nesta.org.uk/feature/future-signals-2025/*.
46 *horizons.gc.ca/en/our-work/*.
47 *technologyreview.com/2025/01/03/1109178/10-breakthrough-technologies-2025/*.
48 *futuretodayinstitute.com/wp-content/uploads/2024/03/TR2024_Full-Report_FINAL_LINKED.pdf*.
49 *deloitte.com/content/dam/assets-zone2/at/de/docs/industries/technology-media-telecommunications/2025/DI_Tech-trends-2025.pdf*.

2 CURRENT SOCIO-TECHNICAL DEVELOPMENTS

Reporting period May 2023 until May 2025

The following socio-technical developments were identified as relevant and topical issues for Parliament and Austria in the four reporting periods from May 2023 to May 2025. The selection shows a broad spectrum of topics with far-reaching social, economic, political and ecological effects. Austria has expertise in these areas, representing economic development potential from research, innovation and technology policy perspectives. At the same time, these socio-technical developments show a new need for parliamentary action and the scope of parliamentary action - in each case, in a broader societal context.

30 topics

New topics May 2025
Smart implants
Non-military drone defence
Humanoid robots
Hybrid forms of work
AI agents
Plastic and human health
Updated topics May 2025 (originally November 2023)
Brain organoids
Battery systems of the future
Protein turnaround – making widespread use of alternative protein sources
Forest: Fires and restoration
Health consequences of digitalisation
Collaborative industrial robots
Topics November 2024
Intelligent social agents to combat loneliness?
Phages for therapy and biocontrol
Self-Driving Labs
Textile recycling
Green concrete
Digital patient twins
Updated topics November 2024 (originally May 2023)
Artificial uterus systems and synthetic embryos
Medication against obesity
Generative AI and democracy
Large heat pumps
Environmental impact of space travel
Drought resilience
Topics May 2024
Resilient fertilizer supply
Emotion recognition as an area of hope for AI?
Solar storms and space weather
Biocomputers
Negative emission technologies
A non-English AI language model

SMART IMPLANTS

© CC0 (PublicDomainPictures/pixabay)

SUMMARY

Smart neurotechnological implants facilitate direct interaction between the nervous system and technology, integrating energy self-sufficiency, bidirectional communication, and adaptive control. They enhance established therapies, such as deep brain or vagus nerve stimulation, and offer potential for new applications in orthopaedics, prosthetics, and the treatment of chronic diseases. Technical challenges include long-term stability and autonomous control; ethical challenges relate to autonomy, identity, and data protection. Market development is characterised by high regulatory hurdles and economic risks, particularly for start-ups. With the further development and proliferation of advanced implants, human enhancement and neuroabandonment — i.e., the discontinuation of the supply of implanted medical technology by manufacturers (e.g., due to insolvency) — could present increasingly significant risks. A broad public debate on the benefits and risks of smart implants is advisable.

Opportunities and risks associated with smart implants: medical advancement requires ethical and regulatory clarification.

OVERVIEW OF THE TOPIC

Invasive vs. non-invasive neurotechnology

Neurotechnological applications enable direct electrical interaction between nerve signals and machine systems via *interfaces.* Depending on whether the interface is implanted, a distinction is made between invasive and non-invasive systems. Furthermore, according to the type of interaction, a distinction is made between conductive and stimulating systems. While non-invasive systems have limited data resolution, implanted electrodes facilitate targeted signal transmission to or from the nervous system, which opens up a wide array of therapeutic possibilities, including the ability to compensate for physical limitations (e.g., cochlear implants for hearing loss, control of prostheses).

Smart implants feature autonomous and adaptive functions.

In recent years, significant progress has occurred in the field of neural implants, attributed not only to the miniaturisation of electrodes but also to advancements in materials science, microsensor technology, and AI-based data analysis. Collectively, these developments have facilitated a new class of applications that can be described as smart implants, integrating three key characteristics: 1) They are active implants with their own power supply, allowing them to fulfil their function to a certain extent autonomously. 2) They integrate conductive and stimulating functions (closed loop) and can, therefore, combine diagnostic and therapeutic capabilities. 3) They are referred to as "smart" because they possess intelligent sensor functions that enable them to react to vital data in real time and automatically adjust stimulation patterns.[50] Unlike conventional implants, smart implants mainly perform their intended function automatically, not just within preset parameters, making them particularly intriguing for various clinical applications.

Application potential and prospects

Smart implants have the potential to enhance established neurotechnology-based treatment approaches significantly. These include *deep brain stimulation* (DBS), which has been used since the late 1990s for the symptomatic treatment of movement disorders (Parkinson's disease, dystonia and essential tremor) and now also for severe cases of epilepsy, obsessive-compulsive disorder and depression. In DBS, electrodes linked to a pulse generator are implanted in various areas of the brain, depending on the condition, where they emit stimulating electrical signals impulses. Due to its functional analogy to a pacemaker, DBS is also referred to as a "brain pacemaker." Conventional DBS systems possess only stimulating functions and emit impulses continuously. This approach has not proven particularly effective in some cases and may also lead to side effects. The first devices are now available for the treatment of Parkinson's (e.g., the Percept PC from Medtronic), which can record local field potentials and adapt their stimulation patterns accordingly (Thenaisie et al., 2021).

"Brain pacemaker"

A similar development has taken place with *vagus nerve stimulation* (VNS). This treatment method has been established since 1994 and is approved for epilepsy and severe depression. Its effectiveness is being investigated for other clinical pictures, such as anxiety and panic disorders or obesity (Goggins, Mitani, & Tanaka, 2022). With invasive VNS, the left-sided vagus nerve, which is essential for regulating the autonomic nervous system, is directly stimulated using electrodes attached to the neck. Newer VNS systems can automatically trigger stimulation when an epileptic seizure is imminent, with an increase in heart rate serving as a

Treatment of epilepsy

[50] *atlas-digitale-gesundheitswirtschaft.de/blog/2020/03/20/intelligent-implants/.*

critical biomarker. The potential of adaptive VNS is also being investigated for the treatment of cardiovascular diseases (Ottaviani, Vallone, Micera, & Recchia, 2022). Other possible fields of application for smart implants, which are currently still in the experimental stage, include orthopaedics and the treatment of chronic diseases prosthetics:

Applications in orthopaedics...

– In *orthopaedics*, research is being conducted into the extent to which smart implants can support bone healing by monitoring the fracture using various parameters and, if necessary, helping the healing process with active stimulation (Ernst, Richards, & Windolf, 2021). In one research project, for example, implant plates were developed that can deform independently of each other.[51]

...therapy of chronic diseases...

– Smart microimplants that utilise targeted and adaptive electrical stimulation to treat chronic diseases such as type 2 diabetes or high blood pressure remain the subject of ongoing research (Horn et al., 2019). Based on pharmaceuticals, such applications are also referred to as electroceuticals.[52]

...and prosthetics

– In the field of *prosthetics*, work is being conducted on limb prostheses that utilise smart implants to provide the wearer with sensory feedback perceived as natural, which is essential for the fine control of complex hand prostheses, for instance (Raspopovic et al., 2021). This is to be achieved by the implant transmitting information from pressure sensors in the prosthesis to the nervous system.

Technical challenges: algorithmic control and long-term stability

The development of smart implants is associated with various technical challenges. Their function relies on the sensory monitoring of a biomarker to be determined, which is algorithmically translated into stimulation patterns. On the one hand, a suitable biomarker must be identified for the specific task that the available sensors can measure. On the other hand, controlling the input-output ratio is a demanding task. Currently, the algorithms are still based on mechanistic models; in the future, this task could be taken over by self-learning AI models (Eickhoff et al., 2023). The sensor unit, power supply, microprocessors, and electrodes must also be accommodated in a very small space. A significant issue affecting all neuroelectric implants is the long-term stability of the tissue-sensor interface, which tends to deteriorate over time due to corrosion or the foreign body reaction of the surrounding tissue. Encouraging results have been obtained with new biocompatible materials, such as hydrogels, which can be utilised to create soft implants instead of rigid ones.

51 *devicemed.de/smarte-implantate-foerderung-knochenheilung-a-97168f5e7d1daf2935763c6ba86ae764/.*

52 *medizin-und-technik.industrie.de/technik/forschung/elektrozeutika-sollen-helfen-chronische-krankheiten-ohne-medikamente-zu-behandeln/.*

Ethical challenges, among others:

Alongside technical challenges, smart implants also present ethical dilemmas that should be considered as early as possible during the development phase. These concerns particularly pertain to neuromodulating implants that exert their effects in or near the brain, such as DBS. Such applications can influence consciousness and the psyche, leading to alterations in personality (Aggarwal & Chugh, 2020). If the implant automatically adjusts the stimulation patterns, this could profoundly affect the patient's sense of autonomy and identity. Moreover, there are challenges concerning the most intimate privacy, as the functioning of these implants necessitates the measurement and storage of neuronal data (see ***Neurorechte***). With regard to data security and protection, however, smart implants increase reliance on the manufacturer and its control strategies yet generally lessen the necessity to share personal data and measured values, as these are usually processed locally. Due to the complexity of implantation and the associated surgical risks, the non-medical application of intelligent implants, such as in the context of human enhancement (see ***cyborg***), is likely to remain a topic for the future for some time. Nevertheless, it is essential to monitor developments in the premedical and non-medical fields, as US companies, including Elon Musk's Neuralink, are reportedly working on neurotechnological applications for non-clinical purposes (Kostick-Quenet et al., 2022).

Patient autonomy

data protection

future human enhancement

Smart implants are high-risk products

For medical applications, the risks must be weighed against the clinical benefits, which are to be ensured by the legal approval conditions. The Medical Device Regulation (MDR) has been in force in the EU since 2021. Smart implants are high-risk medical devices that are subject to stringent requirements for clinical evaluation and testing. Development and approval are correspondingly lengthy and demanding processes associated with higher economic risks for manufacturers, especially since the applications are often only suitable for smaller patient groups. When start-ups and manufacturers fail on the market, either as companies or with their products, smart implants pose serious risks. This refers to cases in which the supply of implanted medical technology breaks down, affecting both patients who are directly impacted and the clinicians treating them, as well as the manufacturers. There is no longer any support for basic issues such as maintenance, calibration, and repair, as well as necessary software updates and services (referred to as "abandonment"). The only solution typically involves the removal or explantation of the hardware, which will ultimately cease to function, presenting additional surgical risks and potentially incurring financial costs for patients—while also leaving them without a solution for their symptoms.[53] The problem is exacerbated in the case of specialised, innovative applications that are aimed at only a small group of patients. In contrast to widespread mass applications, such as insulin pumps or pacemakers, these niche products often have only one manufacturer on which users depend. The abandonment issue is likely to become more acute with advances in the field of smart implants, which pose challenges for patient risk education and the sustainable design of entrepreneurial business models. Lastly, systemic solutions—such as the development of institutional aftercare services in areas of documentation and data use—need to be proactively created to remedy the situation. It should be noted that cases of "neurological device abandonment" (Okun et al., 2024), the unplanned abandonment of

Difficult economic conditions harbour new risks

"Abandonment" problem

53 ***nature.com/immersive/d41586-022-03810-5/index.html.***

neuromedical technology in the patient's body, are drastic examples of how interim treatment, therapeutic, rehabilitative or supportive benefits achieved through technology can become an additional burden for already vulnerable individuals and social groups.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Austrian players

In Austria, the Medical University of Vienna's Centre for Medical Physics and Biomedical Engineering is a renowned research institute specialising in application-oriented research within the field of neural engineering and smart implants. The country also boasts an internationally competitive medical device sector, comprising 626 companies with a total annual turnover of approximately € 19 billion.[54] As the approval of medical devices is uniformly regulated at the EU level, there is no need for regulatory action in this regard. In 2023, QMD Services GmbH, based in Vienna, received approval as a European conformity assessment body, facilitating market access for domestic companies. However, due to the increased approval requirements, measures such as funding programmes and consulting services are necessary to support start-ups and SMEs, particularly in the development of advanced implants. Furthermore, supplementary measures are required to strengthen the innovation system and develop recommendations for addressing the abandonment problem, involving the most important stakeholders.

No regulatory need

Targeted support and advice required

Dealing with the abandonment problem

PROPOSAL FOR FURTHER ACTION

Evaluation of implications and business models, as well as public discourse

In light of the future challenges posed by both abandonment and human enhancement, there is a need for a thorough evaluation of the ethical, legal, socio-cultural, and, last but not least, economic implications of smart implants and the business models of their developers and providers. The findings regarding how the life cycle of individual applications can be designed responsibly, as well as how the entire Austrian ecosystem for smart implants can be made resilient, should be channelled into a public discourse on the risks and opportunities of these advanced technologies. This should particularly address parties and stakeholders who may be affected.

REFERENCES

Aggarwal, S., & Chugh, N. (2020). Ethical Implications of Closed Loop Brain Device: 10-Year Review. *Minds and Machines*, *30*(1), 145-170. **doi.org/10.1007/s11023-020-09518-7.**

Eickhoff, S., Garcia-Agundez, A., Haidar, D., Zaidat, B., Adjei-Mosi, M., Li, P., & Eickhoff, C. (2023). A feasibility study on AI-controlled closed-loop electrical stimulation implants. *Scientific Reports*, *13*(1), 10163. **doi.org/10.1038/s41598-023-36384-x.**

[54] *oegbmt.at/fileadmin/documents/veroeffentlichungen/Dossier_2023_v5-0.pdf*.

Ernst, M., Richards, R. G., & Windolf, M. (2021). Smart implants in fracture care - only buzzword or a real opportunity? *Injury*, *52*, S101-S105. ***doi.org/10.1016/j.injury.2020.09.026.***

Goggins, E., Mitani, S., & Tanaka, S. (2022). Clinical perspectives on vagus nerve stimulation: Present and future. *Clinical Science*, *136*(9), 695-709. ***doi.org/10.1042/CS20210507.***

Horn, C. C., Ardell, J. L., & Fisher, L. E. (2019). Electroceutical Targeting of the Autonomic Nervous System. *Physiology*, *34*(2), 150-162. ***.doi.org/10.1152/physiol.00030.2018.***

Kostick-Quenet, K., Kalwani, L., Koenig, B., Torgerson, L., Sanchez, C., Munoz, K., ... Lazaro-Munoz, G. (2022). Researchers' Ethical Concerns About Using Adaptive Deep Brain Stimulation for Enhancement. *Frontiers in Human Neuroscience*, *16*, 813922. ***doi.org/10.3389/fnhum.2022.813922.***

Okun, M. S., Marjenin, T., Ekanayake, J., Gilbert, F., Doherty, S. P., Pilkington, J., ... Giordano, J. (2024). Definition of Implanted Neurological Device Abandonment: A Systematic Review and Consensus Statement. *JAMA Network Open*, *7*(4), e248654. ***doi.org/10.1001/jamanetworkopen.2024.8654***

Ottaviani, M. M., Vallone, F., Micera, S., & Recchia, F. A. (2022). Closed-Loop Vagus Nerve Stimulation for the Treatment of Cardiovascular Diseases: State of the Art and Future Directions. *Frontiers in Cardiovascular Medicine*, *9*. ***doi.org/10.3389/fcvm.2022.866957***.

Raspopovic, S., Valle, G., & Petrini, F. M. (2021). Sensory feedback for limb prostheses in amputees. *Nature Materials*, *20*(7), 925-939. ***doi.org/10.1038/s41563-021-00966-9.***

Thenaisie, Y., Palmisano, C., Canessa, A., Keulen, B. J., Capetian, P., Jiménez, M. C., ... Zutt, R. (2021). Towards adaptive deep brain stimulation: Clinical and technical notes on a novel commercial device for chronic brain sensing. *Journal of neural engineering*, *18*(4), 042002. ***doi.org/10.1088/1741-2552/ac1d5b.***

NON-MILITARY DRONE DEFENCE

© CC0 (PublicDomainPictures/pexels)

SUMMARY

The rapid development of drone technology has led to civilian applications across various fields, including research, logistics, and security. Unmanned aerial vehicles (UAVs) are also being increasingly utilised in agriculture, logistics, and leisure activities. However, they also play a crucial role in modern warfare. This proliferation raises security concerns, as drones can be misused for espionage and terrorist activities. Technologies for detecting and neutralising drones are vital for mitigating these risks. In Austria, civilian drone operations are regulated by EU directives and overseen by several government agencies. Ongoing monitoring of technological developments is essential for addressing the continually evolving challenges of UAV technology.

OVERVIEW OF THE TOPIC

Drones are developing and spreading rapidly, including in the civilian sector.

The term "drone" is commonly used to refer to remotely controlled aerial vehicles employed for military or commercial purposes. In scientific practice, the term "unmanned aerial vehicle" (UAV) has become established. In a civilian context, UAVs are utilised in research, logistics (e.g., delivery drones), agriculture, and forestry by security companies, various authorities (e.g., police and fire departments), and as a leisure activity. Commercial-off-the-shelf (COTS) UAV systems and components, in particular, have found widespread use. The available models, featuring HD/4K/8K cameras, GPS control, and a signal range of up to 9 kilometres, as well as flight times of up to 40 minutes, are offered at a price range of approximately €100 to €4,000. Commercially available drones now possess extensive autonomy capabilities; however, private individuals are not allowed to fly without maintaining visual contact unless they hold a licence. An autopilot typically ensures that the aircraft remains stable while controlling the drone's orientation, position, and speed. Additionally, autonomous systems can ensure that the UAV returns to its base or lands safely in the event of a communication failure. In the case of fully autonomous UAVs, only various parameters need to be specified for the drone to perform the task independently.

The potential for misuse of drones in the civilian sector is very high.

The increased use of UAVs will inevitably create new challenges for civil security (Del Re et al., 2024). Accidents or violations of the law involving UAVs often occur unintentionally. These incidents can typically have serious consequences. For instance, drones flying near airports have caused flight cancellations on several occasions, resulting in losses amounting to millions. Consequently, many COTS UAVs are equipped with systems that automatically detect no-fly zones and either alert the pilot or prevent the drone from entering these areas. However, such systems offer little assistance in cases of intentional misuse of UAV technologies. Since the system relies on GPS, it can be easily bypassed, such as by deactivating the UAV's GPS detection. By integrating them with other technologies, drones can also be outfitted with new harmful functionalities, resulting in a high potential for misuse. Some notable innovations by private individuals include modifying drones to collect data or arm them for offensive purposes. The firing of a handgun or a flamethrower attached to a drone has been tested. Spray cans have also been affixed to drones for large-scale advertising posters (Rassler, 2016).

Espionage

Drones are increasingly used for espionage, as various incidents have demonstrated. Video-capable UAVs can spy on critical infrastructure, individuals, or organisations, exploiting the captured images and video material for private, commercial, or strategic purposes. In addition to cameras, UAVs may be equipped with other advanced sensors that capture sensitive information, such as telecommunications data. In recent years, military facilities and company premises in Germany have been spied on several times by drones, the exact extent of which is unknown.[1] Other incidents illustrate the potential use of drones for terrorist purposes. In 2018, Greenpeace crashed two UAVs into a French nuclear power plant to demonstrate the vulnerability of such facilities to terrorist attacks. In 2015, a small UAV dropped a package of radioactive sand on the roof of the Japanese Prime Minister's office to protest against the Japanese government's nuclear energy policy (Friese et al., 2016). *Experts anticipate a substantial rise in such threats*

1 *correctiv.org/hybride-kriegsfuehrung/2025/02/18/spionage-drohnen-ueber-deutschland*.

(Rassler & Veilleux-Lepage, 2024). The potential for decentralised manufacturing, such as 3D printing, along with the capacity to produce and repair UAVs on-site, may further enhance the availability and efficiency of UAVs for malicious actors. Another risk is the recombination of UAVs with other emerging technologies. Drones could also be employed for high-tech innovations in the future. Technologies such as facial recognition, LLM/AI, autonomy/robotics, nano-explosives, energy weapons, improved computing power, and data mining amplify the potential for previously unknown applications (Rassler, 2016; Rassler & Veilleux-Lepage, 2024).

Anti-drone systems require modern detection systems.

The rapid development of drone technology has transformed effective drone defence into a technological race. On the one hand, anti-drone systems require modern detection systems that can identify drones swiftly before they pose a threat. On the other hand, identified drones must then be neutralised using appropriate methods. Detection systems utilise various sensors, including radar, optical sensors, infrared sensors, acoustic detectors, and radio frequency analysis (Park et al., 2021). Detecting small drones places particularly high demands on sensor technology. Millimetre-wave radar is well-suited for detecting very small drones at long ranges distances.[2] The analysis of frequency bands (e.g., Wi-Fi, Bluetooth) or radio frequencies used by drones for communication is also employed. Other systems process video or thermal images to detect moving objects in the air, using software to recognise suspicious movement patterns. Detection systems must operate in real-time, particularly in high-security environments, to respond to threats before they escalate into danger. Modern systems utilise AI-driven algorithms to detect threats and make more efficient decisions.

Hard or soft, high-tech or low-tech measures:

- High-energy lasers

- Networks

- kamikaze drones

- projectiles

- Jamming

- Takeover of communication

In drone neutralisation, a distinction is made between soft measures, where the drone is forced to land, and hard measures, where the drone is physically intercepted or shot down. The latter include both high-tech and low-tech solutions (Park et al., 2021). The most advanced technologies include micro-missile-equipped anti-drone drones[3] and Directed Energy Weapons (DEWs). High-energy lasers (HELs) stand out as a particularly cost-effective solution that can turn off drones through focused beam heating at a cost of approximately one U.S. dollar per shot. Simpler interception solutions include nets, the use of kamikaze drones, and various projectile-based measures. In terms of soft measures, several sophisticated electronic solutions have been developed to prevent unauthorised drone use. These are grouped under the heading of "jamming". High-power microwaves (HPM), which generate electromagnetic pulses, are specifically designed to disrupt drone electronics and are proving particularly effective against coordinated drone swarm attacks. Radiofrequency (RF) jammers emit targeted RF energy to disrupt communication links between drones and their controllers, while GPS spoofing technologies send false navigation signals to mislead drone guidance systems. Perhaps most impressively, cyber-hijacking systems have been developed that allow authorities to gain complete control of UAVs by targeting their communication infrastructure.

---

2 *fhr.fraunhofer.de/en/areas/industrial-high-frequency-systems-IHS/small-drone-detection-with-millimeter-wave-radar.html.*

3 *derstandard.at/adblockwall/story/3000000263216/airbus-introduces-an-european-anti-drone-drone-with-micro-missiles?ref=niewidget*.

Defence of non-military drones as commercially successful market

In non-military defence against drones, soft measures are generally preferred over hard ones to avoid collateral damage from crashing drones. The question of which systems are best suited is, at the very least, a question of cost. Military applications of drone defence systems have incorporated several advanced features that often render them too sophisticated and costly for civilian use. The commercial market for drone defence solutions has experienced remarkable growth, and several companies, including those based in Austria, offer defence systems for the civilian sector. At the Austrian Formula 1 Grand Prix, for example, the AARTOS drone detection system was employed to protect spectators, drivers, and crews from the unauthorised use of drones.[4] The system, operated from a mobile unit, successfully detected and controlled unauthorised drones. To ensure the safety of approximately 250,000 spectators at the Airpower24 air show in Zeltweg, the Austrian Armed Forces implemented drone defence strategies in collaboration with AARONIA Austria.

The following must be clarified. difficult legal and organisational questions

How security authorities should address the increasing number of unidentified drones of unclear origin flying over critical infrastructure and military facilities is, at the very least, a challenging organisational and legal question. Whether private individuals are allowed to shoot down drones is not finally regulated and depends, for example, on whether personal rights are violated and whether the means used are proportionate.[5] In Austria, on the other hand, only security authorities are permitted to set up jamming transmitters.[6] In 2023, the EU Commission presented a comprehensive strategy to counter potential threats from civilian drones to ensure that rapid technological developments and the growing number of drones do not lead to an uncontrolled increase in threats in civilian areas.[7] The specific responsibilities for protecting facilities and the population, as well as dealing with decision-making dilemmas (e.g., accepting collateral damage from unidentified drones), must be regulated at the national level.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Handling drones in airspace regulated by EU law - special national regulations are possible

The number of privately and commercially used drones in Austria is increasing rapidly; by 2023, over 70,000 drone operator licences have already been issued. According to the EU Drone Regulation, member states can establish no-fly zones, such as those surrounding airports or military facilities. Responsibility for the defence and control of drones in Austria is divided among several government agencies. At an operational level, *Austro Control GmbH* is the primary subordinate civil aviation authority in Austria, responsible for ensuring safety and security in civil aviation, as well as implementing regulations related to unmanned aerial vehicles

4 *drone-detection-system.com/news/austrian-grand-prix-aaronias-high-speed-drone-detection-system-aartos-supports-security-teams-during-formula-1-weekend-in-spielberg/*.
5 *wienrecht.at/?view=article&id=430:darf-man-drohnen-abschiessen&catid=15*.
6 *industriemagazin.at/fuehren/industriespionage-ist-die-drohnenabwehr-rechtlich-gedeckt/*.
7 *eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52023DC0659*.

(UAVs), commonly referred to as drones. When incidents occur, they must first be reported to Austro Control's Search and Rescue Centre, which then forwards these reports to the Safety Investigation Board (SUB). The SUB, tasked with investigating drone-related incidents, assesses each case and determines whether a full investigation is necessary. The practical implementation of drone defence, particularly in urban areas and at public events, rests with security authorities, such as federal or state police and, in some instances, the Directorate for State Security and Intelligence (DSN). However, the conditions under which private individuals or companies may also combat drones and the methods they may employ are not clearly regulated by law.

PROPOSAL FOR FURTHER ACTION

Given the ongoing development of drone technology and its potential for misuse, organisations with security responsibilities cannot afford to overlook the need for permanent technology monitoring. Furthermore, organisational responsibilities, regulations, and guidelines for drone detection and defence must be clearly defined, consistently developed, and ultimately enforced. From today's viewpoint, it remains uncertain which high-tech or low-tech innovations may pose a threat to civil security through the recombination of various technologies. Above all, the creativity involved in the permanent search for a technical advantage in warfare, as can currently be observed in Ukraine, heightens the likelihood of unwanted drone functionalities becoming available and deployable in the near future. A Technology Assessment-study could explore the risks associated with the misuse of advancements in drone technology and chart the available defence technologies, highlighting their advantages and disadvantages. Cost considerations and the specific challenges of the situation in Austria should also be identified.

To protect the population, the development of drone technology must be continuously monitored and evaluated.

REFERENCES

Del Re, A., et al (eds.) (2024). *Unmanned aerial systems: Civil drones at the intersection of economics, law, security and social acceptance*. Wiesbaden: Springer Fachmedien Wiesbaden. **doi.org/10.1007/978-3-658-43719-0.**

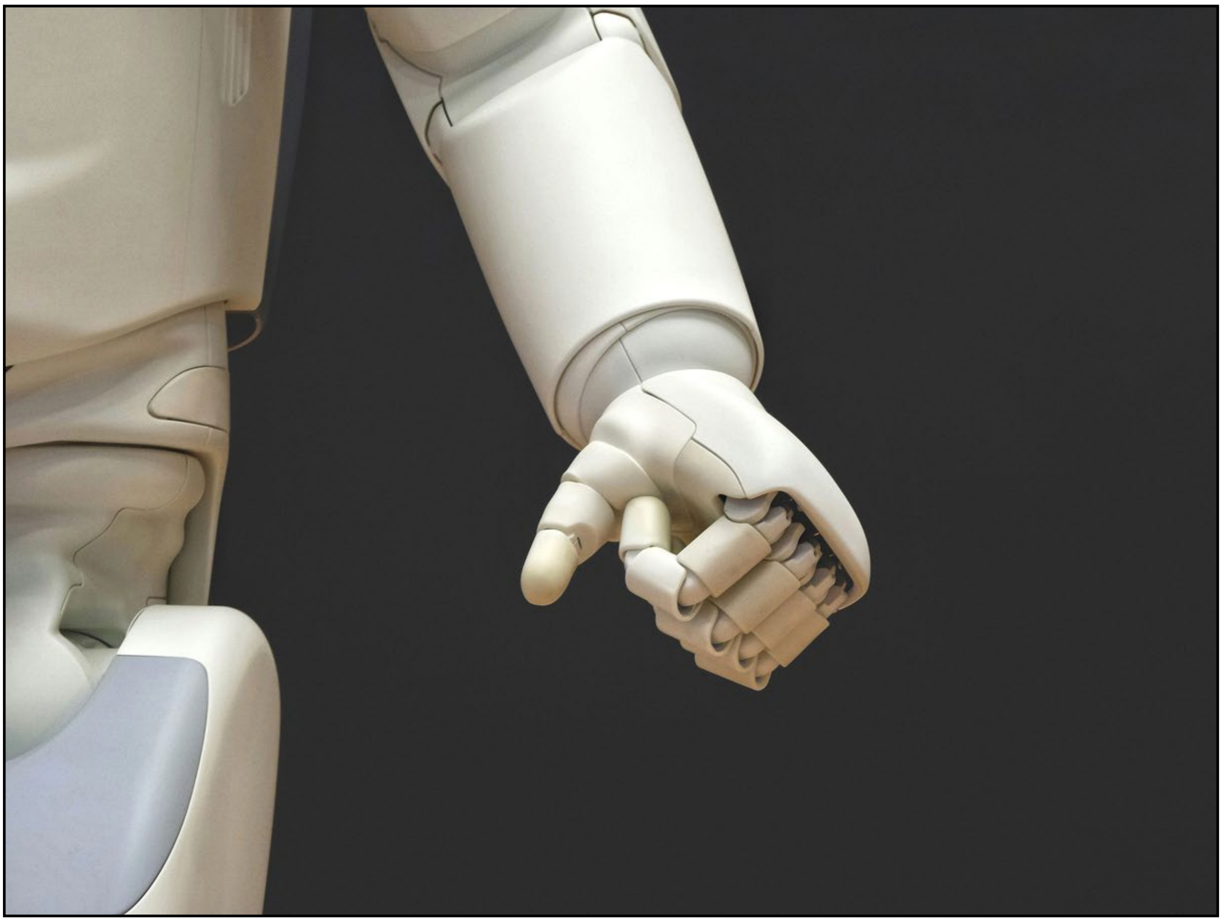
Friese, L., Jenzen-Jones, N. R., & Smallwood, M. (2016). *Emerging unmanned threats: The use of commercially-available UAVs by armed non-state actors*.

Park, S., et al. (2021). Survey on Anti-Drone Systems: Components, Designs, and Challenges. *IEEE Access*, *9*, 42635-59. **doi.org/10.1109/ACCESS.2021.3065926.**

Rassler, D. (2016). *Remotely Piloted Innovation: Terrorism, Drones and Supportive Technology*. West Point: Combating Terrorism Center. ***govinfo.gov/content/pkg/ GOVPUB-D109-PURL-gpo182659/pdf/GOVPUB-D109-PURL-gpo182659.pdf.***

Rassler, D., & Veilleux-Lepage, Y. (2024). The paradox of progress: How 'disruptive,' 'dual-use,' 'democratised,' and 'diffused' technologies shape terrorist innovation. *TATuP - Journal for Technology Assessment in Theory and Practice*, *33*(2), 22-28. **doi.org/10.14512/tatup.33.2.22.**

HUMANOID ROBOTS



© CC0 (Possessed Photography/unsplash)

SUMMARY

Until now, humanoid robot applications have primarily held a prominent position in science fiction but have yet to establish a significant market presence. However, they could now be on the brink of a breakthrough. This is partly due to advancements in artificial intelligence, specifically through multimodal language models that can process image data, voice data, and sensor data. Despite ongoing challenges in development and production, humanoid robots possess considerable potential for use in various areas of human life, including military operations, industry, rescue missions, healthcare, education, personal assistance, entertainment, and agriculture. The increasing utilisation of humanoid robots raises legal and ethical questions regarding liability, data protection, and potential job displacement.

OVERVIEW OF THE TOPIC

Humanoid automata - an old dream

Human-like robots are commonly referred to as humanoid or android robots, depending on how closely they resemble actual humans. Humanoid robots typically resemble humans, although they have a mechanical appearance, often featuring a head, torso, arms, and sometimes legs. *Android* robots, on the other hand, attempt to replicate human appearance as realistically as possible, for example, with silicone skin, clothing, wigs, or highly realistic details such as eyelashes (Mara, 2022). Humanoid robots, designed to resemble the human form, have been under development for many years. These robots are particularly suitable for interacting with people and performing tasks in everyday environments. However, the dream of a "humanoid automaton" is an ancient concept already present in Greek and Chinese mythology; Leonardo da Vinci constructed a similar automaton in the 15th century.

Humanoids vs. androids

Overall, the development of humanoid robots over the last 50 years can be categorised into three phases. Following the challenges of bipedal gait in the 1970s, walking robots with limited intelligence emerged in the early 2000s. Finally, from 2010 to the present, humanoid robots exhibiting greater intelligence have been developed (Tong, 2024). Significant progress has been made in the locomotion of bipedal robots across various environments, demonstrating their flexibility and adaptability. The development and control of humanoid robots have become a major focus of research, resulting in rapid advancements in motion planning, visual performance, and behaviour control through the utilisation of learning algorithms (Tong, 2024).

Wide range of applications

Humanoid robots offer considerable potential for use in various areas of human life, including military operations, industry, rescue operations, healthcare, education, personal assistance, entertainment, and agriculture (Tong, 2024). For example, they could assist elderly individuals with daily tasks, offer quasi-social interaction, and support both cognitive and physical training. Humanoid service robots for warehouse and logistics work are already available for sale or rent to large companies.[1] Tests are also underway for initial applications in the automotive industry[2] and on oil rigs. More communication-oriented models are being offered for hospitals, educational institutions and the catering sector, for example.[3] Humanoid robot policemen are already being used to support the Chinese police in simple tasks. Furthermore, once they are sufficiently developed, humanoid robots could transform military conflicts by replacing or supplementing human personnel on the battlefield.[4]

Dual-use

1 *agilityrobotics.com*;*apptronik.com/apollo* .
2 *vdi-nachrichten.com/technik/automation/humanoids-robot-boston-dynamics-shows-first-application-in-car-manufacturing/*.
3 *probo-robotics.at.*
4 *uscc.gov/sites/default/files/2024-10/Humanoid_Robots.pdf*.

Several leading robotics companies have unveiled advanced humanoid prototypes, including Figure 01 from Figure AI, Apollo from Apptronik, Atlas from Boston Dynamics, Digit from Agility Robotics, Optimus from Tesla, G1 from Unitree, Walker S from UBTech, and GR-1 from Fourier Intelligence. These robots currently demonstrate skills such as sorting objects, cleaning, lifting boxes, and walking, with some being capable of interacting with humans. However, they typically perform these relatively simple tasks at a slower pace than the average human (USCC, 2024). Challenges such as slow reaction times and technical errors remain significant barriers (Andtfolk, 2022).

Several providers on the market

Over the past decade, significant breakthroughs in deep learning, particularly in large language models (LLMs) and large multimodal models (LMMs), have led to major advances in humanoid robotics, enabling new achievements across various fields. In conjunction with advancements in sensor technology, the communication, decision-making, and autonomy capabilities of robots are primed for a substantial leap forward. The integration of generative AI into humanoid robotics is often viewed as the beginning of a new era, referred to as "humanoid AI robots" or "embodied AI" (Cao, 2024). This dynamic is evident, for instance, in NVIDIA's development of a comprehensive AI platform for leading firms in the field of humanoid robotics. In contrast, another major AI platform, Huggingface, has acquired the manufacturer of an open-source humanoid.[5]

Humanoid AI as the new era of robotics

Alongside autonomous robots, research is also being conducted into remote-controlled humanoid robots, although these two control methods are not mutually exclusive. Remote control allows for the integration of human cognitive skills and expertise with the physical capabilities of the robot. However, the complexity of robots presents a challenge for remote control, particularly in unpredictable and dynamic environments with limited communication (Darvish, 2023).

Autonomous and remote-controlled humanoids

According to estimates by Goldman Sachs, the global market for humanoid robots is expected to grow from the current $1-2 billion to $38 billion by 2035. Much of the hardware required for humanoid robots is either already available or about to be launched on the market. Key components, such as cameras, motors, sensors, gears, and batteries, are largely ready for commercial use.[6] The cost of manufacturing humanoid robots has fallen significantly. While estimates from 2023 still amounted to $50,000 for simple models and $250,000 for advanced versions, Goldman Sachs currently estimates the cost to be between $30,000 and $150,000 per unit. Such optimistic forecasts assume that, in addition to being used for dirty, dangerous and boring jobs (such as handling toxic waste), humanoid robots could become the next "must-have" for consumers to perform a variety of household tasks. Some companies have announced that they will soon conduct at-home tests.[7] However, this market promise has been around since at least the 1960s and has been widely discussed in science fiction for many years.

High market expectations

Japan, the USA, and China are leading nations in humanoid robotics research. Key institutions include the University of Tokyo, Waseda University, and Osaka University in Japan; the Beijing Institute of Technology and Tsinghua University in

China invests to break American and Japanese dominance.

5 *humanoidroboticstechnology.com/news/hugging-face-announces-acquisition-of-pollen-robotics/*.

6 *goldmansachs.com/insights/articles/the-global-market-for-robots-could-reach-38-billion-by-2035*.

7 *heise.de/news/Figure-AI-Erste-Tests-fuer-humanoide-Roboter-im-Haushalt-noch-2025-10299391.html*.

China; and the Massachusetts Institute of Technology (MIT) in the United States. Other countries, such as Italy, Germany, France, the UK, and South Korea, have also made significant contributions to this field (Tong, 2024). Humanoid robots are also regarded as a symbol of a nation's technological strength and innovation, similar to space technologies. In the United States and China, the commercialisation of humanoid robots is advancing at a rapid pace. Key technologies are currently concentrated in a small number of companies that specialise in developing sensors and actuators, as well as advanced hardware such as graphics processors and associated AI models. China is fostering innovation and introducing it to the domestic robotics market to decrease its reliance on technologies dominated by the US and other non-Chinese firms (USCC, 2024).

The development of highly intelligent humanoid robots remains a challenge.

The development of highly intelligent and adaptable humanoid robots remains a major challenge. Currently, few humanoid robots utilise large language models (LLMs) or generative AI. This gap reveals considerable untapped potential but also highlights the existing challenges in the realm of humanoid AI (Cao, 2024). To fully harness the potential capabilities of humanoid robots, further advancements in both hardware and software are required (Tong, 2024). Challenges include persistently high development and maintenance costs, significant energy consumption, effective human-machine collaboration, access to high-precision components, precise control and coordination, and limited environmental perception.[8]

Human-like robots seem scary: Uncanny Valley

The well-known uncanny valley hypothesis, also known as the acceptance gap, posits that an increasing similarity of artificial figures to humans does not necessarily correspond to greater sympathy. Initially, sympathy rises as the human resemblance increases; however, if the resemblance is very high yet imperfect, characters tend to be rejected and perceived as uncanny. This break in sympathy is also referred to as the acceptance gap (Mara, 2022). It is also crucial to emphasise the significance of comprehensive testing phases and stringent safety checks before robots are deployed among humans.[9]

Gendering of humanoid/ android robots reinforces stereotypes

A meta-study indicates that scientific understanding of the impact of assigning gender-specific characteristics to robots is limited. It remains unclear whether this practice is beneficial or detrimental regarding design. The manipulation of human gender perception in robots occurs through voice, names and pronouns, facial features, clothing and colours, hairstyles, and body shapes. While it has a minimal overall effect on likability or acceptance, it considerably reinforces stereotyping in human-robot interactions (Perugia, 2023). For example, it can be observed that female-gendered robots are preferred for service activities, which raises a question from a feminist perspective as to whether users' preferences for female service robots should be supported, even if they stem from a discriminatory understanding of a gender-specific society. A similar dynamic can be observed with children, who tend to prefer "female" robots less when they exhibit emotions such as anger. It was also shown that men were significantly more accepting of rejecting behaviour in male-read robots than in female-read robots. Overall, this suggests that female-read robots, like females, are less liked when they fail to behave in a compliant or approving manner (Perugia, 2023).

8 *topbots.com/humanoid-robots-overview-2024*.
9 *heise.de/news/malfunction-humanoid-robot-schlaegt-bei-tests-um-sich-10374306.html*.

Ultimately, the future development of humanoid robots will depend on market demand and the ability to meet practical needs. When integrating robotics and AI into companies, managers should prioritise the psychological and social well-being of employees. Generative AI has the potential to enhance human-machine communication in this context. A human-centred approach, an ethical orientation, employee training, and respect for human rights are essential for the responsible implementation of initiatives (Obrenovic, 2025).

Future development also comes from an ethical perspective.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Research into humanoid robots is being conducted at several universities in Austria, including the Vienna University of Technology and JKU Linz, with a focus on the psychology of robots.[10] Suppliers of components for humanoid robotics are also based in Austria.[11] It is predicted that the robotics market in Austria will experience annual sales growth of 7% and a total volume exceeding €600 million by 2029.[12] Service robotics, which typically includes humanoid robots, is anticipated to contribute around two-thirds of the total. Once the technology advances and becomes affordable enough, humanoid robots could significantly impact various industries by addressing labour shortages and reducing costs. Conversely, they might also adversely affect the labour market by replacing tasks and, consequently, jobs. Currently, humanoid robots exert no direct influence on labour productivity. Instead, their impact is indirect, occurring through the creation of entirely new work processes and the adaptation or continuation of existing ones. (Del Giudice, 2023). Initial application tests involving humanoid robots are currently taking place at the libraries of the City of Vienna, for instance. The increasing utilisation of humanoid robots raises legal and ethical concerns regarding liability, data protection, job displacement, and safety issues. Responsible development, in alignment with societal values, is crucial for the widespread acceptance and success of humanoid robots. The formulation of appropriate regulations necessitates collaboration between representatives from technology, ethics, and political decision-makers.

Economic factor, labour market, military

Significant legal and ethical issues

PROPOSAL FOR FURTHER ACTION

A study on this topic could, on the one hand, continue the analysis of development and market opportunities initiated here and, on the other hand, examine the literature on the effects on society, law, and the economy. The study could be based on the following key questions: In which everyday areas of application is it expected to spread? What are the opportunities and risks (legal, ethical)? What is the current state of regulation? Are the existing regulations sufficient (e.g., about liability)?

TA study on the prospects and effects of humanoid robotics

10 *jku.at/lit-robopsychology-lab/*.

11 *schaeffler.com/en/news_media/press_releases/press_releases_detail.jsp?id=88086784.*

12 *de.statista.com/outlook/tmo/robotik/oesterreich*.

REFERENCES

Andtfolk, M., et al. (2022). Humanoid robots in the care of older persons: A scoping review. *Assistive Technology, 34*(5), 518-526, **doi.org/10.1080/10400435.2021.1880493.**

Cao, L. (2024). AI robots and humanoid ai: Review, perspectives and directions. *arXiv preprint arXiv:2405.15775*.

Darvish, K., et al. (2023). Teleoperation of Humanoid Robots: A Survey. *IEEE Transactions on Robotics, 39*(3), 1706-1727.

Del Giudice, M., et al. (2023). Humanoid robot adoption and labour productivity: a perspective on ambidextrous product innovation routines. In *Artificial Intelligence and International HRM* (pp. 33-59): Routledge.

Mara, M., et al. (2022). *Human-Like Robots and the Uncanny Valley: A Meta-Analysis of User Responses Based on the Godspeed Scales* (Vol. 230): Hogrefe Publishing, **doi.org/10.1027/2151-2604/a000486.**

Obrenovic, B., et al. (2025). Generative AI and human-robot interaction: implications and future agenda for business, society and ethics. *AI & SOCIETY, 40*(2), 677-690, **doi.org/10.1007/s00146-024-01889-0.**

Perugia, G., & Lisy, D. (2023). Robot's Gendering Trouble: A Scoping Review of Gendering Humanoid Robots and Its Effects on HRI. *International Journal of Social Robotics, 15*(11), 1725-1753, **doi.org/10.1007/s12369-023-01061-6** .

Tong, Y., et al. (2024). Advancements in Humanoid Robots: A Comprehensive Review and Future Prospects. *IEEE/CAA J. Automatica Sinica, 11*(2), 301-328.

USCC (U.S.-China Economic and Security Review Commission). (2024). *Humanoid Robots*, **uscc.gov/research/humanoid-robots.**

AI AGENTS

© CC0 (Mohamed Mohassi/unsplash)

SUMMARY

AI agents take generative AI from "talking to doing"

AI agents build upon recent developments in generative AI, focusing on performing actions in the digital or physical world rather than generating content. Through contextual understanding, the use of tools, and the ability to plan, AI agents can tackle complex tasks and pursue goals without close human supervision. In advanced deployment scenarios, multiple specialised AI agents collaborate effectively. However, from the technological foundation of large language models, AI agents also inherit their disadvantages, such as unreliability and a lack of reasoning skills. In many of the advertised scenarios, such as automatic vacation planning and booking, there are specific concerns regarding liability and the safeguarding of highly sensitive data.

OVERVIEW OF THE TOPIC

AI agents are the latest developments in generative AI

In the field of artificial intelligence (AI), there are currently new developments arising under the term AI agents that build on the success of generative AI, which underlies large language models such as ChatGPT. While generative AI originally focused primarily on generating content, such as text, images, sound, and video, the next step is being taken with AI agents: agents are intended to take AI "from talking to doing," so to speak. Although there is no uniform definition of AI agents, there is general agreement that they can, to some extent, take actions and pursue goals independently. This can happen in virtual space (see ***Intelligent Social Agents***) or in physical space (see also ***Cobots*** and ***Humanoid Robots***). Therefore, while chatbots can explain how users can complete tasks (but these ultimately have to be carried out by humans), AI agents should take action themselves and, for instance, make purchases, search the internet for information, or arrange appointments.

Setting actions instead of producing content

Tools allow AI agents to interact with the environment

A central component of AI agents is the use of extensions, commonly referred to as tools (Kelbert et al., 2024). While large language models in their pure form can only access the information available during training, tools enable them to overcome this limitation. A relatively straightforward tool is access to an Internet search, for example, to obtain up-to-date information that could not have been included during training. Similarly, tools that allow language models to access company data and documents function in a comparable manner.

Automated use of computers and web browsers

Last year, various AI agents capable of operating a computer or, at the very least, a web browser entered the market. These systems enable the automation of work steps that previously required programming skills and often involved access to programming interfaces. The ability to navigate the internet and fill out forms, for example, allows such AI agents to make hotel and flight bookings, order products, and perform similar tasks that were once reserved for human users.

AI agents for solving complex problems

If several tools are combined, AI agents promise to automate tasks as complex as booking an entire holiday—under favourable conditions, at a convenient time (through calendar access), and with accommodations that match personal preferences (Heikkilä, 2025). Another use case is automated research on the internet, as well as in some scientific databases, known as deep research. Agents will also increasingly take on programming tasks independently in software development. According to rumours, OpenAI is planning an AI agent that will be able to conduct extensive research, data analysis, and more — at “PhD-level” (Edwards 2025). However, part of the rumour is also that this AI agent will cost USD 20,000 per month.

Understanding the context is essential

The successful realisation of AI agents, however, demands several prerequisites: on the one hand, the AI agent must be taught what its "environment" is and how it can be accessed. This means that "it" must know which tools are available and what purpose they serve—in other words, it must understand the context in which it is operating. To organise an appointment, for example, the AI must "know" whether and how it can access the user's calendar and when it is appropriate to do so. For this purpose, Anthropic introduced the Model Context Protocol (MCP) in November 2024, which enables the company's AIs to have standardised access to various data sources, including databases, files, and even Google Drive.

Planning is required to achieve a defined goal

To pursue a goal independently, AI agents must also be capable of developing, implementing, and, if necessary, adapting a plan (Wang et al., 2025). Only then is it possible to provide the AI agent with a relatively vague goal without prescribing the exact execution step by step. If this capability is achieved, AI agents promise to be a genuine relief for many tasks.

Collaboration of several AI agents to achieve complex goals

However, planning AI agents with access to context through tools is merely the first step in current developments. The subsequent step involves enabling AI agents to collaborate. Individual AI agents can be customised for specialised tasks, yet they can also work together to tackle more complex tasks in dynamic environments. A beneficial outcome of these collaborations is that individual AI agents can be highly specialised, thereby increasing their efficiency. Here, too, various efforts are presently underway to standardise these interactions, for instance, through the A2A protocol presented by Google in April 2025.[1] Important aspects of this protocol include coordinating agents with one another and ensuring the secure exchange of information. The A2A protocol facilitates interaction with various technologies, such as databases and SAP, as well as platforms (e.g., PayPal), and is supported by multiple service providers, including Deloitte and Accenture. This should also allow AI agents to collaborate across company boundaries.

Control of machines and robots

Another direction in the development of AI agents is the influence of robots on the physical world. Microsoft, for instance, has developed the AI model Magma, which can control both computer programmes and robotic arms (Yang et al. 2025).

Generative AI gives new impetus to old AI topics.

In principle, the planning, the interaction of several agents (in the form of so-called multi-agent systems), and the control of machines are not new topics in AI research. However, large language models provide a new technological foundation for this, and the current high level of interest is granting these efforts a significant financial boost.

Large action models for learning behaviour instead of text

A further development of large language models relevant to AI agents is the so-called large action model. While large language models specialise in understanding and generating text (by predicting which words will come next based on previous parts of the text), large action models are trained to perform specific actions. This means that they are specifically trained to execute actions in both digital and physical spaces. For example, they learn which elements in a programme are clickable and which steps lead to the desired result, such as transferring data to an Excel spreadsheet (Wang et al., 2025). Just as large language models require a large amount of text data, large action models demand extensive datasets that encompass information about user intentions (to understand goals better), context, and desired actions. They often require some form of memory and a method for users to provide feedback (Wang et al., 2025).

Greater usefulness raises new questions.

Overall, AI agents promise to make generative AI significantly more useful and have the potential to fully automate routine tasks. At the same time, the claim to perform actions as independently as possible raises some questions.

Logic is not a strength of generative AI

Lack of reliability of generative AI as a challenge

Firstly, the new AI agents are also based on the technology of large language models. These have the *fundamental problem of so-called "hallucinations*", which have been reduced in recent years but have still not been fundamentally overcome. Planning over several steps, in particular, requires logical thinking—a not exactly a strength of generative AI (Petrov et al., 2025). Recently popularised "thinking" models (utilising so-called chain-of-thought approaches) also appear to operate "as if". These models "think" ahead to provide users with answers that recognise and correct contradictions on their own. However, researchers have

[1] *developers.googleblog.com/en/a2a-a-new-era-of-agent-interoperability/.*

shown that the thinking steps leading up to an answer are often inconsistent with the answer.[2] This unreliability can lead to more immediate problems for AI agents who wish to take action in virtual or even physical reality, in contrast to chatbots, for instance. If AI agents also operate robots, poor reliability can result in property damage and personal injury.

Access to sensitive data harbours risks

Secondly, the issue of privacy and data security becomes particularly significant in use cases such as automatic bookings, appointment scheduling, and payments. Access to highly personal and sensitive information, including address books, appointment calendars, emails, and payment details, is often necessary for the effective use of these applications. If this data falls into the wrong hands, it can result in considerable harm. Nonetheless, there have already been efforts to minimise this risk. By running AI (and therefore processing data) on the user's device (such as a smartphone or laptop) or company infrastructure, it is increasingly feasible to ensure that data remains on the device or within the company. This development is also known as edge AI or AI on devices and is facilitated by specialised AI computing units present in many modern devices.

Edge AI and AI on Devices as progress for data security

Questionable control over incentives for AI

A third risk involves managing the incentives of AI agents: How can users genuinely trust that an AI agent will, for instance, book the cheapest flight as instructed or promised rather than opting for a company with which the AI provider has business connections?

AI agents raise liability issues

Ultimately, the question of liability arises: Who is liable for the damage if, for example, a payment was made via an AI agent that the user did not intend to use? Which contracts can be legally concluded via an AI agent?

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

High development momentum with relevance for Austria as a technology recipient

AI agents, as a further development of generative AI, are highly dynamic. At the same time, they raise several questions, particularly regarding regulation. For example, it is not entirely clear which legal norms apply to AI agents. They represent a form of artificial intelligence within the meaning of the EU's AI Act. In terms of risk classification, however, they presumably do not fall under the category of high-risk AI—at least not in general (Bostoen & Krämer, 2024). Depending on the design of the AI agents, however, they could fall under prohibited AI practices, for instance, if they exploit the circumstances of vulnerable persons or groups (Art. 5(b) AI Act).

AI Act: consider vulnerable people

Virtual assistants regulated by the Digital Markets Act

The EU Digital Markets Act (DMA) explicitly defines "virtual assistants" as a central platform service, namely as "software that can process orders, tasks or questions, including based on audio, visual, written, gestural or motion input, and that enables access to other services or controls connected physical devices based on those orders, tasks or questions" (Art. 2(12) DMA). This suggests that AI agents are subject to the same regulations as search engines and online marketplaces. Although the DMA was not developed with today's AI agents and their capabilities in mind, focusing instead on voice assistants such as Siri or Alexa, which have comparatively limited capacities, it at least establishes a foundation for potentially

---

[2] *anthropic.com/research/reasoning-models-dont-say-think*; see also: *nytimes.com/2025/05/05/technology/ai-hallucinations-chatgpt-google.html*.

regulating AI agent providers as gatekeepers, provided they possess the appropriate market power.

A key question remains whether users are adequately protected from malfunctions of AI agents under the current legal framework and whether the issue of liability for AI agents should be addressed through new legal acts. In the event of malfunctions, which may also arise from misinterpretation of user requests, potentially significant damage can be inflicted upon individuals, as previously mentioned. However, companies also face the question of whether contracts concluded by AI agents are legally binding. Therefore, there is a need for clarification in this regard.

High damage potential for individuals and companies

The ongoing high level of dynamism in the field of AI sometimes makes it challenging to maintain a well-founded understanding of current developments. Particularly in the areas of liability and consumer protection, it is essential to quickly create a comprehensive overview and identify potential options for action. If no new legal standards are necessary, clear recommendations and guidelines from the AI Service Desk (KI-Servicestelle)—specifically for companies, AI providers, and consumers—are advisable as a minimum.

High dynamics raise questions about regulation.

Action by the AI Service Center indicated

PROPOSAL FOR FURTHER ACTION

In light of this context, continuous monitoring of developments in the field of AI agents and AI in general would be advisable. A first step in this direction would involve a comprehensive study that explores the development options and questions raised in this text in greater depth while also potentially establishing a monitoring process for technical and legal issues.

REFERENCES

Bostoen, F., & Krämer, J. (2024). *AI Agents and Ecosystems Contestability*. Centre on Regulation in Europe.

Edwards, B. (2025, March 7). *What does "PhD-level" AI mean? OpenAI's rumored $20,000 agent plan explained*. Ars Technica. **arstechnica.com/ai/2025/03/what-does-phd-level-ai-mean-openais-rumored-20000-agent-plan-explained/.**

Heikkilä, M. (2025, February 12). *Sam Altman predicts: AI agents could make your everyday life easier - but how exactly?* **t3n.de/news/sam-altman-ki-agenten-alltag-erleichtern-aber-wie-1644963/.**

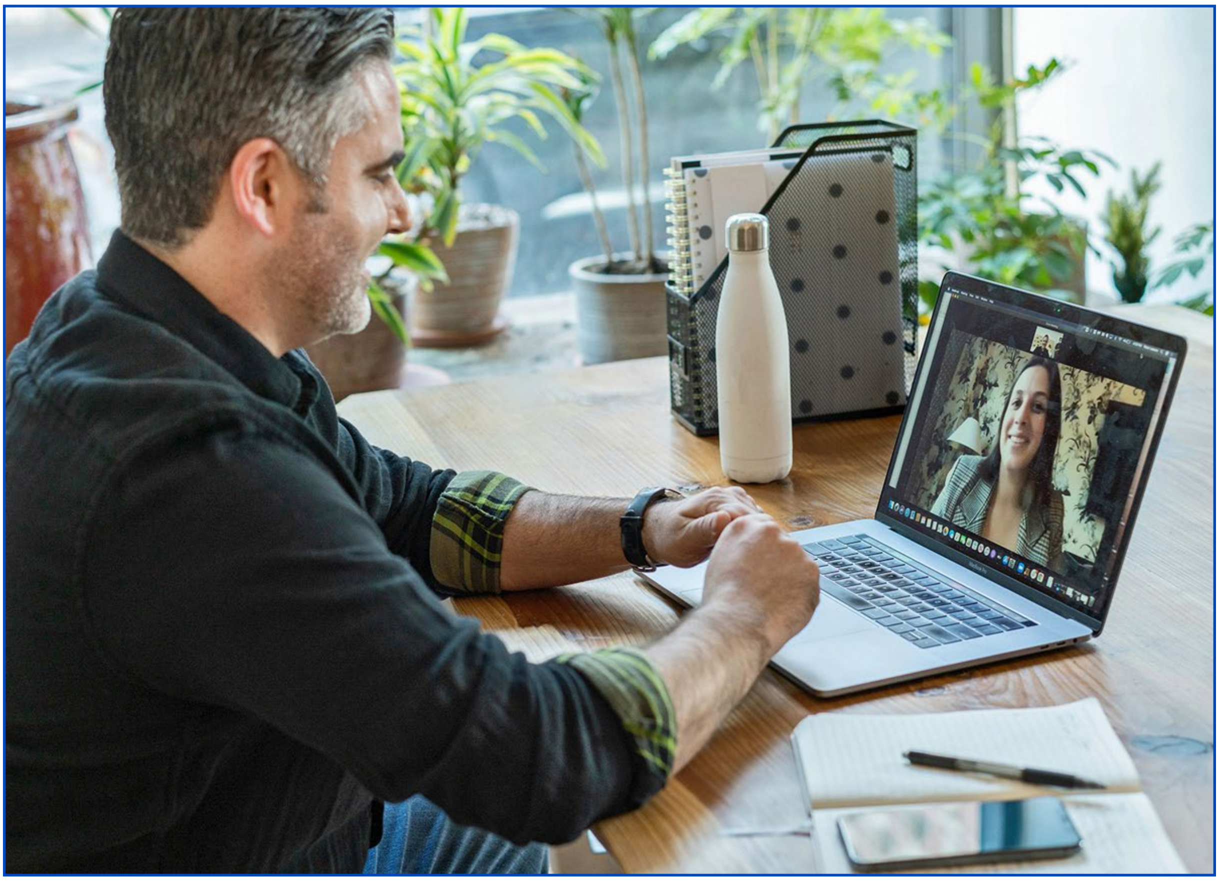
Kelbert, P., Siebert, J., & Jöckel, L. (2024, March 19). *Large action models (LAMs), tool learning, function calling and Agents*. Blog of Fraunhofer IESE. **fraunhofer.de/blog/large-action-models-multi-agents/.**

Petrov, I., et al. (2025). *Proof or Bluff? Evaluating LLMs on 2025 USA Math Olympiad* (arXiv:2503.21934). arXiv. **doi.org/10.48550/arXiv.2503.21934.**

Wang, L., et al. (2025). *Large Action Models: From Inception to Implementation* (arXiv:2412.10047). arXiv. **doi.org/10.48550/arXiv.2412.10047.**

Yang, J., et al. (2025). *Magma: A Foundation Model for Multimodal AI Agents* (arXiv:2502.13130). arXiv. **doi.org/10.48550/arXiv.2502.13130.**

SOCIAL IMPLICATIONS OF HYBRID WORK



© CC0 (Ana Achim/unsplash)

SUMMARY

Home office still widespread, open questions remain

During the COVID-19 pandemic, there was a sudden and sharp increase in the use of home office to avoid contracting infections. Current studies indicate that the frequency of working from home has decreased since the end of the pandemic but remains above pre-pandemic levels. In addition to working from home, the term 'hybrid working' also encompasses mobile working. Depending on its specific form, hybrid working offers advantages on individual (time savings, work-life balance) and social levels (reduction in traffic, attractiveness of peripheral regions), but disadvantages remain: on an individual level, risks such as constant accessibility, ergonomics, and high productivity pressure arise. At a societal level, the possibility of hybrid work is unevenly distributed, depending on the sector and role within the company, and reliance on non-European technology companies may increase.

OVERVIEW OF THE TOPIC

Working from home has become significantly more common since the coronavirus pandemic

During the COVID-19 pandemic, there was a sharp rise in remote work to avoid contracting the virus at the workplace and on public transport. Since the end of the pandemic, the prevalence of this work arrangement has declined significantly; however, it remains more widespread than before the pandemic. In some regions, a notable countermovement appears to be underway. For instance, some of the largest publicly listed companies in the US have implemented a "return-to-office policy" - with no measurable impact on company performance (Bath & Brauchle, 2025)

A study by the German TAB

To assess the social consequences of hybrid work, the Office of Technology Assessment at the German Bundestag (TAB) conducted a concise study (Hubel et al., 2024). As part of this study, experts from various fields were consulted on the potential future effects, design options, and the need for further research. The results are briefly summarised below and translated to the Austrian context.

Clarification of terms: teleworking, home office, mobile, hybrid working

Home office, mobile working, or hybrid working: what all these terms have in common is that employees do not perform their work tasks in a traditional office setting[1] on the employer's premises. The variant of working from one's permanent residence, which has become widespread during the pandemic, is referred to as home office. Mobile working, on the other hand, occurs while on the move, such as in a café or park. An extreme form of mobile working is exemplified by the so-called "digital nomads," who often work remotely on an international basis. Hybrid working is generally used as a broad umbrella term to encompass this diversity.[2]

Despite the decline, working from home remains above the pre-pandemic level.

As Hubel et al. (2024) report, there was a sharp increase in the use of home offices in Germany during the pandemic, when infection restrictions were in place. While 83% of employees worked exclusively or predominantly in the office before the pandemic, this figure fell to between 53% and 66% in the period from April 2020 to January 2021. After the infection restrictions were lifted, on-site work resumed. However, this is distinguished by the fact that the number of individuals who worked at least partially from home remained constant. What did decrease significantly, however, was the proportion of those who worked almost exclusively from home. Among all those who worked from home, this proportion decreased from 70% in 2021 to 53% in 2023. Therefore, there was a greater mix of days spent working from home and in the office.

Sectoral differences regarding the possibility of hybrid work ...

Hybrid work remains a relevant phenomenon. A discernible sectoral differentiation exists: hybrid work is significantly less common in sectors with a high level of interaction work (e.g., stationary retail, social professions) and in industrial and technical professions. The question remains as to whether more teleworking is possible in these sectors (e.g., through technical innovations) or whether there are fundamental limits to this (Hubel et al., 2024).

---

1 Since the coronavirus pandemic, interactive formats such as distance learning, lectures via video link, etc. have also become more established. As a result, hybrid work generally refers to knowledge work and, in particular, screen-based work (Bath & Brauchle, 2025) and not, for example, conventional field service, assembly and construction work.

2 In some literature, the term "hybrid working" is understood differently, namely as work situations in which some employees are present on site, while others - especially in meetings - are connected remotely, similar to so-called hybrid conferences.

... with potential for social polarisation...

Hubel et al. (2024) also highlight the risk of polarisation among workers in these various teleworking options. While academics, for instance, benefit from the flexible possibilities of teleworking, this is not feasible for factory workers and care workers, among others. This polarization can also be reflected within an organisation. For example, hybrid work may be more acceptable for certain sections of the workforce, while others, such as secretaries, are expected to be on-site at all times.

... and within a company

However, even among those who can telework, the conditions are not equally distributed (Hubel et al. 2024). The equipment in the home office (an office chair and a large screen versus a laptop at the kitchen table) also depends on the employees' financial strength. This includes the ability to set up their study, which can affect the ergonomics of the home office and potentially lead to health consequences. Furthermore, not all employees can isolate themselves from other household members when working from home.

Concrete design is important for its impact on health.

In general, the answer to the question of how hybrid work affects mental health seems to depend heavily on its specific design (Bath & Brauchle, 2025; Gerich, 2025; Hubel et al., 2024). On the one hand, hybrid work facilitates an improvement in work-life balance under favourable conditions, such as allowing small errands to be folded into the workday or through the time savings that come from not needing to commute to work. At the same time, hybrid work makes it more difficult to draw a clear boundary between work and personal life, as it often entails expectations of constant availability and high productivity pressure. Adherence to breaks also suffered during the peak phase of working from home, but is likely to improve again due to the often partial use of the home office (Nowshad et al., 2024).

Gender-specific effects not clear

The data situation appears somewhat unclear regarding whether teleworking has gender-specific effects. The extent to which women working from home provide disproportionate amounts of childcare has not been sufficiently investigated (Hubel et al. 2024). For instance, in Germany, more women than men in the 26-35 age group work from home, but the reasons for this remain unexplained. In Austria, prior to the pandemic, a higher proportion of men in the 25-49 age group worked from home; however, after the pandemic, the number of women working from home increased, except in 2023.[3]

Social contacts, affiliation and informal exchange pose challenges

Frequent hybrid working can lead to telepressure, as employees may feel less visible in the home office, which may increase their commitment and result in additional stress (Hubel et al., 2024). The opportunities for spontaneous arrangements are also diminished in hybrid work. Overall, the need for social contact and a sense of belonging are reasons for the decline in working from home since the pandemic (Nowshad et al., 2024).

The workplace loses importance due to the rise of teleworking

If hybrid work becomes more commonplace, it will also affect the significance of the workplace, as companies' choices of location may undergo permanent changes. Experts surveyed by the TAB (see above) estimate that the demand for office space will continue to decline. A 12% reduction in office space is forecasted for Germany (Hubel et al., 2024). A shift in the type of office space in demand is reported for Vienna, with an emphasis on flexibility, collaboration, and retreat

[3] Employed persons working from home as a percentage of total employment, by gender, age and occupational status: *ec.europa.eu/eurostat/databrowser/bookmark/850c9cbc-fdf1-47bd-9af1-b3402252d89e?lang=de*.

options for concentrated work (EHL Gewerbeimmobilien GmbH, 2025). Rural regions can likely benefit from the increased attractiveness to employees resulting from the enhanced availability of remote work options, such as home offices (Hubel et al., 2024).

Reduced commuter traffic leads to lower emissions and time savings

In addition to saving time, reducing commuting also has positive environmental effects. Experts largely agree that this decrease in traffic volume outweighs the additional energy requirements of digital technologies, such as online meetings (Hubel et al., 2024). However, the decline in commuting also brings the risk that purchases originally made en route to work will shift to online retail. Alongside daily commuting, the rise of video conferencing has further decreased travel (Nowshad et al., 2024), enhancing the environmental footprint and lowering travel costs.

Hybrid meetings remain a challenge

Despite the extensive experience and technological advancements that have been gathered, hybrid meetings—where part of the team is on-site, and part is connected via the internet—continue to pose challenges (Nowshad et al., 2024). Remotely connected participants are still often not as well integrated as those onsite, which makes active participation and effective communication more difficult. However, future developments, such as AI-supported moderation and improved sound and image quality, could bring further improvements in this area. The Delphi survey of experts conducted by the TAB also shows that technologies can make a substantial contribution to enabling hybrid forms of work in the future, particularly collaboration platforms, AI, and mixed and virtual reality.

New challenges for managers

However, technology is not proving to be the most important factor for hybrid working; the development of a hybrid working culture, hybrid management styles, and team structures is regarded as much more significant (Hubel et al., 2024). Among managers, experiences during the pandemic contributed to the growing acceptance of remote work. Additionally, the higher satisfaction of employees while working from home played a crucial role in this trend. Overall, working from home places greater demands on managers to ensure a functioning exchange within the workforce.

Concerns about surveillance and data security

Many software solutions used for hybrid working offer the potential for more detailed monitoring. Increased surveillance is, therefore, a concern for employees (Hubel et al., 2024). Additionally, teleworking presents greater challenges regarding data security compared to working at the company site.[4]

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

The level of home offices in Austria is above the pre-pandemic level …

In Austria, there was also a significant increase in home office use during the COVID-19 pandemic, followed by a subsequent decline. Nevertheless, the prevalence remains above the pre-pandemic level. Eurostat figures indicate that 29.8% of all employees usually or sometimes worked from home in 2020, the highest figure recorded during the pandemic. Since then, this figure has decreased to 28.1%, but it is still considerably higher than in 2019, when it was 22%. The "Flexible Working" study, conducted by Deloitte in collaboration with the Universities

[4] This is also the direction taken by the data protection authority, which points out that GDPR compliance may not be guaranteed in the case of hybrid work: *parlament.gv.at/gegenstand/XXVII/SNME/253838/*.

of Vienna and Graz since 2017, also reveals a similar trend in home office use (Nowshad et al., 2024).

... as well as sectoral differentiation ...

A sectoral differentiation in hybrid work can also be observed in Austria. The Flexible Working Study highlights the need to examine working conditions in the care, craft, and production sectors in greater detail, as the authors primarily focused on office workers. It is therefore not surprising that in 65% of the companies surveyed, "at least half of the employees were regularly" (p. 5) working from home—significantly more than the aforementioned Eurostat data (which includes all employees) would suggest.

... and increased acceptance

Acceptance among managers also seems to have increased in Austria. According to the flexible working study, most managers did not perceive any loss of productivity as a result of hybrid working. However, managers remain more sceptical about hybrid forms of work than the workforce, especially regarding communication and performance monitoring. For this reason, informal exchange, in particular, should be actively promoted, as it can be crucial for networking, innovation, and fostering cohesion within the company (Nowshad et al., 2024).

The new teleworking law establishes new framework conditions

The new Teleworking Act (Telearbeitsgesetz) came into force in Austria on 1 January 2025, replacing the Home Office Act (Homeoffice-Gesetz). Certain legal issues are now more clearly regulated, and new opportunities for hybrid work have been enabled. In addition to the previously defined home office (in the narrower sense), which is now extended to include the residences of relatives and coworking spaces, "teleworking in the broader sense" is also defined: it occurs in changing locations. This includes working in a coffee shop, in a park, or on the train. This legal distinction is relevant to the protection of the employee during the commute (Wegschutz): This does not apply to teleworking in the broader sense of the term.

PROPOSAL FOR FURTHER ACTION

Exploring potential in other sectors

From a technology assessment perspective, the primary question is how the positive aspects of hybrid work can benefit other employee groups. Which technologies (e.g., augmented or virtual reality) facilitate at least partial hybrid working in sectors such as production and care? Further research is required to mitigate the risk of social polarization.

Furthermore, more comprehensive studies are needed to identify the hybrid forms of work that best achieve positive health, social, and ecological outcomes while mitigating negative consequences. What indicators can guide a successful balance between working in the office and remotely? How can exchange and communication be effectively organised without encouraging pressure to perform, constant availability, and employee monitoring?

Investigating the potential of teleworking for rural areas and urban peripheries

It is also suggested that the potential of innovative teleworking constellations be explored. A particular focus could be placed on the positive effects for rural areas; for example, could municipalities specifically offer coworking spaces to enhance their attractiveness? Should the rental of coworking spaces by multiple employers in rural areas be promoted, thereby making companies more appealing to skilled workers from other regions, on the one hand, and mitigating the rural exodus, reducing commuting activities, and thus relieving the burden on public transportation, while also decreasing greenhouse gas emissions, on the other? Similar initiatives can also bolster peripheral areas in urban regions.

Digital sovereignty in the home office

Finally, at the national and EU levels, the question of digital sovereignty is central to the ongoing relevance of hybrid work: To what extent does hybrid work depend on non-EU providers due to the crucial role of IT infrastructure? What alternatives are available from the EU, or where is there a lack of European offerings for video conferencing, coordination, collaboration platforms, and similar tools? Especially in turbulent geopolitical times, it would be critical if a strong dependency on non-European infrastructures were to develop. An in-depth study should be conducted on technologies for hybrid working, focusing on digital sovereignty, compliance with EU law (including the AI Act and GDPR), as well as the ethical, social, and environmental consequences.

REFERENCES

Bath, J., & Brauchle, S. (2025). Effectiveness of mandatory office quotas in hybrid work models. *Journal of Ergonomics*. **doi.org/10.1007/s41449-025-00459-4.**

EHL Gewerbeimmobilien GmbH. (2025). *Office real estate. Market report spring 2025*.

Gerich, J. (2025). Come to stay: What can be learned from the pandemic experience for the impact and positive design of working from home? *Journal of Ergonomics*, *79*(1), 36-50. **doi.org/10.1007/s41449-024-00421-w.**

Hubel, N., Peters, R., de Saussure, M., Nerger, M., Meißner, L., & Hungerland, T. (2024). *Social impacts of hybrid forms of work* (No. 2; TA-Kompakt). Office of Technology Assessment at the German Bundestag. ***tab-beim-bundestag.de/projekte_gesellschaftliche-auswirkungen-von-homeoffice.php.***

Nowshad, A., Wolfsberger, J., Kellner, B., Korunka, C., Jäger, S., & Kubicek, B. (2024). *Flexible Working 2024*, Deloitte.

PLASTIC AND HUMAN HEALTH

© CC0 (Raspopova Marina, Thomas Bayer/unsplash)

SUMMARY

Micro- and nanoplastics are ubiquitous and are primarily ingested by humans through respiration and food consumption. The research field concerning their health effects on humans is relatively nascent, presenting several methodological challenges. Nonetheless, increasing evidence suggests that there are significant health impacts. While most microplastic particles are excreted, some enter the bloodstream via the intestines or lungs and accumulate in blood vessels, the brain, and other organs. These accumulations can cause inflammation and are associated with an elevated risk of heart attack, stroke, or death. Microplastics are linked to cancer, asthma, neurological disorders, intestinal diseases, and immune reactions that may promote autoimmune diseases.

OVERVIEW OF THE TOPIC

Micro- and nano plastics: worldwide distribution

Microplastic and nanoplastic pollution is a global problem, as microplastics have been detected in soils, cities, rivers, oceans, air, the highest mountains, Antarctic ice, and ultimately in humans. Microplastics are either intentionally produced in industry, for example, in the form of beads or pellets for further processing or formed through the decomposition and weathering of plastic products, such as tyres. In some cosmetics, microplastics are banned under EU regulations; in others, there are long transitional periods for the ban, in some cases extending well into the 2030s. Most plastics are hardly or only very slowly biodegradable, meaning that the environmental impact of plastic production increases as plastic production rises. Microplastics are generally defined as particles between one micrometre (one-thousandth of a millimetre) and five millimetres in size, below which they are referred to as nanoplastics. ***Microplastics*** and their environmental impact were already addressed in the Monitoring (2019) in the form of a general overview.

The young field of research into health risks in humans

Researchers have studied the biological effects of microplastics and nanoplastics for decades, primarily focusing on rodents and human cells. Studies on rodents have demonstrated that microplastics can damage various organs, including the intestines, lungs, liver, and reproductive and nervous systems.[1] The first evidence of microplastics in the human gut was discovered in a 2019 study conducted by Vienna General Hospital. Since then, this young field of research has continued to develop, with efforts to clarify the exposure, effects, and risks of these particles on human health. However, there are still too few studies to make conclusive statements at present. Recently, plastic has been detected in various human tissues and organs, including the brain, blood, lungs, placenta, and breast milk (Guo, 2024). Additionally, plastic has been detected in the heart and bone marrow (Guo, 2024). The detection of nanoplastics remains in its infancy. Due to their small size and the various environments in which they are found, it is particularly challenging to identify and measure them. For instance, there is currently no method for detecting nanoparticles in the lungs (OPECST, 2024). Other limitations of the study methodology relate to the choice of study subjects. For example, most studies are conducted on the most commonly used commercial particles, such as polystyrene, which do not accurately represent the particles that occur in the environment. Additionally, laboratory processes need to be adapted, as the ubiquity of plastic, even within laboratories, means that sample contamination cannot always be ruled out. Most studies are conducted with healthy individuals; however, individuals with certain intestinal diseases have been found to possess significantly higher levels of microplastics, and they should be included in future studies (OPECST, 2024).

Absorption via respiration ...

Despite methodological limitations, a growing number of recent research findings suggest that this approach is associated with significant health risks. What is certain is that we ingest ubiquitous microplastics and nanoplastics primarily through the air we breathe and the food we consume. Microplastics in the air are more prevalent in areas with high human population and activity, particularly indoors. The principal sources of microplastics in the air include synthetic fibres, urban dust, and tyre abrasion (Ezhava et al., 2025). In Paris, it has been shown that between 3 and 10 tons of plastic are emitted into the air each year, the majority of which consists of fibres originating from textiles, for example (see ***textile***

1 *nature.com/articles/s41591-024-02968-x#article-info*.

recycling). People there inhale approximately 30 million plastic particles each year (OPECST, 2024), which are thus part of the particulate matter issue. The toxicity of plastic particles often depends on their shape and size. Fibres, for example, are problematic because their length means that they are either not absorbed or only partially absorbed by the phagocytes of the immune system through phagocytosis, potentially causing persistent inflammation (OPECST, 2024). This dynamic is also well-documented in the asbestos debate, where needle-shaped asbestos, in particular, resulted in lung cancer.

...through food...

We ingest approximately the same amount of plastic through our food as we do through our breathing. Animals and even plants ingest plastic particles, which then enter the human food chain, where they accumulate and harbour harmful chemicals and pathogens. The use of feed and fertilisers containing microplastics can contaminate livestock. This means that residues of microplastics can end up in products sourced from these animals, such as meat, dairy products, and other animal-derived goods from farms (Zeng, 2025). Effects are particularly well-researched in marine life, where microplastics cause tissue damage, oxidative stress, changes in immune system gene expression, neurotoxicity, growth disorders, and behavioural changes (Grattagliano, 2025). Microplastics have been detected in fish, as well as in various food products, including seafood, salt, sugar, honey, fruit, vegetables, rice, drinking water, and beer.[2] One study found that liquids in plastic bottles contain approximately 250,000 particles per litre, most of which are in the form of nanoplastics (OPECST, 2024). Even chewing gum releases thousands of tiny plastic particles.[3] The most common polymers in our food are polyethene (PE), polypropylene (PP), and polystyrene (PS). Other examples include polyethene terephthalate (PET), polyvinyl chloride (PVC), and polymethyl methacrylate (PMMA) (Bocker 2025).

One study discovered that 25 per cent of the 14,000 chemicals in plastics that come into contact with food (e.g., packaging) are detectable in the human body. Another study revealed that 61 plastics that come into contact with food can increase the risk of breast cancer (OPECST, 2024).

...and skin

The absorption of plastic through the skin is also being discussed. However, absorption tends to occur to a lesser extent via hair follicles and sweat glands. Microplastics, especially synthetic fibres smaller than 25 µm, can penetrate the skin's pores and trigger immune reactions by activating various skin cells. This process can impair the skin's barrier function, with individual susceptibility varying with pore size (Ezhava et al., 2025).

Micro- and nanoplastics enter the bloodstream and accumulate in organs.

Most plastic particles are excreted, but some enter the bloodstream through the intestinal wall or lungs and are deposited in blood vessels, the brain and other organs. These deposits can cause inflammation. A study shows that patients with deposits in the carotid artery (plaques) containing micro- and nanoplastics (MNPs) have an increased risk of heart attack, stroke or death (Marfella, 2024).

A groundbreaking study revealed that microplastics are deposited in brain tissue at a rate up to 30 times higher than in the liver and kidneys. Furthermore, brain samples from deceased individuals in 2024 contained about 50% more microplastics than those from 2016 (Nihart, 2025).

---

2 *ages.at/mensch/ernaehrung-lebensmittel/rueckstaende-kontaminanten-von-a-bis-z/mikroplastik*.

3 *spektrum.de/news/microplastik-ein-kaugummi-gibt-tausende-mikroplastikpartikel-ab/2257702*.

Various forms of cancer, asthma, neurological disorders and intestinal diseases

Overall, the accumulation of plastics in the human body can lead to various health problems. These include multiple types of cancer, such as blood or lung cancer, asthma, neurological symptoms such as fatigue and dizziness, as well as inflammatory bowel diseases and intestinal flora disorders. Most studies conducted to date have confirmed that nano- and microplastics can induce cell death and have mutagenic and cytotoxic effects (Winiarska, 2024). Microplastics can trigger immune responses in humans, potentially leading to autoimmune diseases or compromised immunity in susceptible individuals. Over time, cellular damage and alterations in immune function could lead the body to attack itself. However, further research is necessary to understand the effects on the immune system and their potential influence on the nervous system (Ezhava et al., 2025).

Hormonally active plasticisers and unknown additive chemicals

Furthermore, plastics often contain hormonally active plasticisers (endocrine disruptors) along with numerous other chemicals that are not typically required to be disclosed, as plastic formulations, such as those for car tyres, are often regarded as proprietary company secrets. In addition to plasticisers, endocrine disruptors encompass persistent organic pollutants, heavy metals, and pesticides (Prähauser, 2024). Acceptable limits for individual substances in the human body fluctuate according to research. Almost the entire population now surpasses the permissible limit for the well-known plasticiser, bisphenol A, since the threshold was reduced 20,000-fold in 2023 following new evidence (OPECST, 2024). Furthermore, microplastic particles act as carriers for pathogens and carcinogenic pollutants from the environment. These adhere to the water-repellent surface of the plastic, which the animal then ingests.

Reproduction issues and fetus-health

Microplastics could affect male reproductive health, posing risks such as oxidative stress, hormonal disruption, inflammation, and cell damage. The scarcity of human research underscores the pressing need for in-depth studies to clarify the impact of microplastics on male fertility (Kumar & Mangla, 2025). It was previously assumed that the placenta acts as a protective barrier for the fetus. Recent studies indicate that the placenta can accumulate plastic particles, potentially impairing its function. These particles can also penetrate the interface between the mother and fetus, exposing the developing fetus to hazardous chemicals contained in plastics, such as endocrine disruptors and *persistent organic pollutants* (Anifowoshe et al., 2025).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Anchoring the precautionary principle in law

Plastic pollution is everywhere, and people cannot entirely prevent exposure in their daily lives; they can only minimise it. Many questions regarding the effects and toxicity remain unanswered, despite clear indications of serious health risks effects. In such a situation, the precautionary principle[4] should be applied to reduce the population's exposure as far as possible. Although the precautionary principle is enshrined in European REACH legislation, it is not implemented adequately, as plastics contain numerous unregulated substances that complicate testing. Only 161 plastic chemicals have been classified as non-hazardous; however, these assessments are often based on insufficient data or only partially on

[4] *epub.oeaw.ac.at/0xc1aa5572_0x003ebf2f.pdf*.

hazard criteria. For over 10,000 chemicals found in plastics, there is no available risk information. Globally, only 6% of these chemicals are covered by the regulations of international treaties such as the Basel and Stockholm Conventions and the Montreal Protocol (OPECST, 2024). There are still significant gaps in our understanding of the health effects of nano- and microplastics under real environmental conditions, particularly regarding long-term exposure, the influence of particle size, chemical composition, and interactions with other environmental pollutants (Bocker & Silva, 2025). Although the toxicity of chemicals is increasingly well documented, data on their persistence, bioaccumulation, and mobility remain limited. These factors are not consistently considered in risk assessments (OPECST, 2024).

The global treaty against plastic pollution has been effective in preventing it so far.

After two years of negotiations, UN member states failed to reach an agreement on a global treaty to end plastic pollution at the 2024 talks in Busan, South Korea. Resistance from oil-producing countries and plastic manufacturers prevented this from occurring. The negotiations are set to resume in 2025.[5] The use of microbeads in cosmetics has been banned across the EU since 2023, and efforts are also being made to prevent the contamination of animal feed by packaging materials and to implement control measures.[6] The USA has biomonitoring data on the extent of the population's exposure to plastic chemicals. One study estimates the annual societal cost of three key chemicals to be £675 billion, although only one or two health effects per chemical were investigated (OPECST, 2024). The most effective way to reduce the production of microplastics is to minimise plastic waste. Ways to achieve this include reducing plastic production, opting for alternatives such as glass, cardboard, or biodegradable materials, and repurposing discarded plastic to create new products (Ezhava et al., 2025).

PROPOSAL FOR FURTHER ACTION

Austrian follow-up to the French TA study

A study by the French parliament's TA institution (OPECST, 2024) outlines nine clear recommendations for the negotiators of the global plastics agreement, which would have significant implications for national legislation. Based on this, an Austria-specific TA study could explore which recommendations are pertinent to the Austrian context and how they should be adapted.

REFERENCES

Anifowoshe, A. T., et al. (2025). Microplastics: A threat to Fetoplacental unit and Reproductive systems. *Toxicology Reports, 14*, 101938, **sciencedirect.com/science/article/pii/S2214750025000563.**

Bocker, R., & Silva, E. K. (2025). Microplastics in our diet: A growing concern for human health. *Science of The Total Environment, 968*, 178882, **sciencedirect.com/science/article/pii/S0048969725005170.**

[5] *environment.ec.europa.eu/news/eu-regrets-inconclusive-global-plastics-treaty-2024-12-02_en*.

[6] *ages.at/mensch/ernaehrung-lebensmittel/rueckstaende-kontaminanten-von-a-bis-z/mikroplastik*.

Ezhava, S. R., et al. (2025). Hazards of microplastics on human health and its mitigation strategies. *Toxicology and Environmental Health Sciences*, ***doi.org/10.1007/s13530-025-00249-9***.

Grattagliano, A., et al. (2025). An Overview on Microplastics Hazards to the Marine Ecosystem and Humans' Health. *Water, 17*(7). ***doi.org/10.3390/w17070916***.

Guo, X., et al. (2024). Discovery and analysis of microplastics in human bone marrow. *Journal of Hazardous Materials, 477*, 135266, ***sciencedirect.com/science/article/pii/S0304389424018454.***

Kumar, N., & Mangla, M. (2025). Microplastics and impaired male reproductive health-exploring biological pathways of harm: a narrative review. *Biology of Reproduction*, ioaf054, ***doi.org/10.1093/biolre/ioaf054***.

Marfella, R., et al. (2024). Microplastics and Nanoplastics in Atheromas and Cardiovascular Events. *New England Journal of Medicine, 390*(10), 900-910, ***doi.org/10.1056/NEJMoa2309822***.

Nihart, A. J., et al. (2025). Bioaccumulation of microplastics in decedent human brains. *Nature Medicine, 31*(4), 1114-1119, ***doi.org/10.1038/s41591-024-03453-1***.

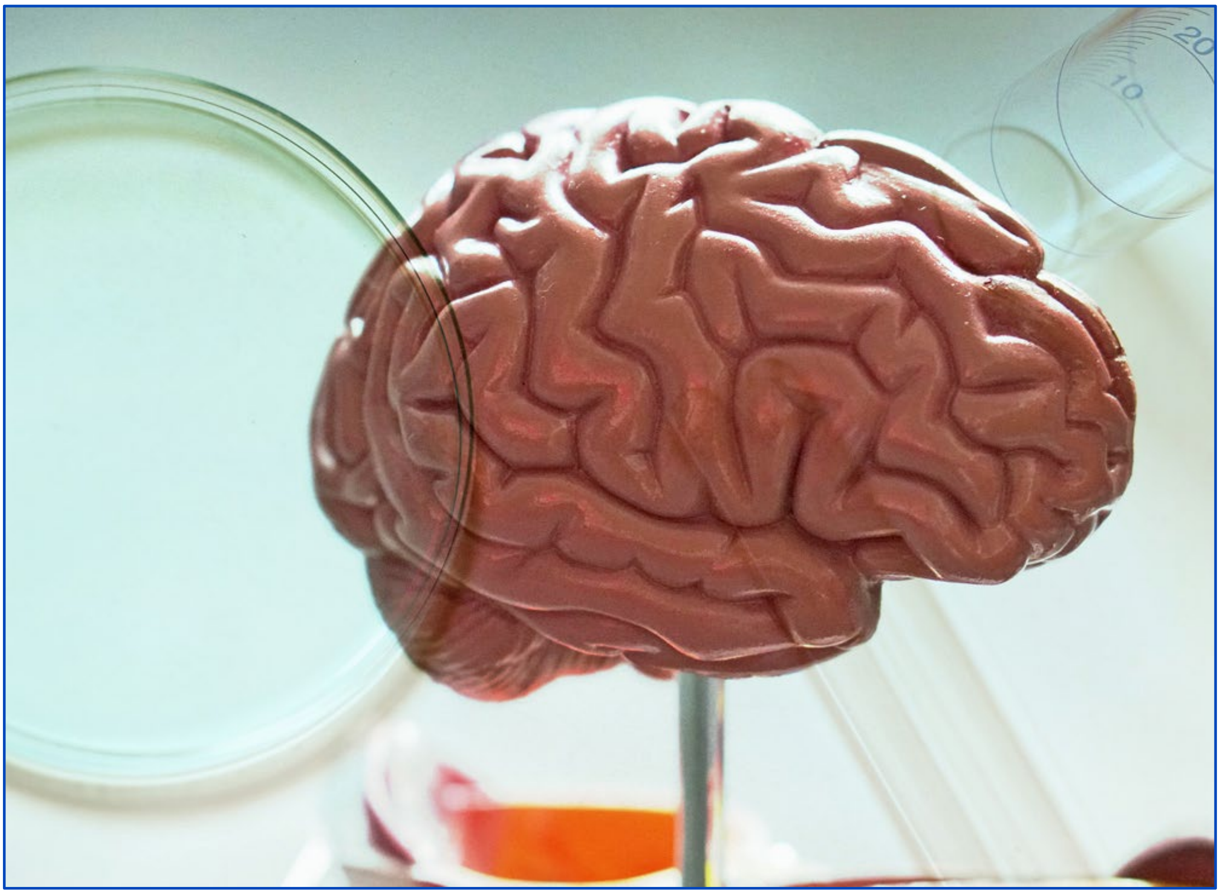
OPECST (2024). *Les impacts des plastiques sur la santé humaine (l'Office parlementaire d'évaluation des choix scientifiques et technologiques, Assemblée nationale, France)*, ***assemblee-nationale.fr/dyn/17/rapports/ots/l17b0560_rapport-information#***.

Prähauser, L., et al. (2024). *Ecotoxicological risk assessment of nano- and microplastics (NanoTrust Dossier No. 066 - December 2024)*, ***epub.oeaw.ac.at/ita/nanotrust-dossiers/dossier066.pdf***.

Winiarska, E., et al. (2024). The potential impact of nano- and microplastics on human health: Understanding human health risks. *Environmental Research, 251*, 118535, ***sciencedirect.com/science/article/pii/S0013935124004390***.

Zeng, H., et al. (2025). Microplastics in animal-derived products and their potential risks to human health. *TrAC Trends in Analytical Chemistry, 185*, 118187, ***sciencedirect.com/science/article/pii/S016599362500055X.***

BRAIN ORGANOIDS (UPDATED)



© CC0 (Robina Weermeijer/unsplash)

SUMMARY

In recent years, the development of three-dimensional structures from human stem cells, which currently only partially replicate the structures and functional characteristics of the brain—known as brain organoids—has enabled the creation of new model systems for researching brain development and neurological diseases. However, ethical issues that may arise, particularly from the development of consciousness and pain perception in such organoids within tissue culture or following their transplantation into the brains of animals, are also discussed. Given the limited complexity of current brain organoids and those likely to be produced in the near future, these concerns are improbable to become significant or necessitate legislative action in the foreseeable future. Regarding potential transplants at prenatal stages - and the possibility of further development and functional integration of human cells into the animal brain - it is advisable to assess whether the current regulations for evaluating and conducting such research are adequate.

Brain organoids: Structures made from human stem cells that represent substructures of the brain

OVERVIEW OF THE TOPIC

Brain organoids in vitro or transplanted into animals

Over the past ten to fifteen years, breakthroughs in generating stem cells from somatic cells and advancements in inducing the development of these stem cells into central nervous system cell types have opened up new possibilities for research into human brain development and neurological diseases. In particular, the production of three-dimensional structures in the laboratory, currently only a few millimetres in size, which form substructures of the brain - with important cellular and molecular characteristics - have contributed to these possibilities (Birtele et al., 2024; Kelley & Pașca, 2022). These structures, created in cell culture dishes ("in vitro") from human embryonic stem cells (ES cells) or via induced pluripotent stem cells (iPS cells) generated from somatic cells, are referred to as brain organoids or neural or cerebral organoids. Organoids can be obtained that form cell types and (partial) structures of different brain areas or that merely resemble individual brain regions in this respect. The former arise through pure self-organisation processes, the latter through the addition of certain signalling molecules. Furthermore, composite structures can be generated by combining region-specific brain organoids, so-called assembloids. Finally, brain organoids can be implanted into the brains of animals (mice, rats, macaques) for further investigations (e.g. of further developmental processes). In an experiment with young rats, the organoids integrated structurally and functionally into portions of the rat brain to such an extent that the rats' reward-seeking behaviour could be triggered by the activation of human nerve cells (Revah et al., 2022).

Limitations and important differences to the brain

Brain organoids differ from the human brain in several important ways. For example, their diameter is only a few millimetres. Furthermore, they possess roughly 40,000 times fewer cells than the brain, which contains about 100 billion cells (including nerve cells and other cell types), and they lack blood vessels for a more extensive supply of oxygen and nutrients. Furthermore, brain organoids currently lack features representative of numerous brain regions, such as specific organisational patterns and connective pathways, as well as the complete diversity of the various cell types found in the brain. They are, therefore, unable to represent the complex connections between brain regions and circuits that underlie information processing in the brain. Finally, the cells in the organoids do not mature beyond the stages typically found in embryonic stages or neonatal brains, which limits their utility for analysing processes of the mature human brain (Birtele et al., 2024; Kelley & Pașca, 2022; NAS, 2021, p. 28 ff.).

Model systems for brain development, neuronal diseases and drug development

Nevertheless, brain organoids already provide important insights and applications (Birtele et al., 2024; Leopoldina, 2022, p. 21 ff.; NAS, 2021, p. 28 ff.). These include research into normal human brain development and neurological diseases, especially those that cannot be adequately studied in animal models. For example, molecular mechanisms of various diseases have been identified using iPS cells (e.g., from patients) that carry mutations associated with neurological diseases. Diseases of this nature include severe idiopathic autism spectrum disorder, severe neurodevelopmental disorders (e.g., Timothy syndrome), or neurodegenerative diseases such as Alzheimer's disease. Additionally, brain organoids have significantly contributed to our understanding of how the Zika virus can lead to microcephaly in infants. Secondly, brain organoids provide a system for identifying target genes for treatments and investigating potential toxins or drugs

(Birtele et al., 2024; NAS, 2021, p. 31). For example, brain organoids have already been used to find potential new drugs for neuropsychiatric diseases such as Parkinson's and Alzheimer's disease (Leopoldina, 2022, p. 26). Brain organoids from iPS cells of different patients could also provide insights into some drugs' modes of action.

Ethical and moral issues

Research involving human brain organoids can significantly enhance the understanding and development of treatment options for serious diseases. Moreover, specific animal experiments could also be reduced, such as testing substances against diseases that cannot be effectively simulated in animal models. On the other hand, some possible ethical problems of this research and potential legal implications are also being discussed, particularly in bioethics circles (Kataoka et al., 2025).

Brain organoids in vitro - development of consciousness?

With regard to experiments involving brain organoids in tissue culture dishes, ethical questions particularly concern potential future advancements towards larger and structurally more complex brain organoids.[1] Concerns exist that these could attain higher levels of consciousness or sentience—potentially reaching levels found only in humans. Elevated levels of consciousness encompass self-awareness, the capacity to formulate long-term plans, and the subjective experience of pain or suffering. However, on the one hand, there is no uniform understanding of "consciousness", and it is unclear whether or which levels of consciousness are limited to humans. Secondly, the neurobiological basis (e.g., in the form of neurological circuits) of consciousness and whether or how consciousness can actually be measured or predicted neurobiologically has not yet been clarified, and there are different, sometimes controversial theories (Lenharo, 2024). Most current methods for assessing consciousness or pain perception cannot be applied to organoids, as understanding these abilities largely depends on observing animal behaviour (NAS, 2021, p. 35 ff.). However, it seems clear—particularly from studies of humans who have sustained injuries in various brain regions—that the levels of consciousness typically attributed to humans rely on highly complex brain areas (such as the prefrontal cortex[2]) as well as multiple brain regions and connections between them (Edlow et al., 2021; NAS, 2021, p. 39). Given the existing characteristics and limitations of brain organoids (see above), it appears highly unlikely that they will achieve such a level of complexity in the near future.

Transplantation of brain organoids - animals with human characteristics?

About the transplantation of human brain organoids into the brains of laboratory animals, there are ethical concerns regarding animal welfare. In addition, there are fears that features such as the subjective experience of pain or suffering and the consciousness of a laboratory animal could be altered in a manner that might render it more human-like (Kataoka et al., 2025). This possibility is being discussed particularly for potential transplantation experiments in non-human

[1] In addition, ethical questions are discussed that concern the appropriate consent of donors (and patients) of stem cells (especially iPS cells) for the generation of brain organoids and their use (e.g., NAS, 2021, p. 47 ff.). As these questions also arise and are discussed in a very similar way for other areas of research, they will not be discussed in detail here or below.

[2] Part of the cerebral cortex located at the front of the brain. This structure is quasi primate-specific and is most developed in humans.

primates. Aside from fundamental concerns that this would violate the nature of the animals, the development of more "human-like" abilities or characteristics would likely mean that a higher moral status or duty of protection would need to be ascribed to them (e.g., Leopoldina, 2022, p. 39; NAS, 2021, p. 60 f.). However, as explained above, more advanced cognitive functions seem to depend on the complexity and functional architecture of the brain. These functions are not solely based on the genetic material of the introduced human cells and their potential developmental processes. To a significant extent, they also require temporally and spatially appropriate cellular and molecular signals from surrounding cells and tissue structures, which regulate cell differentiation and brain development (Kelley & Pașca, 2022). Experts from various disciplines, therefore, assume that the transplantation of current brain organoids or those that can be produced in the foreseeable future into the brains of recipient animals cannot cause such relevant changes (ISSCR, 2021; Leopoldina, 2022; NAS, 2021). The evaluation of transplanting stem cells or brain organoids derived from them into prenatal stages in utero is more uncertain. In this context, human cells could also be functionally more strongly integrated into the animal brain (ISSCR, 2021; Leopoldina, 2022, p. 33 f.).

Although not strictly comparable to the transplantation of brain organoids, introducing human stem cells into early embryonic stages could enable particularly far-reaching development and integration processes — especially if embryos from non-human primates were used. This area of research is sometimes treated together with brain organoid research due to similar objectives (NAS, 2021).

Possible legal and regulatory issues

Based on the bioethical aspects outlined above, two questions regarding possible legal and regulatory implications are discussed in particular. Firstly, whether or to what extent moral duties of protection or even rights as natural or legal persons should apply to brain organoids if they were to develop forms of consciousness or pain perception. And secondly, how the protection of animal welfare is or can be guaranteed in connection with the transplantation of such organoids (Kataoka et al., 2025). No country appears to have legislation specifically governing the research or use of brain organoids. However, there are guidelines from the International Society for Stem Cell Research (ISSCR, 2021). In these guidelines, no specific supervisory processes are considered justified for cultivating neural organoids in vitro, as there is currently "no biological evidence to suggest any issues of concern, such as consciousness or pain perception" in such organoids. For the transfer of human stem cells or neural structures derived from them into the brains of animals after birth, an institutional review (existing in most countries) by committees, which should, however, have expertise in "stem cell or developmental biology", is considered necessary. For transplants into non-human fetuses in utero, on the other hand, a "specialized scientific and ethical oversight process" (not specified) is recommended, which must take place by local laws and guidelines. Such experiments with non-human primates, "must exclude great and lesser ape species hosts [*... e.g., chimpanzees, gorillas, orangutans, gibbons ...*]" (ISSCR, 2021). In Austria, experiments on such monkeys are prohibited by the Animal Experiments Act, and other non-human primates (e.g., macaques) may only be used for certain experimental purposes under particularly restrictive conditions.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

In Austria, globally recognised research on brain organoids is being carried out at the Institute of Molecular Biotechnology (IMBA) of the Austrian Academy of Sciences,[3] and first Austrian start-up companies are using the technology to develop drugs.[4] Such organoids are unlikely to achieve the degree of structural and functional complexity that could lead to ethical problems under discussion for some time. Accordingly, there is no need for regulatory action, at least for the foreseeable future. However, possible developments towards greater complexity of the organoids must be observed. This applies similarly to the potential developments being discussed in connection with transplants of brain organoids into the brains of laboratory animals (after birth). However, regarding possible transplants into animal embryos or foetuses in utero, particularly from non-human primates, it seems advisable to examine whether regulations on this in general and on the necessary expertise of interdisciplinary ethics committees, particularly, are sufficient.

PROPOSAL FOR FURTHER ACTION

Examining regulations and the potential need for legislative action concerning the transplantation of brain organoids into animal embryos or foetuses should involve a dialogue among legal experts, representatives from various scientific disciplines (including stem cell research, comparative neurobiology, and brain research), and Parliament. Furthermore, consideration might be given to establishing a similar process for introducing human stem cells or neuronal cells into the early embryonic stages of animals or to incorporating it into the corresponding activities on brain organoid transplantation.

[3] This includes pioneering work (Lancaster et al. 2013) as well as current research cf. *oeaw.ac.at/imba/research/juergen-knoblich/publications*

[4] Z. E.g. *aheadbio.com*; *norganoid.com*

REFERENCES

Birtele, M., et al. (2024). Modelling human brain development and disease with organoids. *Nat Rev Mol Cell Biol,* published 12 Dec 2024. ***doi.org/10.1038/s41580-024-00804-1*.**

Edlow, B. L., et al. (2021). Recovery from disorders of consciousness: Mechanisms, prognosis and emerging therapies. *Nature Reviews. Neurology*, *17*(3), 135-156. ***doi.org/10.1038/s41582-020-00428-x.***

ISSCR (2021). *ISSCR Guidelines for Stem Cell Research and Clinical Translation*. Version 1.1, May 2021; Engl. Übersetzung, Januar 2022. ***static1.squarespace.com/static/611faaa8fee682525ee16489/t/62ed6a174729ce4782a9a4f0/1659726359925/isscr_germanguidelinesgerman_final.pdf***

Kataoka M., et al. (2025). Beyond consciousness: Ethical, legal, and social issues in human brain organoid research and application. *Eur J Cell Biol, 104(1),* 151470. ***doi.org/10.1016/j.ejcb.2024.151470*.**

Kelley, K. W., & Pașca, S. P. (2022). Human brain organogenesis: Toward a cellular understanding of development and disease. *Cell*, *185*(1), 42-61. ***doi.org/10.1016/j.cell.2021.10.003.***

Lancaster, M. A., et al. (2013). Cerebral organoids model human brain development and microcephaly. *Nature*, *501*(7467), 373-379. *.**doi.org/10.1038/nature12517***

Lenharo, M. (2024). The consciousness wars: can scientists ever agree on how the mind works? *Nature*. 625*(7995)*, 438-440. ***doi.org/10.1038/d41586-024-00107-7.***

Leopoldina (2022). *Brain organoids: Model systems of the human brain: Statement*. Statement, October 2022. ***levana.leopoldina.org/receive/leopoldina_mods_00514doi.org/10.26164/leopoldina_03_00514.***

NAS (2021). *The emerging field of human neural organoids, transplants, and chimaeras: Science, ethics, and governance*. National Academies of Sciences, Engineering, and Medicine. Washington, DC: The National Academies Press. *.**doi.org/10.17226/26078.***

Revah, O., et al. (2022). Maturation and circuit integration of transplanted human cortical organoids. *Nature*, *610*(7931), 319-326. ***doi.org/10.1038/s41586-022-05277-w.***

BATTERY SYSTEMS OF THE FUTURE (UPDATED)

© CC0 (Getty Images/unsplash)

SUMMARY

Global demand for batteries is expected to rise significantly by 2030. The expansion of renewable energy and electromobility primarily drives this. This market will emerge as a strategic area for new business models, technologies, and raw materials on a global scale. At present, lithium-ion batteries dominate this market. The growing utilisation of batteries presents challenges regarding environmental impact, supply chains, and utilisation of critical resources such as cobalt, lithium, nickel, and natural graphite. Research is underway on post-lithium technologies, such as sodium-ion batteries (SIB), to minimise the reliance on rare and costly materials. Establishing common standards and transparent supply chains is essential to encourage the development of new technologies and foster a sustainable, circular battery industry. A comprehensive TA study is proposed to identify opportunities and strategies for battery research, production, and recycling.

Increased use of batteries brings challenges (environment, supply chains, critical resources)

OVERVIEW OF THE TOPIC (UPDATED)

Battery storage as a core element for the energy and transportation transition

Global demand for batteries will potentially increase 14-fold by 2030, and the EU could account for 17% of this demand (Choix & Uhlig, 2021). This is due to the expansion of renewable energies and electromobility in particular. Various studies assume an energy storage requirement of over 2,100 GWh (up to 4,600 GWh) by 2030. The mobility sector alone will account for over 90% of this, stationary energy storage systems for around 6% and electronic devices for around 3%.[1] The growing importance of batteries in various application areas will make this market strategically important for new business models, technologies, raw materials and recycling on a global level. Chinese (CATL 37,9%, BYD 17,2%), Japanese (Panasonic 3,9%) and South Korean (LG 10,8%, Samsung 3,3%) companies currently have the largest shares in battery production (82% in 2022), with China accounting for almost 75% of the global output.[2] In Europe, there are several initiatives to build up lithium-ion production capacities totalling 1939 GWh[3] (2023), which are declining slightly as of 2024 (1424 GWh). These capacities mostly spread across Germany, Sweden, Norway, Hungary and Poland.[4]

The increased ***use of batteries*** poses challenges in terms of environmental impact, value chains and - depending on the electrode material used - the availability of critical and scarce resources. Depending on the scenario, the rising global demand for batteries in the mobility and energy sectors may surpass the currently known reserves of various metals, including cobalt, lithium, nickel, copper, and natural graphite (Weil et al., 2018). The availability and supply of raw materials and their refinement (production of raw materials for industrial use) are becoming increasingly uncertain, and raw material prices are under pressure. More than 80% of the raw materials required in the EU for industry and the economy are imported, many of which are considered critical raw materials (European Commission, 2023). Common standards and transparent supply chains need to be created to build a sustainable, resilient and, where possible, circular battery industry. At the same time, attempts are being made to develop new mining areas in Europe or reactivate old mines (in the case of lithium, for example, in Austria, Germany, Serbia, Czech Republic or Portugal), or extract the raw materials using alternative processes (e.g., lithium using geothermal plants[5]) to reduce dependence on imports. However, the extraction of raw materials in relatively densely populated Europe, particularly conventional mining, is associated with major environmental and social impact (Mononen et al., 2022). Another way to reduce dependence on critical raw materials is to develop new battery systems based on readily available raw materials such as sodium, magnesium, calcium, zinc, potassium, synthetic graphite or hard carbon (Liu et al. 2024).

1 *pem.rwth-aachen.de/cms/pem/der-lehrstuhl/presse-medien/aktuelle-meldungen/~blicef/-battery-monitor-2025-europaeische-hers/*.
2 *de.statista.com/statistik/daten/studie/490589/umfrage/ranking-zu-den-groessten-herstellern-von-lithium-inonen-akkus-weltweit/*.
3 *battery-news.de/2023/02/03/16260/*.
4 *cicenergigune.com/en/blog/gigafactories-europe-commitment-economic-recovery-battery-factories*.
5 *kit.edu/kit/pi_2023_028_energy-storage-materials-from-hot-deep-water-can-extract-lithium.php*.

Post-lithium batteries as a game changer?

Lithium-ion batteries (LIBs) currently hold a substantial market share and have established themselves as the most promising battery technology for storing renewable energy and supporting electromobility. The development of LIBs has seen significant advancements in energy density and lifespan in recent years while also considerably reducing storage costs (Ziegler & Trancik, 2021). Solid-state batteries are a promising development in the LIB sector. In these, a solid alternative (polymers, ceramics or hybrid) replaces the current liquid electrolyte. This is anticipated to significantly improve the energy density and safety of the relevant battery cells. A key aim of research into new battery systems, known as post-lithium systems, is to minimise potential sustainability conflicts arising from increasing demand and to decrease the use of critical and costly materials with a substantial environmental impact. Post-lithium systems include a wide range of cell chemistries based on Mg, Ca, Al, Na, K or Zn, with the name given depending on the ionic charge within the battery. Among current developments, sodium-ion batteries (NIBs) are regarded as the most advanced technology. Many start-ups and major battery manufacturers aim for a timely market launch of NIBs for stationary and mobility applications. These are based on the same functional principle and manufacturing processes as LIBs and are called drop-in technology (technologies or systems that can be integrated into existing structures without great effort) (Yokoi et al. 2024). Their advantages include using cheaper and more abundant materials (aluminium instead of copper as the current collector, sodium instead of lithium in the active cathode material, and electrolyte salt) (Baumann et al., 2022). Currently, NIBs have the disadvantage of lower energy density compared to LIBs, which affects the overall ecological and economic profile. However, using non-critical materials does not inherently result in more sustainable technology. Therefore, a comprehensive evaluation of the possible environmental impacts and resource considerations is essential (Yokoi et al. 2024). One of the biggest challenges for introducing new technologies is developing the market for components (electrolytes, cathode materials). In general, the problem with new battery systems such as NIBs is commercialisation on a large scale. Research into batteries (1st and 2nd generation) is intense in the EU (Germany, Austria with Varta research hub). However, it is presently restricted to small-scale pilot projects or commercialisation efforts that struggle to compete with the commercial solutions from China, where NIBs are already available in the automotive and stationary sector.

Does recycling all the problems?

Recycling plays a vital role in the availability of relevant materials and will grow more strongly from 2030 onwards as used battery capacities increase.[6] Scaling and automation play an important role in the ecological and economic viability of recycling. According to the EU Battery Directive, which has been in force since 2023, minimum quantities of manufacturing and consumer waste must be reused in new batteries for LIBs. From January 1, 2030, batteries must contain a minimum proportion of *recycled material* (12% cobalt, 85% lead, 4% lithium and 4% nickel). These values are to be increased further from 2035 (20% cobalt, 10% lithium and 12% nickel) (European Union, 2023). In mechanical recycling, batteries are first dismantled, then shredded, and valuable materials are sorted using classification processes (electrolyte residues are removed by pyrolysis). Finally, the black mass (Co, Ni, and Mn) is separated, allowing around 30% of the

[6] *mckinsey.com/de/news/presse/2023-01-16-batterien*.

materials to be recovered. Another form of recycling is pyrometallurgical recycling. The end product of this high-temperature process (300-1,500°C) is a metal alloy (Li, Co, Ni, Cu, Fe). Currently, 40-50% of the materials can be recovered this way, although an increase to around 80% appears possible with further measures, albeit at a high cost. Hydrometallurgy follows the mechanical (or possibly pyrometallurgical) routes mentioned above. Acid digestion and various extraction processes can further process the black mass. High-purity metal salts remain, which can be further separated. Combining the aforementioned recycling processes makes it theoretically possible to recover over 90 % of the materials, which is associated with higher costs and energy expenditure (Neef et al., 2021). An overview of the various recycling technologies can be found in Mohr et al. (2020). For post-lithium technologies, there are changing requirements for recycling, which can or must lead to an adaptation of available processes, as the recyclable material content in post-lithium systems is significantly lower (Weil, Baumann et al., 2020). Furthermore, whether there is a corresponding business case for these recycling processes (value of the recycled materials) must be examined. This poses major challenges for new battery systems in particular, such as NIBs, as their recyclable material content is particularly low. Ideally, batteries should therefore be optimised for recyclability right from the design stage ('design for recycling'). At the same time, second-life utilisation, e.g. in stationary storage systems, can increase the battery service life and thus delay the need for immediate recycling.[7]

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Economic potential for Austria

Austria aims to increase the share of electric vehicles from 21% to 100% by 2030.[8] In addition, there is an increased expansion of photovoltaic storage systems until 2040. ***Large-scale battery storage systems*** are primarily supported by research and demonstration projects. However, there are increasing commercial battery storage projects[9]. Furthermore, the EU Battery Regulation enforces stricter requirements to enhance the environmental compatibility of batteries throughout their life cycle. The topic of recycling is also becoming more prominent. There is a shortage of machinery, building materials, and labour necessary to establish battery production. Generally, scaling up production poses a significant challenge for the entire battery industry. Austria has a high scientific expertise in this area (e.g., AIT, Graz University of Technology). The Ministry for Climate Protection had initially selected six technologically leading industrial companies e.g., the VARTA research hub in Graz), and expanded by five more in 2024, as part of the IPCEI (Important Project of Common European Interest), a major project to promote the battery industry. In addition, there are well-trained specialists along the entire value chain.[10] With the growing global momentum in the battery market, Austria stands to benefit economically in the European context, thanks to the effective management of the value chain. The establishment of a circular

7 *epub.oeaw.ac.at/ita/ita-dossiers/ita-dossier079.pdf*
8 *austriatech.at/de/zahlen-daten-fakten-archiv/*.
9 *ess-news.com/2025/02/10/austria-commissions-its-largest-battery-storage-facility/*.
10 *bmimi.gv.at/themen/innovation/internationales/ipcei/aktive_teilnahmen/EuBatIn.html*.

battery value chain is not only an ecological necessity, but also an industrial policy opportunity for Austria as a business location. Moreover, coordination at a European level is essential for maintaining competitiveness, especially against activities in Asia and North America. In this context, geopolitical risks and trade restrictions and their impact on achieving the transition in transport or mobility must be considered, with special attention to the availability of raw materials.

PROPOSAL FOR FURTHER ACTION

What is needed for a sustainable battery value chain?

A TA study would need to assess the potential for developing relevant measures for research (e.g. concerning alternative technologies), production, and recycling of batteries. It is essential to understand which battery cycle strategies for different battery systems in the near and distant future are suitable for Austria. As part of this analysis, the entire value chain must be considered. The mapping of potential risks regarding Austria's supply of energy storage technologies for stationary and mobile applications seems essential. This must also encompass potential environmental impacts, social factors, and resource issues of energy storage systems.

REFERENCES

Baumann, M., et al. (2022). Prospective Sustainability Screening of Sodium-Ion Battery Cathode Materials. Advanced Energy Materials, 2202636. *.doi.org/10.1002/aenm.202202636.*

Choix, B., & Uhlig, F. (2021). Opinion of the European Economic and Social Committee on 'Sustainability requirements for batteries in the EU'. (COM(2020) 798 final - 2020/353 (COD)). *eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52021AE0122&from=EN.*

European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M., Veeh, C., *Study on the critical raw materials for the EU 2023 - Final report*, Publications Office of the European Union, 2023, *data.europa.eu/doi/10.2873/725585.*

European Union. (2023). Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC (EU). *eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1542.*

Liu, H.; Baumann, M.; Moon, H.; Zhang, X.; Dou, X.; Zarrabeitia, M.; Crenna, E.; Hischier, R.; Passerini, S.; Assen, N. von der; Weil, M. (2024). Life cycle assessment of bio-based hard carbon for sodium-ion batteries across different production scales. *Chemical Engineering Journal*, 495(153410). *doi:10.1016/j.cej.2024.153410.*

Mohr, M., Peters, J. F., Baumann, M., & Weil, M. (2020). Toward a cell-chemistry-specific life cycle assessment of lithium-ion battery recycling processes. *Journal of Industrial Ecology.* *doi.org/10.1111/jiec.13021.*

Mononen, T., Kivinen, S., Kotilainen, M., Leino, J. (2022). Social and environmental impacts of mining activities in the EU, Policy. Directorate-General for Internal Policies. *doi.org/10.2861/804163.*

Neef, C., Schmaltz, T., & Thielmann, A. (2021). Recycling of lithium-ion batteries: Opportunities and challenges for mechanical and plant engineering. Fraunhofer Institute for Systems and Innovation Research ISI.

Weil, M., Peters, J., & Baumann, M. (2020). Stationary battery systems: Future challenges regarding resources, recycling, and sustainability. In: The Material Basis of Energy Transitions (pp. 71-89). Elsevier. *doi.org/10.1016/B978-0-12-819534-5.00005-2.*

Weil, M., Ziemann, S., & Peters, J. (2018). The Issue of Metal Resources in Li-Ion Batteries for Electric Vehicles. In G. Pistoia & B. Liaw (Eds.), Behavior of Lithium-Ion Batteries in Electric Vehicles (pp. 59-74). Springer International Publishing. *doi.org/10.1007/978-3-319-69950-9_3.*

Yokoi, R.; Kataoka, R.; Masese, T.; Bach, V.; Finkbeiner, M.; Weil, M.; Baumann, M.; Motoshita, M. (2024). Potentials and hotspots of post-lithium-ion batteries: Environmental impacts and supply risks for sodium- and potassium-ion batteries. *Resources, Conservation and Recycling*, 204(107526). *doi:10.1016/j.resconrec.2024.107526.*

Ziegler, M. S., & Trancik, J. E. (2021). Re-examining rates of lithium-ion battery technology improvement and cost decline. *Energy & Environmental Science*, 14(4), 1635-1651. *doi.org/10.1039/D0EE02681F.*

PROTEIN TRANSITION – MAKING WIDESPREAD USE OF ALTERNATIVE PROTEIN SOURCES (UPDATED)

© CC0 (Chuttersnap/Unsplash)

SUMMARY

Protein turnaround: Reduction of animal products

Some European countries have already devised strategies to implement the protein transition, which aims to gradually decrease the consumption of animal protein while increasing the intake of alternative, primarily plant-based proteins. Such measures are also highly pertinent for Austria. Agriculture contributes approximately ten per cent of greenhouse gas emissions in Austria and is significantly impacted by the consequences of climate change. In Europe, roughly 70 per cent of agricultural emissions can be attributed to livestock farming. The protein transition could be a significant step towards lowering emissions, and a decrease in Austria's notably high meat and dairy consumption would also yield positive health benefits.

OVERVIEW OF THE TOPIC

Global hunger for protein, with simultaneous oversupply in Europe

Europe's population is very well supplied with protein; in some cases, more protein is provided and consumed per capita than is physiologically necessary or medically advisable. Adults should consume 0.8 g of protein per kilogram of body weight daily. In contrast, older individuals in their mid-60s should consume slightly more, according to the reference values of the Austrian Society for Health Nutrition.[1] In Austria, the average protein consumption is around 15% of the total diet, within the range of nutritional recommendations.[2] However, as in many industrialised countries, the population consumes too much meat and other animal products, too much from a health-physiological point of view, according to the Austrian Nutrition Report (2017), and too much for a climate-friendly food supply.

Meat consumption: three times more than recommended for men

Without reforms to the food system, the anticipated global demand for animal protein cannot be met sustainably (Henchion et al., 2021). Agriculture contributes roughly ten per cent of greenhouse gas emissions in Austria and is significantly impacted by the consequences of climate change. In Europe, approximately 70 per cent of agricultural emissions are due to livestock farming.[3] The reduction of greenhouse gas emissions in the agri-food industry has, to date, garnered little attention in climate policy strategies, where the greatest potential for mitigating emissions in this sector lies in the production, distribution, and consumption of animal products (Penker et al., 2023).

70 percent of agricultural emissions from livestock farming

Agricultural land is limited, yet its products are in demand in many areas. This leads to competition between the cultivation of food, feed, energy and raw materials (acatech, 2023). Meat production, in particular, is extremely resource-intensive; depending on the animal species, between four and ten kilocalories of feed are required for one calorie of meat, along with significant water and energy consumption. Cows can, for instance, utilise food unsuitable for human consumption (such as grass); however, if they are fed other feedstuffs (such as soy) or if land is used to cultivate these, it creates competition for land. The EU livestock sector heavily imports vegetable protein for animal feed, especially soybeans from Argentina, Brazil, and the USA. The connections between protein imports, deforestation, and the substantial greenhouse gas emissions from livestock farming, on the one hand, and the incorporation of plant proteins in the human diet, on the other, are becoming increasingly important.[4] The Austrian Protein Strategy outlines the potential and necessity of promoting the increased domestic cultivation of protein crops.[5] However, this mainly concerns a better and, thus, more independent supply of animal feed, which is especially important for meat and milk production.

Limited space: Plate-tank-trough competition

1 *oege.at/d-a-ch-reference-values/roof-proteins/.*
2 *broschuerenservice.sozialministerium.at/Home/Download?publicationId=528.*
3 *food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en#Strategy.*
4 *europarl.europa.eu/RegData/etudes/BRIE/2023/751426/EPRS_BRI(2023)751426_EN.pdf.*
5 *info.bml.gv.at/dam/jcr:bac47722-eb19-4342-a308-c9cc9fecdc48/Abschlussbericht%20Eiwei%C3%9Fstrategie.pdf.*

A balanced, sustainable, and healthy diet, along with reducing food loss and waste, presents significant opportunities for both the adaptation to and mitigation of climate change while yielding substantial benefits for biodiversity and human health (IPCC, 2023). The IPCC defines a diet as one composed of plant-based foods, such as cereals, legumes, fruits and vegetables, nuts and seeds, and animal-based foods produced in resilient, sustainable, and low-GHG systems. The scientific EAT-Lancet Commission developed the Planetary Health Diet, which summarises nutritional guidelines for the global population that should significantly enhance human health while ensuring adherence to planetary boundaries during production. The goal is to achieve a sustainable food system.[6]

Necessary climate protection through a balanced diet

To provide animal products at a low cost, livestock farmers have endeavoured to enhance productivity (improving breeds, optimising compound feed, etc.). However, this pursuit of productivity has resulted in animals being kept in cramped spaces under unsuitable conditions (Takefuji, 2021). Increasing the production of plant-based and alternative proteins could help challenge the dominant factory farming system and may even render it superfluous in the long run.

Abuses in animal welfare

Plant plants or microorganisms can produce alternative proteins (unicellular bacteria, algae, fungi) (see also *cell factories*). Animal-free milk protein can be generated through fermentation using microorganisms. Numerous companies concentrate on the fermentation of animal-free meat, eggs, or dairy products (Takefuji, 2021). In plant-based protein products, protein is extracted from plants and combined with other plant-derived ingredients to make the product as meat-like as possible. Microbial protein, referred to as single-cell protein (SCP), indicates that microbial cells are cultivated (cell cultures) and harvested (Takefuji, 2021). Overall, the development of alternative products that closely match the nutritional and sensory properties of conventional products remains a significant challenge. Furthermore, insufficient safety assessments and unclear legal standards lead to confusion in the food industry, hindering progress (Malila et al., 2024). Additionally, highly processed foods are increasingly linked to adverse health effects (Lane et al., 2024).

More plant-based and alternative proteins: Bacteria, yeasts, fungi and algae

Fermentation

The use of genetically modified bacteria and fungi for producing microbial proteins has progressed rapidly due to the development of new genetic engineering tools like CRISPR. In industrial biotechnology, this process is also known as precision fermentation. This topic is not as contentious as genetically modified crops, mainly involving closed systems. However, it attracts social attention, particularly due to potential health risks. There is ongoing controversy over whether such products fall under GMO Regulation since consumers do not consume the organism itself but rather the protein derived from it, for instance.

Tailor-made microorganisms and enzymes produce protein.

Microbially produced proteins are derived from fermentation processes involving bacteria, yeasts, algae, and fungi. This form of protein is already utilised in animal feed, and there is increasing interest in its application for human consumption. Low environmental impacts, such as a low land requirement and only about 10% of the water consumption compared to soy cultivation, show the potential. However, microbial protein production consumes substantial amounts of energy and

Low space requirement but currently high energy requirement

6 *thelancet.com/commissions/EAT.*

necessitates rigorous toxicological testing, which currently restricts its widespread application. Enhanced energy efficiency and improved production processes could eliminate these limitations (EPRS, 2023). Increased food production in bioreactors and vertical farming could help make large urban regions more self-sufficient.

Mushroom mycelium as a pioneering source of protein

Multicellular fungi contain various bioactive molecules that are not, or only insufficiently, present in plant and animal foods and are considered ***functional foods*** to prevent multiple human diseases (Bell et al., 2022). They are recognised for their high nutritional value, such as their high protein, low fat, and low energy content. Furthermore, they are regarded as the most underutilised and known nutritious food resource (Kumar et al., 2021). The fruiting bodies of mushrooms have always been an integral part of the human diet, and recently, the mushroom mycelium growing underground has gained increasing importance in the production of new foods. Foods produced through the fermentation of mushroom mycelium are a high-quality alternative to animal proteins, which can also facilitate the upcycling of food waste in a circular economy (Molitorisová & Monaco, 2023). Recent research has demonstrated that many edible mushroom strains can be cultivated in liquid cultures, producing high levels of biomass and a variety of bioactive compounds such as proteins, enzymes, lipids, and carbohydrates safely for use in the food industry (Bakratsas et al., 2021).

Insects as efficient converters of residual and waste materials into high-quality protein and fat

Insects as food and feed have recently gained significance as a sustainable strategy for protein production in recirculating systems. For instance, mealworms are regarded as efficient biomass converters that produce protein from low-value by-products such as wheat bran or brewing residues (Derler et al., 2021). Whether insects will emerge as a significant source of protein for humans and livestock remains controversial, as the sustainability of their breeding largely depends on their feeding practices. (acatech, 2023). Nonetheless, certain production methods for extracting fat and protein from insects use less land and water while emitting significantly fewer greenhouse gases and ammonia. Insects have traditionally been consumed in Asia, Africa, and South and Central America, where they are either farmed or harvested from the wild and are integral to the traditional diet. In Europe, the primary obstacle to implementation appears to be consumer acceptance; however, the behaviour of European consumers regarding edible insects has only recently been examined, making it challenging to evaluate (Mancini et al., 2019).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Austrian strategy for the protein transition

Experts widely agree that while many civil society actors and scientists advocate for an integrative food policy aligned with climate targets, this conflicts with interests aiming to preserve the status quo, the existing trade system, and the current structure of EU agricultural policy (Penker et al., 2023). Promoting more plant-based diets is relatively new in food policy; thus, few policy goals and timelines for their implementation have been established. However, without such political commitments, regulated implementation is challenging (Quack et al., 2023). Overall, microbial proteins are fairly well established in EU legislation and are bolstered by research policy. However, the market for microbial proteins cannot grow without economic measures to promote sustainable and healthy food production. The EU has implemented various initiatives to improve access to funding and markets and enhance the competitiveness and innovation of small and medium-sized enterprises.[7] Denmark[8] and the Netherlands[9] have already developed strategies to implement the protein transition, which aims to gradually reduce the consumption of animal protein and increase the consumption of alternative, mainly plant-based proteins. Such measures are also relevant for Austria.

PROPOSAL FOR FURTHER ACTION

FTA Study as an overview on technologies, products and players

Most alternative protein pathways involve specific technological choices and the associated expectations and promises regarding their benefits for sustainability, health, and animal welfare. A societal shift towards alternative proteins could have profound implications for land use, environmental impact, and food consumption. Long-term strategic decisions must be based on a continually updated, well-founded overview of the ecological footprints of actual products and processes, along with an assessment of future innovations that can be anticipated. This could be achieved through a comprehensive FTA study involving stakeholder participation. The transformation of protein production and consumption cannot be isolated; it necessitates cross-sectoral cooperation across entire supply chains and coordination of private and political decision-makers.

7 *europarl.europa.eu/RegData/etudes/ATAG/2022/729539/EPRS_ATA(2022)729539_EN.pdf.*
8 *gfieurope.org/blog/denmark-publishes-worlds-first-national-action-plan-for-plant-based-foods/.*
9 *wur.nl/en/newsarticle/five-major-players-launch-masterplan-for-protein-transition-as-economic-engine-in-the-netherlands.htm.*

REFERENCES

acatech. (2023). *Sustainable agriculture*. Retrieved from **acatech.de/publikation/acatech-horizonte-nachhaltige-landwirtschaft/**.

Bakratsas, G., et al. (2021). Recent trends in submerged cultivation of mushrooms and their application as a source of nutraceuticals and food additives. *Future Foods, 4*, 100086. **doi.org/10.1016/j.fufo.2021.100086.**

Bell, V., et al. (2022). Mushrooms as future generation healthy foods. *Frontiers in Nutrition, 9*. doi:10.3389/fnut.2022.1050099.

Derler, H., et al (2021). Use Them for What They Are Good at: Mealworms in Circular Food Systems. *Insects, 12*(1). doi:10.3390/insects12010040

EPRS. (2023). *EU protein strategy*. Retrieved from **europarl.europa.eu/RegData/etudes/BRIE/2023/751426/EPRS_BRI(2023)751426_EN.pdf**.

Henchion, M., et al (2021). Review: Trends for meat, milk and egg consumption for the next decades and the role played by livestock systems in the global production of proteins. *Animal, 15*, 100287. **doi.org/10.1016/j.animal.2021.100287.**

IPCC. (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.

Kumar, K., et al (2021). Edible Mushrooms: A Comprehensive Review on Bioactive Compounds with Health Benefits and Processing Aspects. *Foods, 10*(12), 2996.

Lane, M. M., et al. (2024). Ultra-processed food exposure and adverse health outcomes: umbrella review of epidemiological meta-analyses. *BMJ, 384*, e077310, **bmj.com/content/bmj/384/bmj-2023-077310.full.pdf**.

Malila, Y., et al. (2024). Current challenges of alternative proteins as future foods. *npj Science of Food, 8*(1), 53, **doi.org/10.1038/s41538-024-00291-w**.

Mancini, S., Moruzzo, R., Riccioli, F., & Paci, G. (2019). European consumers' readiness to adopt insects as food. A review. *Food Research International, 122*, 661-678. **doi.org/10.1016/j.foodres.2019.01.041.**

Molitorisová, A., & Monaco, A. (2023). *Innovating Food Law With Mycelium: EU Regulations*. Frankfurt am Main: Fachmedien Recht und Wirtschaft (Schriften zum Lebensmittelrecht; 46).

Penker, M., Brunner, K.-M., & Plank, C. (2023). Nutrition. In C. Görg, et al. (Eds.), *APCC Special Report: Structures for climate-friendly living (APCC SR Climate-friendly living)*: Springer Spektrum: Berlin/Heidelberg.

Quack, D., Wunder, S., Jägle, J., & Meier, J. (2023). Development of policy approaches to support more plant-based diets. Partial report (WP3) of the project Sustainable Economy: Socio-ecological Transformation of the Food System (STErn) Retrieved from **umweltbundesamt.de/publikationen/entwicklung-von-politische-handlungsansaetzen-fuer**.

Takefuji, Y. (2021). Sustainable protein alternatives. *Trends in Food Science & Technology, 107*, 429-431. **doi.org/10.1016/j.tifs.2020.11.012.**

FOREST: FIRES AND RESTORATION (UPDATED)

© CC0 (Karsten Winegeart/unsplash)

SUMMARY

On average, more than 200 forest fires occur in Austria each year, most of which are directly or indirectly caused by humans. Forest fires impose significant ecological, economic, and social costs. Due to climate change, the number of fires has increased substantially in recent decades, and a further rise in fire risk is quite likely because of prolonged droughts and heat waves. Fifty per cent of Austria's forests consist of spruce trees, particularly fire-resistant. Technological advancements in fire prediction and control, along with heightened public awareness of the issue, can aid in reducing the risk of forest fires. The recolonisation of burnt areas is an extremely dynamic process; in the future, other species, more deciduous trees, and modified reforestation strategies will be essential.

Climate change: More fires require new strategies.

OVERVIEW OF THE TOPIC

Austria-wide 85 % of forest fires, directly or indirectly, are man-made

The Austrian forest fire database displays all recorded forest fires and differentiates between natural, man-made, and unknown fire causes.[1] So far, in 2023, over one hundred fires have been recorded across Austria, with human activity being the primary cause. In 2024, 129 forest fires were documented, of which approximately 80% were directly or indirectly attributed to human actions (the long-term average is 85%, and around 90% of forest fires globally are man-made). Typical causes of fires include uncontrollable blazes, discarded cigarettes (likely the most common cause), flying sparks from railways, severed power lines, arson (approximately 10%), hot ashes, shooting practice and fireworks.[2] Contrary to popular belief, glass bottles and shards of glass are unlikely to cause fires (T. Müller, 2007). Lightning is Austria's only relevant natural cause of forest fires, accounting for around 15 % of cases. Only in a few cases is the cause of the fire unknown.

Fire hazard: The condition of the forest, weather and topography are decisive.

Alongside fuel, weather and topography play a crucial role in the behaviour of forest fires. The moisture content of leaves, needles, grass, and other debris on the ground determines the risk of a fire igniting; however, a trigger is always necessary. The greatest fire risk arises after prolonged periods of drought, particularly in high temperatures and strong winds (e.g., foehn). Geosphere Austria (formerly ZAMG) assesses the current meteorological forest fire risk based on weather data, which provides very accurate estimates in the summer months. However, the accuracy decreases in the cooler seasons, and the assessment is also limited to the mountains.[3]

Climate change: forest fires are also increasing in the Alps

Climate change is leading to rising temperatures across land masses, resulting in prolonged periods of stable weather conditions, which in turn causes exceptionally hot and dry summer spells. When these conditions coincide with already parched soils and drier-than-usual forests and meadows, the risk of forest fires significantly increases (Henner & Kirchengast, 2021). The annual number of forest fires has nearly doubled since the 2000s. Increased hot days and more pronounced dry periods, driven by human-induced climate change, are the primary factors contributing to the heightened risk of forest fires in Austria, which is also expected to rise. Furthermore, the increase in recreational activities in the Alpine region and the closer integration of natural areas with settlements also play a significant role in this issue (Müller et al., 2020).

Comparison with Southern Europe or North America is only possible to a limited extent.

Although fires occur more frequently in April and at the height of summer, this country does not have a distinct forest fire season like southern Europe or North America. The distribution of forest fires can vary significantly depending on the prevailing weather conditions in each season. Additionally, the forest structure here is much more fragmented and well-connected by forest roads, making it considerably easier to combat fires. Fires also encounter barriers relatively quickly, preventing them from spreading effectively.

---

1 *fire.boku.ac.at/firedb/de/*.
2 *boku.ac.at/oekb/wald/forschung/themen/bewirtschaftungskonzepte/waldbewirtschaftung-und-klimaaenderung/waldbrand*.
3 *zamg.ac.at/cms/en/weather/weather-oesterreich/waldbrand* (only with login).

High damage and costs – in the short and long term

Nevertheless, significant damage occurs yearly, and the associated long-term costs can only be partially captured economically. Substantial direct costs arise from firefighting, the equipment and maintenance of fire departments, the loss of timber, reduced income for affected forest owners, and the renaturation measures for burnt areas. Forest fires compromise the protective role of mountain forests, increasing their susceptibility to natural hazards such as avalanches and mud-flows. Natural resources are lost, agricultural and forestry land is devastated, and the potential for subsequent soil erosion diminishes the quality and fertility of the soil, resulting in reduced productivity. Additionally, in some cases, air quality is significantly worsened by the pollutants released, leading to both short- and long-term health damage, contributing to the already strained health system—a burden that cannot be ignored in the future. Such health damage is also unevenly distributed across the global population (Xu et al., 2023). Increased Information on health protection for the population during major fires could encourage people to wear masks, use air filters, or stay at home, for instance. Last but not least, significant amounts of greenhouse gases are released, indicating that increased forest fires are both a consequence and a driver of climate change.

Border areas of forests and urban space are becoming more explosive

In other countries, areas where forest vegetation directly adjoins settlements and infrastructure—such as on the outskirts of many cities—are particularly critical zones, as the likelihood of forest fires occurring is very high, with significant damage expected simultaneously. These areas could also become more problematic in Austria in the future.

The Forest Fire Action Programme of the Federal Ministry of Agriculture, Forestry, Regions and Water Management defines specific short-, medium-, and long-term measures across three target corridors: researching and understanding forest fires; preventing and combating forest fires collaboratively; and disseminating and implementing knowledge about forest fires. These measures address seven fields of action, from creating harmonised databases to targeted investments in firefighting and focused education offers.[4]

R&D of new Forest fire fighting technologies

Numerous research and development activities are exploring new technologies for forest firefighting. For example, unmanned, remote-controlled, or automated vehicles and aircraft (such as firefighting drones) could bolster firefighting efforts. Additionally, 5G antennas installed on drones can enhance mobile radio networks during operations, while unmanned gliders can provide real-time imagery to support emergency services (Czerniak-Wilmes & Jetzke, 2023).

Prevention through improved AI prediction

The AI-supported evaluation of complex environmental data from satellite or drone-based remote sensing has significantly advanced in predicting forest fires in recent years (see also ***Remote sensing with AI***). However, predicting the likelihood of a fire often entails significant decisions with numerous consequences. Particularly in the public sector, the traceability and transparency of models may become increasingly important, for instance, regarding liability issues. Initial studies have now demonstrated that applications using explainable AI models yield positive outcomes in fire prediction. Explainable AI models could be incorporated into

4 *schutzwald.at/dam/jcr:25eb5825-44e7-4a6e-9460-5b38977a085c/BML_Publikation_A4_Aktionsprogramm-Waldbrand_V03_WEBVERSION_barrierefrei-1.pdf*.

decision support systems, especially when human and natural environments are closely connected. For instance, AI could assist forest administrations in preventing and mitigating forest fire disasters while also aiding in developing strategies for effective fire management, response to areas after fires, and enhancing their resilience (Cilli et al., 2022). An important risk mitigation strategy is to establish an effective wildfire detection system that can immediately notify the relevant authorities upon detection. Studies show that the application of deep learning models in wildfire monitoring is promising, achieving accuracy rates of over 90% (Saleh, 2024). Digital twin technology could become a valuable tool for improving wildfire prevention and monitoring, emergency response and post-fire recovery efforts. By creating virtual models of wildfires that reflect real-world conditions, a digital twin platform enables the integration of data from multiple sources - including remote sensing, weather forecasts and ground-based sensors - providing a comprehensive perspective to support emergency response and informed decision-making (Li, 2024).

Prevention through changed forest management

The requirements for forest management are evolving in the new climate change regime. For example, the resilience of native forests can be enhanced by encouraging fire-resistant, site-adapted tree species. (Müller et al., 2020). Deciduous and mixed forests, for instance, are less flammable than coniferous forests. Approximately 50% of Austrian forests are composed of spruce trees, which are especially vulnerable to fire and bark beetles. The proportion of spruce is anticipated to decline, particularly in lower region altitudes.[5] Research into and the promotion of more climate-resistant forest species and forest management methods are considered priorities for future studies (Henner & Kirchengast, 2021).

High knowledge requirement for restoration

In Central Europe, fires have ravaged extensive forest areas in recent years, and the risk is expected to escalate. However, relatively little is known about succession, meaning the regrowth of various species, reforestation, and the effects of forest management in this region. A recent study revealed that natural regrowth is more effective than artificial reforestation (Schüle et al., 2023).

Natural regrowth and more deciduous trees than pioneers

The recolonisation of burnt areas is a highly dynamic process that depends on various factors. In many instances, however, natural regeneration provides a rapid and cost-effective method of reforestation, which appropriate silvicultural measures can enhance. Schüle et al. (2023) recommend leaving surviving trees on site as green islands to create nearby seed sources. Disturbance of seedlings should be avoided, so forest management should be carried out according to the life cycles of naturally grown tree seedlings. Primarily, the benefits of deciduous pioneer trees ought to be utilised to establish more diverse, less fire-prone forests in the long term following forest fires.

Proposed solutions for the new conditions in the European Alpine region include adapting firefighting measures and technologies, for instance, during times of water shortage (see also *drought resilience*) or the deployment of controlled technical fires; advocating for specialised emergency forces to assist local emergency services; and ensuring prompt and effective air support (Müller et al., 2020).

5 *fireblog.boku.ac.at/2021/05/12/brandgefaehrdete-fichte/.*

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Research on specific forest fires, including prevention and combating efforts, has already been incorporated into the Forest Action Programme (see above), which thus addresses the increasing risk in a forward-looking manner. Further research is required, especially regarding restoring burned areas; conventional reforestation methods may need to be reassessed, and traditional coniferous species might have to give way to more resilient deciduous trees. It would also be sensible to adopt a broader perspective on the topic, as, in addition to ecological and economic effects, increased fires also have a wider social impact, particularly if natural and residential areas become more closely intertwined in the future. The long-term consequences of increased fires should be realistically factored into existing budgets, such as the anticipated growing burden on the healthcare system due to climate change impacts like forest fires. More attention is needed on strategies that better consider the health protection of populations affected by major fires.

PROPOSAL FOR FURTHER ACTION

Assessment of new firefighting technologies, reforestation strategies

From an FTA perspective, it would be beneficial to evaluate the current research and development status in new and adapted forest firefighting technologies and strategies to establish a stronger knowledge base for informing research policy decisions. About the new reforestation measures, a comprehensive stakeholder process would be beneficial, allowing for the collection of insights beyond academic sciences, such as from private forest owners or nature conservation organisations.

REFERENCES

Cilli, R., et al. (2022). Explainable artificial intelligence (XAI) detects wildfire occurrence in the Mediterranean countries of Southern Europe. *Scientific Reports, 12*(1), 16349, ***doi.org/10.1038/s41598-022-20347-9.***

Czerniak-Wilmes, J., & Jetzke, T. (2023). Forest Fire Fighting Technologies, TAB, Topic Brief No. 60, ***dx.doi.org/10.5445/IR/1000156299.***

Henner, D. N., & Kirchengast, G. (2021). How does climate change increase the risk of forest fires in Austria? KKL-ÖAW Study Report.

Li, Y., et al. (2024). Review and perspectives of digital twin systems for wildland fire management. *Journal of Forestry Research*, *36*(1), 14, ***doi.org/10.1007/s11676-024-01810-x***.

Müller, M. M., et al. (2020). Forest fires in the Alps - State of knowledge, future challenges and options for an integrated fire management. Fully revised German version of the original: Forest fires in the Alps - State of knowledge, future challenges and options for an integrated fire management, ***alpine-region.eu/sites/default/files/uploads/result/2233/attachments/200717_waldbraendealpen_weissbuch_final_online_austria.pdf***.

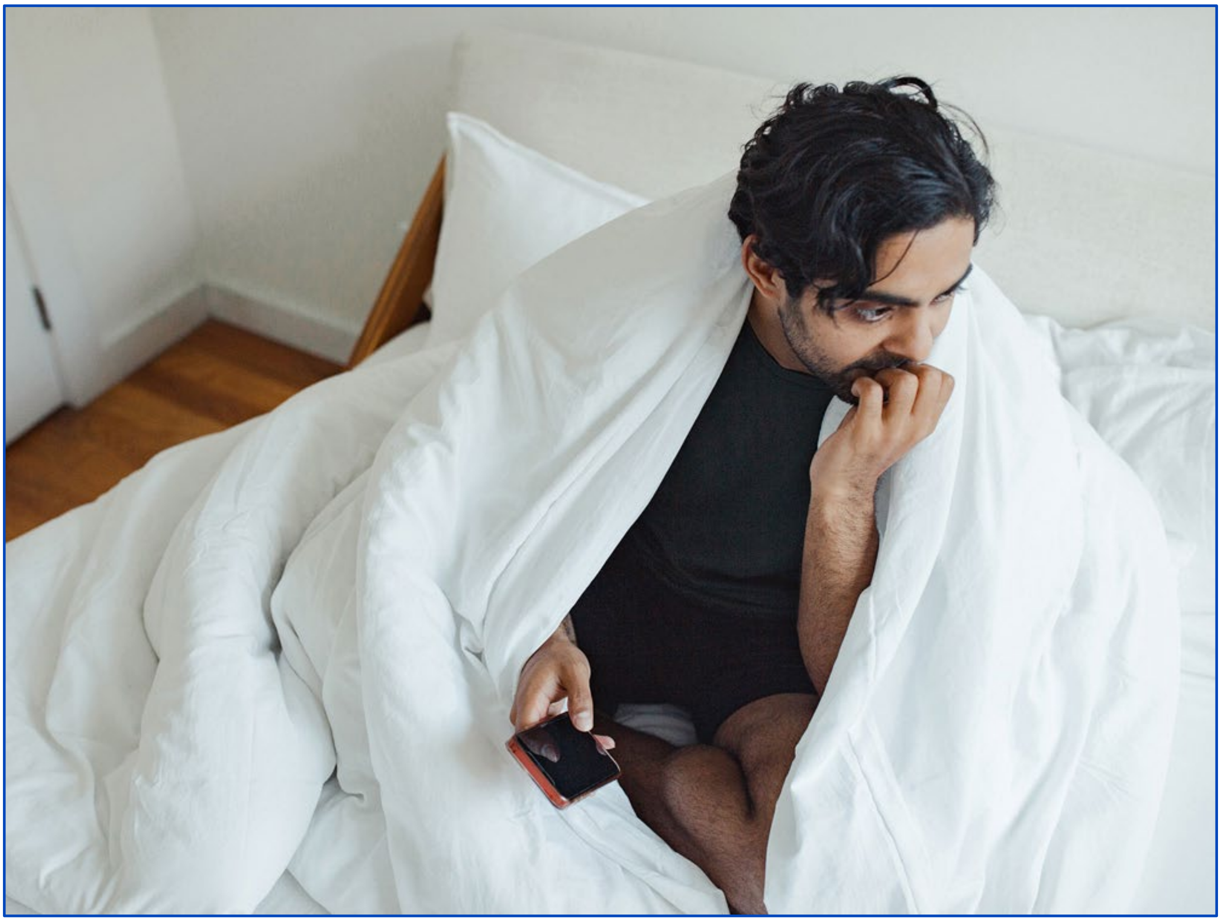
Müller, T. (2007). Does glass cause forest fires? (Diploma thesis). TU Braunschweig, ***soil.tu-bs.de/download/downloads/pubs/2007.AFZ-18-990-TMueller-Verursacht-Glas-Waldbraende.pdf***.

Saleh, A., et al. (2024). Forest fire surveillance systems: A review of deep learning methods. *Heliyon*, *10*(1), ***doi.org/10.1016/j.heliyon.2023.e23127***.

Schüle, M., et al. (2023). Early natural tree regeneration after wildfire in a Central European Scots pine forest: Forest management, fire severity and distance matters. *Forest Ecology and Management*, *539*, 120999, ***ciencedirect.com/science/article/pii/S0378112723002335***.

Xu, R., et al. (2023). Global population exposure to landscape fire air pollution from 2000 to 2019. *Nature*, *621*(7979), 521-529, ***doi.org/10.1038/s41586-023-06398-6***.

HEALTH CONSEQUENCES OF DIGITALISATION (UPDATED)



© CC0 (Karsten Winegeart/unsplash)

SUMMARY

What consequences does problematic use of digital media have on health?

Mobile phones today are predominantly smartphones, and children receive their first devices at an increasingly younger age. Most children possess their smartphones from school year 3 onwards. These devices capture the attention of young people in particular (though adults are also affected); their presence and the need to focus on them interrupt nearly every other activity. Research has shown notable physical and, especially, psychological difficulties and even illnesses that can arise from excessive smartphone use, whether in duration or frequency. It is essential to equip children to engage with digital media in a health-conscious way by incorporating the beneficial use of these tools into education and training.

OVERVIEW OF THE TOPIC

Do we need a "cell phone ban"?

In Austria, a ban on mobile phones and similar devices in schools up to the eighth grade has been in force since 1 May 2025[1]. This came after lengthy discussions about a general ban, with opposing voices expressing doubts about its usefulness[2] and enforceability. In the discussion surrounding "mobile phone bans," two extreme positions often arise: a return to a "healthy" childhood of the past, devoid of the internet and smartphones, versus a long-overdue modernisation. Ultimately, however, the situation must be viewed much more nuancedly. Not everything in the past benefited children, and digitalisation has brought numerous advantages; thus, turning back the clock is neither sensible nor feasible. In recent years, numerous studies have explored the health consequences of digitalisation processes, particularly in communication. However, several unanswered questions remain because of the lack of long-term studies.

How does digitalisation change schools and students?

Digitalisation brings numerous changes, not all of which can be considered detrimental. This development causes uncertainty and imposes excessive demands on parents and teachers. At the same time, students face increasing social pressure to engage with digital media more frequently, even as they lack the essential skills to navigate these platforms and their implications content.[3]

Why are smartphones important for young people?

Smartphones mean something different to young people who have grown up with smartphones - so-called cellular natives (Rosenberg & Blondheim 2025) - than they do to older people.[4] While those who did not grow up with smartphones use them primarily for communication, photography, setting alarms, accessing information, or entertainment, their usage has shifted or expanded among younger individuals. On the one hand, it serves as a window to a world where children can embark on a journey of discovery without their parents.[5] On the other hand, significantly more communication occurs via smartphones, particularly during adolescence. However, this facilitates the exchange of information and forms a virtual group to which you belong when you are available and from which you feel excluded when offline. It is like a mutual assurance of being present (cf. the concept of "co-presence", e.g., Urry 2002). This device allows for much more self-expression among young people than is true for older generations. This makes it particularly challenging to withdraw the device from younger individuals.[6]

What is nomophobia?

Nomophobia[7] is a portmanteau term for "no mobile phone phobia" that has been around since 2008. It outlines the symptoms of anxiety and withdrawal that arise when devices are faulty, the battery is depleted, or there is a lack of network

---

1 *bmb.gv.at/Themen/schule/zrp/dibi/saferinternet/faq_handy.html*.
2 *edu.de/lp/smartphones-in-schulen.*
3 Digital Economy and Society Index (DESI) of the European Commission, Country profile Austria 2022: .*digital-strategy.ec.europa.eu/de/policies/desi-austria*
4 *elternguide.online/jugendliche-und-ihr-smartphone/*.
5 Wagner describes this as a "secret garden" in "The Digital Generation" (p. 22).
6 For the consequences of media exposure in early childhood, see GAIMH 2022.
7 For the causes, see Vagka 2023; related: FOMO - fear of missing out.

coverage, resulting in users being unable to go online and reachable. [8] Nomophobia can be viewed as the consequence of an addiction to smartphones, presenting symptoms akin to those of other non-substance-related addictions. Nomophobia has not yet been included in the DSM-5[9] but has been proposed as a "specific phobia" based on specifications from DSM-4 (Bragazzi 2014) and described as a syndrome, which is often based on other mental health conditions. The ICD-11[10] does not include nomophobia either, but since the last edition, it has included gaming disorder alongside internet addiction. As Turkle (2011) explains, people also hide behind the "wall" of technology to avoid social (and therefore synchronous) contact with others.

Smartphone abstinence rated positively by young people

Recent studies paint a more nuanced picture of the characterisation of smartphone use as an addiction. For example, an experiment involving 80 Israeli adolescents showed that 79 of the test subjects surprisingly lasted a whole week without a smartphone, despite some of the study participants labelling themselves as 'addicted' (Rosenberg & Blondheim 2025). The authors explain this surprisingly high rate by the fact that other forms of satisfaction emerged in the course of the 'withdrawal', for example through more intensive interactions with the immediate social and physical environment: 'new' opportunities for exchange with classmates, family members and a more attentive perception of the environment, but also better concentration on lessons. After the 'withdrawal', participants reported that they missed the time without a smartphone - which emphasises the other forms of satisfaction without a smartphone.

The health consequences of problematic user behaviour

Excessive use (duration and frequency) of cell phones and social media impacts health (BMSGPK 2020; for the internet, see EPRS 2019). There is a clear positive correlation between insufficient exercise and extended daily screen and smartphone usage (Quehenberger 2020), as well as between intensive smartphone use and a generally unhealthy lifestyle (Koivusilta 2005). If this behaviour becomes chronic, the lack of exercise leads to further consequences, such as obesity, cardiovascular disease, and, during adolescence, when exercise is particularly important, mental health issues. Furthermore, myopia appears to be increasing in the population, which is attributed to more time spent in front of a screen and less time engaged in outdoor activities nature.[11] There is also evidence of reduced life satisfaction with frequent use of cell phones (Volkmer 2019). The causality here remains unclear. Existing mental health issues may prompt an increased search for emotional relief through contact with friends and family via smartphones, which initially triggers the negative consequences associated with high screen time.[12] Walsh et al. (2018) report that screen time exceeding two hours each day also adversely affects children's cognitive development. Adolescents

8 *theguardian.com/technology/2023/sep/11/lost-your-phone-and-feel-your-lifes-falling-apart-youve-got-nomophobia*

9 Diagnostic and Statistical Manual of Mental Disorders (ed.: APA - American Psychiatric Association).

10 International Statistical Classification of Diseases and Related Health Problems (ed.: WHO – World Health Organization).

11 PostNote 653 (2020): Screen use and health in young people, *researchbriefings.files.parliament.uk/documents/POST-PN-0635/POST-PN-0635.pdf*.

12 Compare here also Schmutzer's (1994, ch. 8) description of technology as a social substitute.

predominantly use smartphones for social media. There are also correlations with clinical issues arising from these platforms' interactions and problematic use. This promotes the development of depressive episodes and even depression, with a heightened risk of suicide. Eating disorders and low self-esteem are also intensified (BMSGPK 2020). Cyberbullying, grooming, hate speech, and other such problematic online behaviours can also be psychologically stressful. More recent studies also confirm the assessment that heavy use of smartphones and social media has a negative impact on young people's health (Goodyear et al. 2025).

High psychological stress among young people

This must also be viewed against the backdrop of the pandemic, during which young people were already facing significant pressure due to these circumstances. Lockdowns, social distancing, homeschooling, and similar measures have altered the status of smartphones and their usage, contributing to a "forced" change in behaviour. Distinguishing pathological behaviour, addiction, and new cultural practices is the focus of research. In any case, young people are subjected to numerous factors that result in significant psychological stress, while concurrently, there is a severe shortage of psychiatric and therapeutic care in Austria.

Demographic factors

However, all age groups can be susceptible to potential addiction. The highest risk occurs during adolescence, which decreases slightly with age. Individuals with a higher education and income level tend to be less affected than other segments of the population. However, a lack of proficiency in handling digital media can be observed across the entire population (BMSGPK 2020).

Smartphone ban at schools alone has little positive impact on health

While acknowledging the positive effects of networking, direct telecommunications, and rapid access to knowledge, we must not only consider these alongside the disadvantages of fake news and cyberbullying, but we also need to closely examine their health effects and impacts on child development, aiming for a health-conscious use of digital media. A recently published study investigated the impact of smartphone bans in schools on the mental health of adolescents (Goodyear et al. 2025). The study found no difference in smartphone and social media use or mental health between the comparison groups. Although use at school differed, use outside of school was likely not reduced. However, the study did not investigate whether school behaviour such as direct interactions or bullying improved as a result of the ban. It is therefore questionable whether smartphone bans at school are successful on their own. Instead, use outside of school should also be taken into consideration.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Duty of care and prevention

Health, particularly that of children and young people, should be regarded not only as a matter of the state's duty of care but also as a preventative measure to avoid high costs in the healthcare system in the future, such as prolonged periods of sick leave and substantial treatment costs for mental health illnesses). However, additional measures are needed to enable a desirable childhood and youth. With the above-mentioned ban on smartphones in schools, the current German government has recently created a new framework in an important area of children's and young people's lives.

Lack of effectiveness of current consumer protection

At EU level, various consumer protection regulations have been evaluated to determine whether they provide sufficient protection in the digital environment[13]. Special attention was also paid to so-called 'dark patterns' and addictive usage patterns. The evaluation concluded that the current regulations only have limited effectiveness. Austria could actively contribute to the ongoing discourse at EU level in order to increase their effectiveness.

PROPOSAL FOR FURTHER ACTION

Closing knowledge gaps and improving skills

A comprehensive TA study would be advantageous, uniting the fragmented knowledge on the subject from various disciplines, emphasising gaps in understanding, and identifying the specific challenges faced in Austria. This study could provide a foundation for decision-making regarding further research or regulatory and promotional measures across various sectors, such as adult education and preventive healthcare initiatives. Moreover, the absence of long-term studies can be addressed by commissioning a regular survey on the characteristics of problematic behaviour and general (mental) health. In particular, the ban on smartphones in schools should be evaluated to determine the extent to which it actually leads to better health for children and young people (see UK study above), or at least an improvement in the situation in the school context.

REFERENCES

BMSGPK (Felder-Puig, R., et al.) (2020): Use of smartphones and social media by Austrian pupils, IfGP, Vienna, *ifgp.at/cdscontent/load?contentid=10008.740264&version=.*

Bragazzi, N., Del Puente, G. (2014): A proposal for including nomophobia in the new DSM-V. Psychology research and behaviour management, 7, 155-160, *doi.org/10.2147/PRBM.S41386.*

EPRS - European Parliamentary Research Service, Scientific Foresight Unit (STOA, Authors: Lopez-Fernandez, O., Kuss, D. (2019): Part I: Internet addiction and problematic use, *europarl.europa.eu/RegData/etudes/STUD/2019/624249/EPRS_STU(2019)624249_EN.pdf*.

GAIMH - German Speaking Association for Infant Mental Health (ed.) (2022): Position paper: Digital media and early childhood, self-published, Vienna.

Goodyear, V. A., Randhawa, A., Adab, P., Al-Janabi, H., Fenton, S., Jones, K., Michail, M., Morrison, B., Patterson, P., Quinlan, J., Sitch, A., Twardochleb, R., Wade, M., & Pallan, M. (2025): School phone policies and their association with mental wellbeing, phone use, and social media use (SMART Schools): A cross-sectional observational study. *The Lancet Regional Health - Europe*, *51*, 101211. *doi.org/10.1016/j.lanepe.2025.101211*.

Koivusilta, L., Lintonen, T., Rimpelä, A. (2005): Intensity of mobile phone use and health-compromising behaviours-how is information and communication technology connected to health-related lifestyle in adolescence?, Journal of Adolescence, Vol. 28, Issue 1, pp. 35-47, *doi.org/10.1016/j.adolescence.2004.05.004.*

[13] *ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13413-Digitale-Fairness-Eignungsprufung-des-EU-Verbraucherrechts_de*.

Quehenberger, V., et al. (2020): Health-competent smartphone use. Helpful tools for parents, children and adolescents, IfGP, Vienna, *ifgp.at/cdscontent/load?contentid=10008.739660&version=.*

Rosenberg, H., & Blondheim, M. (2025): What (missing) the smartphone means: Implications of the medium's portable, personal, and prosthetic aspects in the deprivation experience of teenagers. *The Information Society*, 1–17. *doi.org/10.1080/01972243.2025.2490487*.

Schmutzer, M.E.A. (1994): Ingenium und Individuum - Eine sozialwissenschaftliche Theorie von Wissenschaft und Technik, Springer, Vienna/New York.

Turkle, S. (2011): Alone Together: Why We Expect More from Technology and Less from Each Other; Hachette UK/London.

Urry, J. (2002): Mobility and Proximity, Sociology, 36(2), 255-274. *doi.org/10.1177/0038038502036002002.*

Vagka, E., et al. (2023): Prevalence and Factors Related to Nomophobia: Arising Issues among Young Adults. Eur. J. Investig. Health Psychol. Educ. 2023, 13, 1467-1476. *doi.org/10.3390/ejihpe13080107.*

Volkmer, S. A., Lermer, E. (2019): Unhappy and addicted to your phone? - Higher mobile phone use is associated with lower well-being; Computers in human behavior, 93, 210-218, *doi.org/10.1016/j.chb.2018.12.015.*

Wagner, L. (2019): Die Generation Digital, Leykam, Vienna/Graz.

Walsh, J., et al. (2018): Associations between 24 hour movement behaviours and global cognition in US children: a cross-sectional observational study, The Lancet Child and Adolescent Health, 2(11), *doi.org/10.1016/S2352-4642(18)30278-5.*

COLLABORATIVE INDUSTRIAL ROBOTS (UPDATED)

© CC0 (Thomas Bayer/DALL-E)

SUMMARY

Robots play a crucial role in the automation of industrial production. Until now, most have been installed within their safety zones to avoid endangering employees. The ongoing development of collaborative robots (cobots) aims to merge the advantages of robots with human skills. Although cobots are generally somewhat less powerful than traditional industrial robots, they are also less expensive, more flexible, and easier to program, making them appealing to SMEs. Designing human-friendly working environments represents the central challenge in terms of collaboration between humans and machines. This intricate system involving humans, machines, and production processes demands clear guidelines, an adequate research budget, training for all participants, and, last but not least, a thorough ethical evaluation of the overall system.

Cobots – a new generation of robots with new challenges

ÖAW

Created: November 2023 (WP)
Updated: November 2025 (FF)

OeAW-ITA with KIT-ITAS
parlament.gv.at/dokument/fachinfos/zukunftsthemen/152_cobots.pdf

OVERVIEW OF THE TOPIC

Cobots – Collaborative robots: a promising market

Industrial robots play a significant role in the automation of industrial production during the so-called Third Industrial Revolution. They now undertake a considerable share of heavy, repetitive tasks and are typically installed within their safety zones to ensure they pose no danger to employees. The vision of ***Industry 4.0*** with high flexibility, demand orientation, correspondingly small batch sizes and the highest degree of automation has driven great efforts in recent years to combine the advantages of robot production, such as high speed, great strength and precision, with the benefits of human labour, such as experience, decision-making ability, flexibility and dexterity. This led to the development of so-called "collaborative robots" (cobots) designed to work alongside humans. Cobots are in high demand, and sales and installation figures are consistently rising. Nevertheless, they represent only a small portion of the overall robotics market. Only about 7.5% of the global market for industrial robots comprises cobots, although their growth rate—around 50%—is higher than that of the market as a whole. The key players in this market segment are European companies; however, they risk being overtaken by the Asia-Pacific region (Gambao, 2023).

Humans and machines working together

Safety concerns were the primary reason direct interaction between humans and robots could not be achieved for a considerable time. Robots are excessively fast, overly powerful, and lack context sensitivity, meaning they cannot adequately perceive their surroundings. Much of this has been significantly ***improved by better sensor technology***, faster hardware and artificial intelligence. Using the advantages of robots and human capabilities equally is obvious but not new. The first patent was filed by James E. Colgate and Michael A. Peshkin in 1997 when they described an "Intelligent Assist Device (IAD)" (Colgate et al., 1996) as "an apparatus and method for direct physical interaction between a person and a general-purpose manipulator controlled by a computer."[1]

Not quite as fast, but suitable for SMEs

Different categories of cobots can be described based on the potential intensity of cooperation between humans and machines—these range from simple coexistence without a shared workspace to actual, mutually responsive collaboration. In practice, straightforward applications often do not involve interaction between humans and machines currently predominate. Cobots are frequently employed similarly to conventional robots to take advantage of certain benefits they offer. These advantages include generally lower investment requirements and simpler programming. However, cobots tend to be somewhat more lightweight and less efficient than traditional industrial robots, because they must account for potential interactions with humans. These characteristics render cobots particularly appealing for use in SMEs. The primary areas of application currently include installation of parts, assembly, loading of machine tools, palletising, metrology, finishing, quality control, welding, material removal, and screwing.[2] However, there are also various use cases for cobots outside the manufacturing industry (Rahman et al. 2024), particularly in logistics, medicine and agriculture - for example, cobots are already being used to assist with planting and harvesting.

---

1 *de.wikipedia.org/wiki/Kollaborativer_Roboter.*

2 *industriemagazin.at/produktionstechnologie/hier-sind-cobots-fuer-die-industrie-wirklich-sinnvoll/.*

The direct interaction between humans and robots can be both the greatest advantage and limitation of collaborative systems, depending on their impact on human factors such as ergonomics and mental stress (Faccio et al., 2023). This is also the focus of recent work dedicated to the topic of "human-centred work environments". Research in this area examines aspects beyond mere performance data and investigates the interactions between the participants and their contextual conditions within the overall system (human, cobot, production system). The factors that influence or are influenced by the human aspect of cooperation include ergonomics, mental strain, trust, acceptance, and usability. The elements on the cobot side encompass mobility, adaptability, connectivity, operation, consistency, and safety. Flexibility, cost orientation, reconfigurability, networking and agility (Faccio et al., 2023) are considered particularly important for modern production systems. This shows the high complexity of such systems.

Cooperation is highly complex and requires more than just performance data

Existing experimental systems, for instance, allow two individuals to operate a single robotic arm (collaborative avatar platform) to assume distributed roles in the movement sequence or execute movements together that one person cannot achieve alone. In another application, it was shown that a person with technical support can also perform complex movements with several arms at the same time.[3] However, it is essential to assess the risks and opportunities of this technology and its potential social, economic, and ethical implications.

A recent STOA study (Gambao, 2023) outlines the present state of collaborative robotics, highlighting its advantages and disadvantages while focusing on key aspects such as safety.

What it takes:

The policy options presented in the study are as follows:

- Develop clearer regulations for the conditions of human-robot interaction and safety assessments, considering the health and well-being of workers as well as the competitiveness and development potential of cobots;
- Maintain or even increase the budget for research activities involving human-robot interaction or collaborative robotics to maintain the leading position of European companies in the implementation of Industry 4.0 and collaborative robotics in particular;
- Promote measures that support the creation of new real-world applications with a high degree of interaction and the training of all relevant actors in this technology
- Promote ethical assessments to ensure safe human-robot collaboration, worker acceptance and privacy protection. A much more comprehensive ethical analysis is needed, including other fundamental aspects such as acceptance, ergonomic factors, privacy or possible psychological stress for users.

Clear guidelines

Research budget

Training and comprehensive ethical assessment

Even if the reality is far from the vision of humanoid systems capable of independently performing more complex manipulation tasks in unstructured environments (Kehl & Coenen, 2016), there is still much to be done to design cooperative, robot-assisted and human-centred working environments.

[3] *sa2021.siggraph.org/en/attend/emerging-technologies/18/session_slot/626*.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Cobots in the Austrian industry

The use of industrial robots in Austria was recently examined in two separate studies. According to these studies, 38% of companies use more than ten traditional industrial robots. The number of collaborative industrial robots is significantly lower, with only 33% of robot-using companies operating cobots (Clauss et al., 2022). Zahradnik and Rhomberg (2022) reach similar conclusions, noting that 41% of companies utilise industrial robots for manufacturing and/or handling processes and that a significant increase in all types of robotics is anticipated by 2025. It was expected that the use of cobots or mobile robots would also double by 2025. However, this does not appear to be the case: A study on production work in Austria showed that the use of cobots declined in both 2023 and 2024 (Granegger et al. 2024). Accordingly, the authors of the study note a disillusionment on the one hand, but also a more differentiated and targeted use on the other. The authors did not investigate whether there is a connection with the economic downturn. Another explanation could be that cobots are unable to utilise many of the original strengths of robots (high force) due to their reduced performance and are therefore unable to replace established industrial robots (Urrea & Kern 2025). Urrea and Kern also state that the practical use of cobots is lagging behind research.

Decline in cobot use in Austria in 2023 and 2024

The first-time use of cobots, in particular, is often planned for companies without experience with industrial robots. Against this background, it seems particularly relevant for Austrian decision-makers, in addition to participating in international and European research, development and governance activities, to further develop the current framework conditions for creating, producing and using collaborative robots in Austria. As mentioned above, further adaptations of occupational health and safety regulations, standards, and other (safety) guidelines, as well as additional research efforts, such as human-centred human-robot interaction (HRI), and a more comprehensive ethical evaluation of HRI in general, as well as in specific application contexts, are required.

PROPOSAL FOR FURTHER ACTION

Topic profile Cobot Austria

As a preliminary step, a TA study on cobots in the Austrian context could produce a topic profile that translates the aforementioned STOA study into a version tailored for Austria within approximately 1-2 months. This specifically addresses issues of safety and working conditions, impacts on the labour market, and various social, economic, ecological, and ethical aspects.

REFERENCES

Clauss, K., et al. (2022). *Study on the use of robots in Austrian industry – Economic impact of industrial robots in Austrian manufacturing companies*, Fraunhofer.

Colgate, J. E., et al. (1996). Cobots: Robots for collaboration with human operators. *American Society of Mechanical Engineers, Dynamic Systems and Control Division,*, *58*, 433-439.

Faccio, M., et al. (2023). Human factors in cobot era: a review of modern production systems features. *Journal of Intelligent Manufacturing, 34*, 85-106, . ***doi.org/10.1007/s10845-022-01953-w.***

Gambao, E. (2023). *Analysis exploring risks and opportunities linked to the use of collaborative industrial robots in Europe*, ***europarl.europa.eu/RegData/etudes/STUD/2023/740259/EPRS_STU(2023)740259_EN.pdf***.

Granegger, T., Eisl, S., Mayrhofer, W., & Schlund, S. (2024). *Made in Austria: Produktionsarbeit in Österreich 2024*. Technische Universität Wien. ***doi.org/10.34726/1541***.

Kehl, C., & Coenen, C. (2016). *Technologies and visions of human-machine demarcation: Status report on the TA project "Human-machine demarcations: between artificial intelligence and human enhancement"*. ***publikationen.bibliothek.kit.edu/1000063606.***

Rahman, M., Khatun, F., Jahan, I., Devnath, R., & Bhuiyan, A.-A. (2024). Cobotics: The Evolving Roles and Prospects of Next-Generation Collaborative Robots in Industry 5.0. *Journal of Robotics*, *2024*, 1–22. ***doi.org/10.1155/2024/2918089***.

Urrea, C., & Kern, J. (2025). Recent Advances and Challenges in Industrial Robotics: A Systematic Review of Technological Trends and Emerging Applications. *Processes*, *13*(832), 1–20. ***doi.org/10.3390/pr13030832***.

Zahradnik, G., & Rhomberg, W. (2022). EMS 2021 - Modernization of production: Basic evaluation, ***zenodo.org/doi/10.5281/zenodo.8047520zenodo.org/records/8047521.***

INTELLIGENT SOCIAL AGENTS TO COMBAT LONELINESS?

© unsplash.com/Markus Spiske, Logan Weaver; Thomas Bayer

SUMMARY

More and more digital applications are coming onto the market to provide people with emotional support and advice in their everyday lives. Digital social agents are AI-supported chatbots that produce textual and visual content for conversations with users. On the one hand, such applications can strengthen users' mental and emotional health, make it easier for poorer population groups to access psychological support, and, if necessary, support psychological treatments in everyday life. On the other hand, there is a risk of dependency, a long-term increase in loneliness and a loss of interpersonal skills. Whether a dialogue-oriented AI chatbot is more likely to strengthen the user's ability to build relationships with other people or increase loneliness depends largely on the design and discourse on AI.

OVERVIEW OF THE TOPIC

Many people, especially teenagers and young adults, use digital chatbots. for emotional support in everyday life

More and more digital applications are coming onto the market to provide people with emotional support and advice in their everyday lives. They are referred to as intelligent social agents or "conversational AI". These are usually AI-supported chatbot applications that use Generative Artificial Intelligence (GenAI) to provide textual, visual and audio content for conversations with users (Maples 2024). According to manufacturers, intelligent social agents can be sparring partners, advisors, mentors, or friends (see also ***Social (ro)bots: machines as companions***). The most frequently used applications include "Replika" from the USA, the "Xiaoice" app, which is particularly popular in Asia, and the "character.ai" application, which has been available since 2022. Replika and Xiaoice alone have almost one billion active users (Maples, 2024). According to the manufacturer, the character.ai platform is visited by around 3.5 million people every day. Young people, in particular, are increasingly keen to access intelligent social agents (Ragni, 2024).

Intelligent social agents can imitate digital avatars of well-known personalities or private individuals.

The chatbots available on the market use similar methods and advertise with different focuses. The Replika application was developed by the US company Luka to serve as a personal conversation partner and emotional companion. While interacting with users, the chatbot learns about their preferences and interests and adapts its responses accordingly. Replika is available on iPhone and Android platforms and can be used via text, voice, augmented, and virtual reality interfaces. Conversations take place with a ready-made or user-generated avatar (Maples 2024). The character.ai application also offers the option of interacting with a digital "personal teacher, assistant or even friend" who is available to the user "at any time and can help with anything". The platform advertises that conversations with digital avatars of well-known personalities as well as game and cartoon characters are possible. The platform also offers the option of selecting a pre-programmed digital conversation partner depending on the intended use (e.g. coach for job interviews or foreign language teacher, travel planning companion). Both character.ai and "GPT Clones", which will be launched on the Chinese and Japanese markets in 2023 by Xiaoice, which belongs to Microsoft, are trained to imitate specific people. A virtual clone of a public figure can be created with just a little data - three to five minutes of a public video or data from social media (Liu, 2023). Some applications also promise the possibility to create "digital psychological twins" of private individuals using personal information from emails, browser history, and social media activities. Some providers (e.g. the startup "Super Brain") have specialised in the development of digital *avatars of deceased persons* (Zhang 2024) (see also ***Dying 2.0: digital legacy***).

AI therapy bots are used to promote mental health.

Intelligent social agents are used for various purposes. One central application is promoting emotional and mental health (see ***AI emotion recognition***). Replika and character.ai offer avatars for coaching and promoting mental health ("mental health helper"). These are used by many students to encourage their mental and emotional resilience (Maples et al. 2024; Ragni 2024). Some chatbots are specifically tailored to support mental health, such as the chatbot from the start-up "Wysa".[1] Wysa addresses both patients and doctors. Wysa offers the latter support

[1] *wysa.com*.

in the development of customised treatment therapies. In Germany, "Mina"[2] is mainly well known. This application is being tested as a coach and digital psychotherapist and is designed to help people overcome exam nerves, particularly bullying and decision-making difficulties. However, most chatbots, which are based on large language models and are intended to support people with mental stress, are not approved as medical devices. In the UK, the first chatbot application in the field of mental health ("Limbic Access"[3]) was approved (Ragni 2024). This is intended, in particular, to help write initial diagnoses and identify patients who should be prioritised for treatment.

Intelligent social agents can have a positive impact on mental health.

Initial research shows that intelligent social agents can positively impact mental health. A survey of 1006 student users of Replika, which was recently published in the journal Nature, showed that almost half of the respondents had used Replika to act as a friend or companion. The reasons were its permanent availability, conversational ability, and ability to be a non-judgmental conversation partner. Respondents associated its use with reduced anxiety and a sense of social support. Replica was also used for therapeutic support or to process emotions and had a therapeutic effect in over 18% of cases. Almost a quarter reported positive life changes. For example, users reported behaving more empathetically in real-life relationships thanks to Replika. 3% stated that Replika was able to stop their suicidal thoughts (Maples et al. 2024). At the same time, serious shortcomings were found, such as violations of basic European data protection standards or the output of inappropriate (sexual) content (Krempl, 2023). In addition, several cases of suicide have been linked to the intensive use of AI chatbots (see e.g. Schiefer 2024). Independent studies on the effects of intelligent social agents and conversational chatbots are still rare. The engagement mechanisms underlying the applications evolve rapidly and can change fundamentally from application to application and/or over time. In particular, little is known about the long-term use of intelligent social agents. Chatbots' ability to recognise desires and create an "echo chamber of affection" could make their users highly addictive (Mahari and Pataranutaporn, 2024). Mira Murati, Chief Technology Officer of OpenAI, also warned of the dangers of addiction posed by AI. These could arise, in particular, due to the long-term memory of chatbots and the ability to personalise systems to a high degree (Klar, 2023). Excessive use could lead to inner alienation and increased loneliness (Uhle 2024) or even cause a kind of "digital attachment disorder". Users would lose the ability to engage with others and react empathetically (Mahari and Pataranutaporn 2024). The creation of digital avatars of the deceased also raises ethical and legal concerns regarding the consent of the deceased and their family, as well as the emotional health of users. Their use could hinder the grieving process (Zhang 2024).

Little is known about the long-term effects little is known

AI chatbots can facilitate access to psychological support, but cannot replace the medical treatment of mental disorders

AI chatbots that explicitly promote psychological health could make it easier for poorer sections of the population to access psychological support, who would otherwise not be able to afford such a service. However, it becomes particularly problematic when certain functionalities (such as more complex answers and voice messages in the case of Xiaoice) cost more. Some users perceive this as a potential barrier to accessing psychosocial support (Maples, 2024). So far, such AI

2 *minabot.ai/en/*.
3 *access.limbic.ai.*

applications, specifically and solely intended to promote patients' mental health, are not seen as a substitute for, but rather as a support for, psychological treatment. For example, recognising patients' humour, body language, facial expressions, and gestures is central to therapeutic interaction. This is not the case in chatbot-based therapeutic treatment (Stegmaier 2024). Even if these applications cannot replace professionally conducted psychotherapy, they could support treatment by recommending exercises or bridging the time until therapy begins (SWR-Wissen 2023a). Furthermore, most of the current chatbots on the market intended to help people's mental health do not have medical approval (SWRWissen 2023b); they undermine very different, sometimes untransparent, quality assurance mechanisms.

Design and communication decisions impact social skills, health and well-being.

Whether a dialogue-oriented AI chatbot is more likely to strengthen the user's ability to build relationships with other people or increase loneliness depends heavily on the design of the applications. For example, chatbots can be designed to serve as a practice space for learning conflict resolution skills and lead to improved behaviour in their analogue interpersonal relationships (Uhle 2024). Deliberate design decisions to allow users to remain in the digital space for as long as possible (so-called "dark patterns") can, in turn, tend to increase loneliness (Mahari and Pataranutaporn 2024). Furthermore, conversational AI is not always used for what the respective chatbots have been trained for (Longpre et al., 2024). For example, if a chatbot is used for intimate conversations without being instructed, this can decrease the user's well-being (Maples et al., 2024). Not only design decisions but also discourses about AI chatbots or intelligent social agents influence how people interact with them and how well they work. This is because a person's mental model, i.e. their perception of the chatbot, for example, as compassionate and caring or as an emotionless algorithm, shapes their interaction with the chatbot. This mental model results from the cultural background and personal convictions, as well as from social narratives and the discourse of software providers on their products. Careful presentation of the application (so-called "priming"), which portrays a chatbot as empathetic, can increase trust in the system, achieve a higher level of loyalty and thus, higher effects, for example, in improving mental health (Pataranutaporn et al. 2023), although the risk of addiction can also increase. On the other hand, antisocial connotations can undermine the potential benefits of using AI to improve interpersonal communication (Hohenstein et al., 2023). The long-term consequences of positive narratives, which may overshadow the risks, have hardly been researched and are potentially far-reaching. In particular, exploiting positive narratives for marketing or maximising corporate profits could have far-reaching social consequences (Pataranutaporn et al., 2023).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

So far, intelligent social agents have not been at the forefront of social and political discussions about generative AI.

Even though Austria is currently promoting the development of AI skills in society (Federal Chancellery 2024), there is little discussion of the opportunities and risks of using intelligent social agents to develop social skills and promote mental health. Given the rapidly increasing number of users, the unknown long-term consequences for both the health and well-being of users and for social cohesion, and the lack of quality assurance mechanisms and fundamental data protection concerns of some applications, an examination of their opportunities and potential effects would be necessary. In addition, suitable AI chatbots could alleviate some of the pressure on the lack of health insurance-funded therapy places (SWR-Wissen 2023b), but consideration would have to be given to how the effectiveness can be proven and how the applications could be integrated into clinical care without jeopardising fair access to therapy places. In addition, sufficient skills would need to be built among staff and patients.

PROPOSAL FOR FURTHER ACTION

Research into the effects of the spread of intelligent social agents on individuals in private and professional contexts and on societies is still in its infancy. In particular, the long-term consequences of intuitive engagement with intelligent social agents need to be researched on an interdisciplinary basis. In addition, the extent to which the current regulatory framework adequately covers the risks of their use and what regulatory needs arise from the widespread use of AI chatbots should be explored.

A better understanding of the use and impact of intelligent social agents is needed.

REFERENCES

Federal Chancellery (2024). Digital Austria. *digitalaustria.gv.at*.

Hohenstein, J. et al. (2023). Artificial intelligence in communication impacts language and social relationships. Scientific Reports 13 (1), 5487, *doi.org/10.1038/s41598-023-30938-9*.

Klar, R. (2023). Open AI exec warns AI can become 'extremely addictive'. The Hill. *thehill.com/policy/technology/4229972-open-ai-exec-warns-ai-can-become-extremely-addictive/*

Krempl, S. (2023). "Virtual friend": Data protectionists stopped replicating chatbots in Italy. *heise.de/news/Virtueller-Freund-Datenschuetzer-stoppen-Chatbot-Replika-in-Italien-7485010.html*.

Liu, Y. (2023). China's "Black Mirror" GPT Clones Raise Global Concerns. Jing Daily Culture. *jingdailyculture.com/chinas-black-mirror-gpt-clones-raise-global-concerns/*.

Longpre, S. et al. (2024). Consent in Crisis: The Rapid Decline of the AI Data Commons. arXiv. .*doi.org/10.48550/arXiv.2407.14933*

Mahari, R.; Pataranutaporn, P. (2024). We need to prepare for 'addictive intelligence'. MIT Technology Review. *technologyreview.com/2024/08/05/1095600/we-need-to-prepare-for-addictive-intelligence/*.

Maples, B. et al. (2024). Loneliness and suicide mitigation for students using GPT3-enabled chatbots. npj Mental Health Research 3 (1), 1-6. *doi.org/10.1038/s44184-023-00047-6.*

Pataranutaporn, P. et al. (2023). Influencing human-AI interaction by priming Beliefs about AI can increase perceived trustworthiness, empathy and effectiveness. Nature Machine Intelligence 5 (10), 1076-1086. *doi.org/10.1038/s42256-023-00720-7.*

Ragni, M. (2024). Character.ai: Many young people turn to AI therapy bots. THE-DECODER.de. *the-decoder.de/character-ai-viele-jugendliche-wenden-sich-ki-therapiebots-zu/*.

Schiefer, C. (2024). Suicide in the USA: When AI friends become a danger. *br.de/nachrichten/netzwelt/wenn-ki-freunde-zur-gefahr-werden-suizid-in-den-usa-zeigt-tragischen-verlauf-einer-ki-beziehung,USgb6Ux*.

Stegmaier, A. (2024). AI and psychotherapy: Hello, ChatGPT, I'm not doing well. Wr. Zeitung. *wienerzeitung.at/a/hallo-chatgpt-mir-geht-es-nicht-gut*.

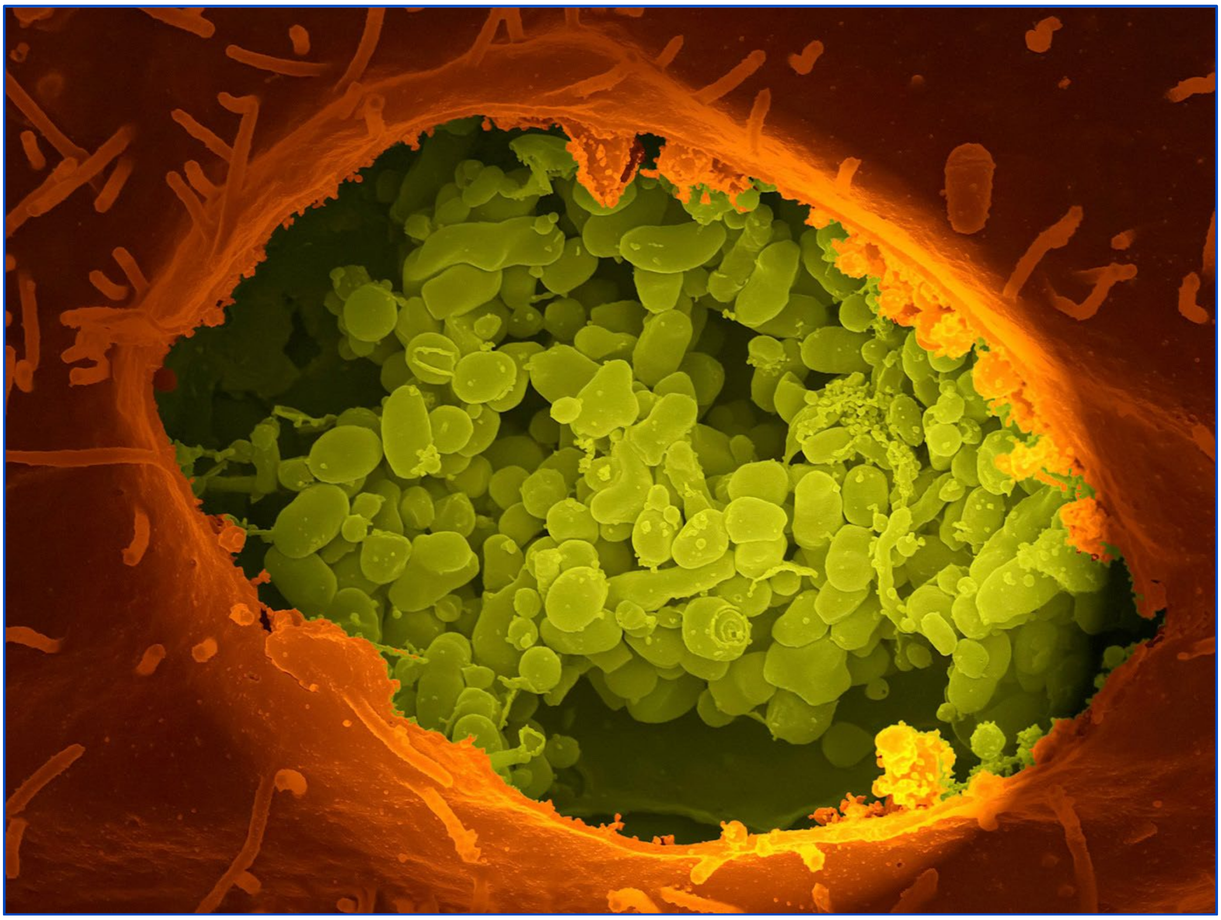
SWRWissen (2023a). Chatbots - the new psychotherapists? swr.online. *swr.de/wissen/chatbots-in-der-psychotherapie-100.html*.

SWRWissen (2023b). Chatbots do not provide reliable medical diagnoses. swr.online. *swr.de/wissen/chatbots-medizinische-diagnose-kein-ersatz-fuer-arztbesuch-100.html*.

Uhle, C. (2024). Artificial intelligence and the future of humanity. Fischer.

Zhang, X. (2024). AI Simulates Posthumous Experience. *shanghaiist.com/ai-simulates-posthumous-experience/*.

PHAGES FOR THERAPY AND BIOCONTROL



© unsplash.com/CDC

SUMMARY

Particularly concerning the problem of antibiotic resistance for human, animal and environmental health, phages – i.e. viruses that infect bacteria – have the potential to make an essential contribution to solving the problem. However, under the current framework conditions in the European Union, it is unlikely that phages will be developed or used more widely for medical purposes or biocontrol in agriculture and the food industry. This would require adjusting or flexibilization of the regulations, which have primarily focused on chemicals, creating effective economic incentive structures and, if necessary, reimbursement models, e.g., for genuinely new antimicrobial drugs, and targeted support for R&D activities. Therefore, what is needed primarily are political initiatives to review the regulation and framework conditions in all application areas and develop them further by adding flexible and innovative regulations.

OVERVIEW OF THE TOPIC

The global spread of ***antibiotic resistance*** (Naghavi et al., 2024) has revived interest in therapeutic use of bacteriophages (phages for short) in human medicine in recent years. Against the background of political efforts at the international level towards more sustainable agriculture and the European Green Deal, phages are also increasingly being discussed as a means of biocontrol (TAB, 2023, p. 55 ff.), i.e., as a natural means of combating pathogenic bacteria in animals, plants and food.

Phages - ubiquitous "bacteria killers" with special properties

Phages are viruses that can infect and destroy bacteria. They are regarded as the most prevalent biological entities on Earth and are found alongside bacteria in all habitats, including the human body, particularly in the intestinal tract (TAB, 2023, p. 42f.). Phages have several unique properties that make them particularly interesting, but also challenging, as a means of combating pathogenic bacteria (e.g. Strathdee et al., 2023; TAB, 2023, p. 63ff.). Antibiotic resistance mechanisms do not typically diminish the effectiveness of phages. While bacterial phage resistance can also emerge, it can be surmounted fairly easily by adapting phages or isolating new ones. In some cases, phages can act synergistically with antibiotics, and some phages can destroy bacteria even if they form protective layers (so-called biofilms), as is often the case with infections that are difficult to treat. Finally, a phage species usually only infects a specific bacterial species or even some strains of it; i.e. the (host) specificity of phages is very high - in contrast to the spectrum of action of many antibiotics. This means collateral damage to beneficial bacteria in the body or the environment can be minimised or avoided. At the same time, however, this property requires that phage preparations must be customised for the respective pathogens.
To be effective against several bacterial species or strains (with possibly developing phage resistances) that often occur in infections, pre-defined, ready-to-use phage preparations must consist of sometimes complex, difficult-to-produce mixtures of different phages ("cocktails") and be regularly updated with new or adapted phages (see above). Especially for some critical, genetically variable pathogens or those for which only phages with a highly narrow host spectrum exist, this approach is usually not possible or successful. Therefore, so-called *personalised* phage preparations tailored to the pathogen strains present in a patient are often produced using phages isolated from phage banks or newly isolated from the environment (e.g., from wastewater) (Strathdee et al., 2023; Pirnay et al., 2024).

Phage therapy– An old approach that has been largely forgotten in the West

Phages were researched and used to combat bacterial infections in humans immediately after their discovery over 100 years ago. Apart from some former Soviet republics (e.g., Georgia, Russia, Ukraine), where phage preparations exist as approved drugs, phages have only been used continuously for experimental treatments in Poland. In contrast, phages have hardly been used therapeutically in Western industrialised countries since the 1940s and the widespread availability of antibiotics (Marongiu et al., 2022; TAB 2023, p. 45ff.).

Phages can currently only be used for therapy in exceptional cases.

No phage preparation has received marketing authorisation as a medicinal product in a Western country. Therefore, phages can only be used for therapy if no approved effective drugs are available (TAB, 2023, p. 147f. and 157ff.). In the EU, member states can allow this for medicines manufactured according to medical specifications for individual patients ("named-patient exemption"). In addition, medicinal products that are prepared in a pharmacy according to a doctor's prescription for a particular patient (often referred to as "magistral preparation") are exempt from authorisation in the EU (TAB, 2023, p. 147 f.). Positive results on efficacy and safety come almost exclusively from case studies of individual patients, often considered to be "beyond treatment", with chronic and/or antibiotic-resistant infections that are difficult to treat, using personalised phage preparations (Pirnay et al., 2024; Uyttebroek et al., 2022). These treatments have been carried out in various EU countries under the exemptions mentioned above (TAB, 2023, p. 162ff.).[1] The first successful Named Patient Use (NPU) treatment was recently carried out in Austria at the Department of Thoracic Surgery at Vienna General Hospital and MedUni Vienna (MUW, 2024). In Belgium, a pragmatic national arrangement for the magistral production of phages according to defined quality standards has become the main route for phage therapy. This also enables the use of phages not produced according to Good Manufacturing Practice (GMP; see below) standards - which allows flexible production of patient-specific phage preparations (Verbeken & Pirnay, 2022; Pirnay et al., 2024). A suitable phage produced in Brussels after isolation from a phage bank there also made the recent treatment trial in Vienna possible.[2]

Clinical trials and other - regulatory and economic - challenges

However, a prerequisite for marketing authorisation of drugs in the EU or the USA is proof of efficacy and tolerability, usually through randomised controlled clinical trials and compliance with GMP principles. The few such studies conducted to date (e.g., in France and Switzerland) - except for one smaller study - could not prove the efficacy of the therapeutic approaches. All studies used predefined phage cocktails and sometimes had conceptual or production-related problems (TAB, 2023, p. 85ff.). Several new clinical studies have been initiated in the last three to four years, including first trials with personalised cocktails and genetically modified phages (TAB, 2023, p. 298ff.). Relatively young biotech companies are conducting the vast majority of these trials, most of which are conducted in the USA (including by companies from the EU or Israel) (TAB, 2023, p. 85f.). However, even if some of these clinical trials are successful and also patient-specific preparations could receive marketing authorisation (TAB, 2023, p. 153f.), critical regulatory and economic challenges would have to be solved for the sustainable success of such products. For example, changes in the composition of (ready-to-use) phage cocktails, which are necessary for regularly updating them, are likely to require lengthy approval procedures after initial approval, if not completely new marketing authorisation applications (Pelfrene, Sebris, & Cavaleri, 2021; TAB, 2023, p. 151f.). Furthermore, phage preparations for more common infections or indications that can be treated with antibiotics would compete with inexpensive, often generic antibiotics. Such competition is essential for the known profitability problems with newly developed antibiotics (TAB, 2023, p. 222). Finally, phage preparations, which could have an exceptionally high or even unique benefit due to their ability to combat (otherwise untreatable) antibiotic-resistant and/or chronic infections, would be restricted to a very limited number of cases. Investments for these products would thus have to be amortised by a relatively small number of treatments (TAB, 2023, p. 221ff.). However, it is highly

1 Z. Partly with phages produced by doctors themselves (e.g., in Germany), which is not permitted in Austria.

2 *ingo-news.at/versorgung/interview-mit-matthias-vossen.html*.

uncertain whether such phage products can achieve similar premium prices as certain cancer drugs or gene- and cell-based therapies for rare diseases.

Phage applications in agriculture and the food industry

In agriculture and the food industry, phages are used in various areas of application (Hüsing, Aichinger, & Fischer, 2022; TAB, 2023, p. 101ff.). In livestock farming, harnessing phages is primarily aimed at veterinary medicines to reduce antibiotic use and feed additives to reduce bacterial contamination of the food produced. In *aquaculture*, phages are also intended to reduce the use of antibiotics. In *plant cultivation*, phages can be essential in preserving plants irreversibly damaged by pathogenic bacteria, especially fruit trees. Currently, copper and, where possible, antibiotics are mainly used, which are highly harmful to the environment. Finally, phages can be used as additives or decontamination means in food processing and preservation to control food-borne pathogens and improve food preservation. The most critical food law categories for this in the EU are food additives or processing aids, decontamination methods for food, and disinfection of equipment or surfaces during food production or storage.

First approved products - but not in the EU

There are a few phage preparations for all these areas of application that have already been commercialised and approved primarily outside the EU. These include feed additives, aquaculture products, preparations for surface decontamination of animal foods, fruit, vegetables or cheese, and phage preparations against certain plant diseases (TAB, 2023, p. 105ff. and 115ff.). Due to the lack of approval, some of these products, developed by European companies (e.g., Micreos, Netherlands; Proteon, Poland), cannot yet be used in the EU. Phage products can only be classified and used as processing aids for food processing, that do not require authorisation, in the EU. However, there is no legal clarity on the cases in which phages should be classified as such, nor are there any reliable figures on this use (Hüsing, Aichinger, & Fischer, 2022, 97f.). As regards plant protection, the Hungarian company Enviroinvest[3]. In addition to technical challenges in developing phage preparations for practical use (e.g., their stability under field conditions), the regulations and approval requirements, which are usually still focused on individual, defined chemicals and are often largely unclear regarding phages, are considered a significant obstacle. These pose organisational and capacity problems for small and medium-sized companies in particular, which are mainly developing commercial applications.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Phages as an option in the fight against antibiotic resistance

In Austria alone, more than 3,000 people died in 2019 in connection with bacterial ***antibiotic resistance*** (IHME, 2023), i.e. an average of one person every three hours. Worldwide, the number of victims amounted to around 4.95 million. Antibiotic-resistant bacteria also play an essential role in the development of sepsis upon infections, which are often associated with long-term damage and the need for care in survivors. Given the health problems for humans, animals and the environment caused by antibiotic resistance and toxic chemicals, the potential use

[3] e.g. ***biokontroll.hu/erwiphage-forte-bakteriofagokkal-a-tuzelhalas-ellen/***.

of phages for therapy and biocontrol could be investigated and utilised more intensively. However, the current framework conditions would have to be adapted so that the use of phages for therapy or agricultural and food applications can become more established in Austria than has been the case. In addition to promoting research to solve scientific and technical problems in developing effective phage products, adjustments to the EU regulations, which are mostly still geared towards non-changing chemical substances or active ingredients, may be necessary. On the other hand, more effective economic incentive schemes for developing and reimbursing genuinely new antimicrobial drugs appear required, particularly for potential phage therapy products (TAB, 2023, p. 221ff.).

PROPOSAL FOR FURTHER ACTION

Initiatives to review regulations

Political initiatives or support would be needed to review the existing regulation in all application areas and develop it further, for example, by adding special guidelines on phages or regulations for incentives to develop phage products. For phage therapy, the EU Commission's proposal of April 2023 to reform European pharmaceutical legislation could offer an opportunity to establish regulations adapted to phage therapeutics with variable compositions. Simultaneously, at the national level, for instance, a commission comprised of representatives from parliament, responsible ministries and authorities could examine whether exemptions under EU law could already be utilised or designed in Austria - for example, inspired by the Belgian model of magistral phage use - in a manner that allows for the flexible production of essential personalised phage preparations under defined quality standards and enables more patients in the country to access them than is currently possible (i.e., beyond Named Patient Use).

REFERENCES

Hüsing, B., Aichinger, H., & Fischer, P. (2022). Bacteriophages in the agriculture and food industry. Fraunhofer ISI. *publica.fraunhofer.de/entities/publication/f7e3af0c-13a1-4724-924d-bdb4938c0e31*.

IHME (2023). The burden of antimicrobial resistance (AMR) in Austria. *healthdata.org/sites/default/files/2023-09/Austria.pdf*.

Marongiu, L., et al. (2022). Reassessment of Historical Clinical Trials Supports the Effectiveness of Phage Therapy. Clinical Microbiology Reviews, 35(4), e0006222. *doi.org/10.1128/cmr.00062-22.*

MUW (2024). With viruses against bacteria: First therapeutic application of bacteriophages in Austria. News, 26.03.2024. *meduniwien.ac.at/web/ über-uns/news/2024/news-im-maerz-2024/fortschritte-im-verstaendnis-von-morbus-crohn-erzielt/mit-viren-gegen-bakterien/*.

Naghavi, M., et al. (2024). Global burden of bacterial antimicrobial resistance 1990-2021: a systematic analysis with forecasts to 2050. The Lancet, 404(10459), 1199-1226. *doi.org/10.1016/S0140-6736(24)01867-1.*

Pelfrene, E. et al (2021). Regulatory Aspects of the Therapeutic Use of Bacteriophages: Europe. In D. Harper, S. Abedon, B. Burrowes, & M. McConville (Eds.), Bacteriophages: Biology, Technology, Therapy (pp. 1165-1177). Cham: Springer. *doi.org/10.1007/978-3-319-41986-2_51.*

Pirnay, J.-P., et al. (2024). Personalised bacteriophage therapy outcomes for 100 consecutive cases: a multicentre, multinational, retrospective observational study. Nature Microbiology, 9(6), 1434-1453. *doi.org/10.1038/s41564-024-01705-x.*

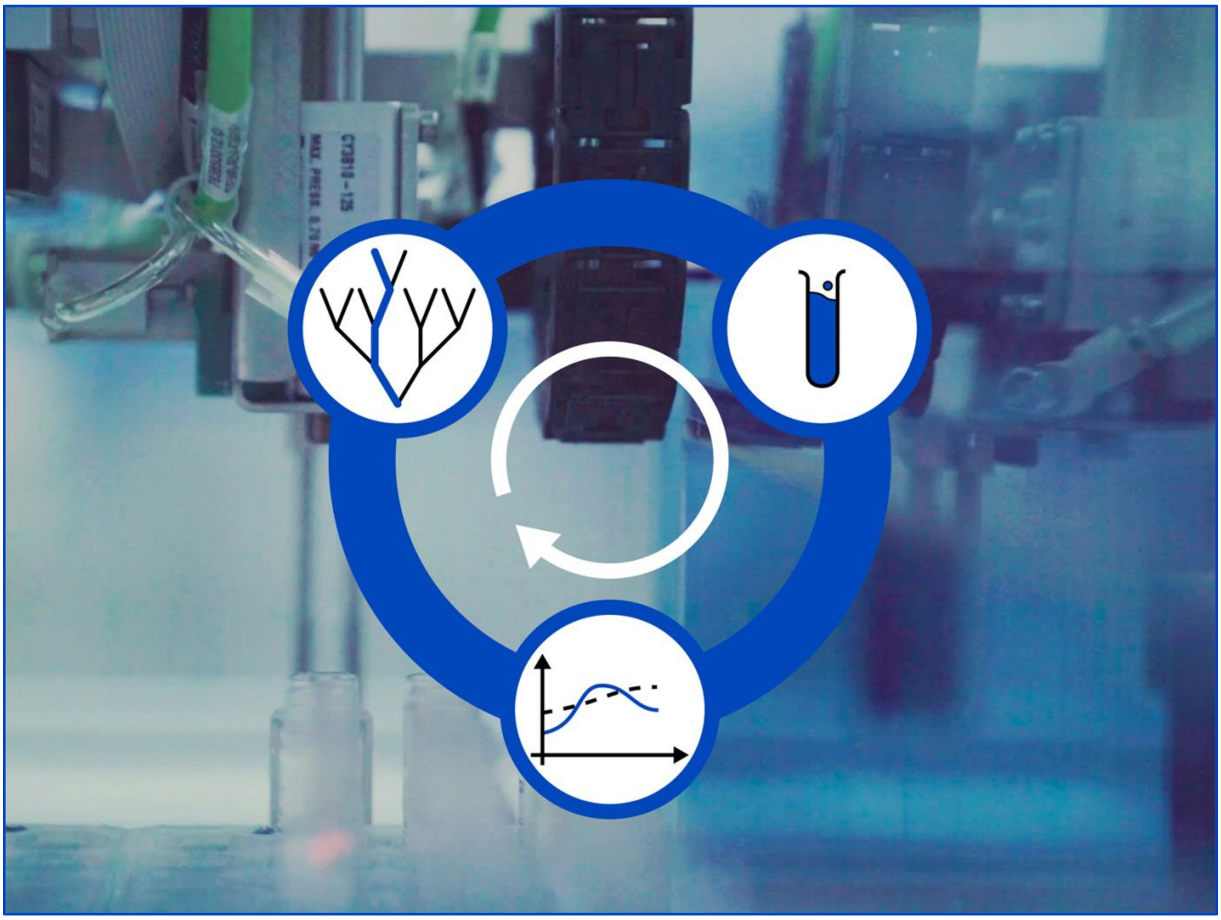
Strathdee, S. A., et al. (2023). Phage therapy: From biological mechanisms to future directions. Cell, 186(1), 17-31. *doi.org/10.1016/j.cell.2022.11.017.*

TAB (Office of Technology Assessment at the German Bundestag) (2023). Bacteriophages in medicine, agriculture and the food industry - application perspectives, innovation and regulatory issues. Innovation analysis. (König, H., Sauter, A.) TAB Working Report No. 206. *doi.org/10.5445/IR/1000160512.*

Uyttebroek, S., et al. (2022). Safety and efficacy of phage therapy in difficult-to-treat infections: A systematic review. The Lancet Infectious Diseases, 22(8), e208-e220. *doi.org/10.1016/S1473-3099(21)00612-5.*

Verbeken, G., & Pirnay, J.-P. (2022). European regulatory aspects of phage therapy: magistral phage preparations. Current Opinion in Virology, 52, 24-29. *doi.org/10.1016/j.coviro.2021.11.005.*

SELF-DRIVING LABS



© unsplash.com/Testalize.me; Fabian Fischer

SUMMARY

Self-Driving Labs (SDL) are laboratories capable of conducting fully automated test series. There are three stages: An experimental setup is designed using artificial intelligence (AI). In the subsequent stage, the experiment uses robots without human intervention. The result of the experiment is then evaluated automatically and provides the basis for the next experiments. In this way, an enormous acceleration can be achieved: On the one hand, the absence of laboratory technicians means that experiments can be carried out around the clock; on the other hand, intelligent control of the series of experiments allows a more targeted search for new substances, molecules and proteins. Furthermore, SDLs facilitate supra-regional access, although this also carries the risk of cyberattacks. Other obstacles hinder the realisation of the potential of SDLs, including the poor data situation, lack of interoperability of instruments, inadequate availability of suitable software, and high investment costs.

Fully automated laboratories to increase efficiency and accelerate scientific discoveries

OVERVIEW OF THE TOPIC

Fully automated control of laboratory experiments using automation and AI

Advances in automation and AI also lead to new scientific research practices. The interplay of mechanical automation, data collection and analysis, and increasing computing power means that the operation of laboratories in some areas of application is undergoing radical change. Contrary to what the term might suggest, "self-driving labs" are not laboratories in self-driving cars but fully automated laboratories for the accelerated and more targeted execution of a series of experiments (Callaway, 2024b). They are particularly relevant for chemistry, biotechnology and materials science (Abolhasani & Kumacheva, 2023; Martin et al., 2023). The primary goal is to find combinations of essential elements with specific desired properties, e.g., molecules, materials and proteins. SDLs represent a fully automated closed loop consisting of roughly three steps: First, a promising experiment is designed using AI. Secondly, this experiment is carried out fully automatically, thanks to robots. Finally, extensive data on the experiment is collected and analysed. Based on this, the AI decides how to conduct the following experiment – the cycle is thus closed.

More efficient search for new molecules, materials and proteins

Higher capacity utilisation through full automation

SDLs can, therefore, carry out a series of experiments without human intervention. Subsequently, they can work continuously 24 hours a day, seven days a week and achieve acceleration through this alone (Martin et al., 2023). Furthermore, the automatic selection of promising experimental designs offers improved control over the experiments and helps avoid unpromising ones. (Abolhasani & Kumacheva, 2023). On the one hand, experiments that have already been conducted can help identify promising experimental setups; on the other hand, (machine-readable) scientific literature and AI-supported model calculations, such as the prediction of protein structures by Google DeepMind's AlphaFold, can also be utilised (Callaway, 2024a).

Reduction in resource consumption by reducing the number of tests thanks to AI

The bottom line is that this should reduce the number of experiments required, leading to lower resource consumption (Abolhasani & Kumacheva, 2023). This is because SDLs are particularly appealing in areas where the interaction of various factors is investigated. These factors include the individual building blocks (e.g. molecules and amino acids), their arrangement or structure, and the environmental conditions under which the experiments are conducted. The more factors that are varied, the greater the number of possible experimental arrangements – exponentially (Abolhasani & Kumacheva, 2023).

Systematic collection of data

In addition to speeding up and saving resources, better documentation of the experiments is a positive side effect of SDLs: The formalisation and digitalisation of all aspects of the experiments are a prerequisite for carrying them out fully automatically. On the one hand, the systematic collection of extensive data can assist the scientific community and lead to improved AI; on the other hand, the volume of data can also aid in the modelling of so-called digital twins of the materials or biological systems under investigation, as data on function and causality can be gathered through the experiments (Martin et al., 2023) (see also ***Digital patient twins***).

Various approaches exist to conducting fully automated experiments (Abolhasani & Kumacheva, 2023). One possibility is to develop and use completely new, automatable laboratory instruments. A pragmatic approach involves programming a mobile robotic arm to execute all necessary tasks (i.e., operating machines and handling materials) in a laboratory designed for humans. Transporting liquids automatically using pumps and tubes for experimental setups is also possible. Successful data transfer between the individual steps of a cycle is essential for success.

Various approaches to mechanical automation

So far, however, there are only a few fully automated laboratories. While some functioning SDLs exist in synthetic chemistry and materials science, the challenges in synthetic biology are more significant (Martin et al., 2023). Here, SDLs are also discussed and developed under the term "foundries". One example in this field is "Eve", an SDL that tested known drugs regarding their suitability for malaria treatment (Martin et al., 2023). A more recent example is AutoBioTech from Forschungszentrum Jülich for automated gene editing of E. coli (Rosch et al., 2024). In materials science and chemistry, SDLs are already successfully utilised to accelerate the development of carbon nanotubes, other nanomaterials, organic substances, and thin-film materials (Abolhasani & Kumacheva, 2023).

Few functioning Self-Driving Labs

Several challenges make the implementation of SDLs difficult. The first hurdle is suitable laboratory equipment. In addition to the high costs, the lack of standardisation of laboratory instruments is a critical point (Abolhasani & Kumacheva, 2023). Experiments in synthetic biology, in particular, often consist of many individual steps, some of which are much more difficult to automate and link than in other areas (Martin et al., 2023). This indicates that various steps may be required depending on the experiment, implying that the laboratory might need configuring differently. This is especially significant for biology, where, as mentioned above, more steps are frequently involved (Martin et al., 2023).

High investments necessary

A second hurdle is the availability of data. A high-quality database is needed to provide AI with a reasonable basis for decision-making. However, some authors attest that the data management of past experiments was often not carried out with adequate quality (Martin et al., 2023). In addition, different laboratories have sometimes developed customised software that is often not interoperable with other systems, which makes integration into SDLs difficult (National Academies of Sciences, 2024). However, software for decision-making, laboratory control and data analysis is unavailable for many use cases (Abolhasani & Kumacheva, 2023). Thirdly, SDLs require highly interdisciplinary expertise: experts from AI, robotics, process automation, chemistry, molecular biology or materials science must collaborate (Hysmith et al., 2024; Martin et al., 2023). However, the cultures of these disciplines are sometimes very different; they may consider other problems worth solving and see each other as competitors or "intruders" in their specialised fields (Martin et al., 2023).

Poor data situation as an obstacle

Interdisciplinary cooperation is essential.

This finally leads to the last hurdle: the possibilities of SDLs and the relevant competencies are currently not present in the curricula of the appropriate degree programs (Martin et al., 2023). Furthermore, a culture of trial and error and relatively intuitive tinkering is often practised in conventional laboratories (National Academies of Sciences, 2024). This practice is opposed to the highly formalised,

Curricula do not yet sufficiently reflect the necessary expertise. sufficiently planned and rule-based way in which SDLs must be operated. These two ways of working must be combined sensibly to maximise their advantages.

Cloud labs: Global accessibility via the Internet

The challenges mentioned also present opportunities. One such opportunity is that researchers can access SDLs remotely via the cloud. There are already so-called cloud labs that can be rented on demand and are controlled through software (National Academies of Sciences, 2024). This also gives researchers access to laboratory infrastructure that could not finance the construction of their laboratory. In addition, the circle of potential users is global. However, it is essential for these cloud labs that both the experiments to be conducted and the individuals or institutions performing them are meticulously checked in advance to ensure responsible research.

Open source instruments as an opportunity

The question of responsible access also arises in open-source laboratory hardware. By promoting open-source hardware, the cost of SDLs could be reduced (Abolhasani & Kumacheva, 2023), which would also counteract the problem of lack of interoperability (see above). However, if the blueprints were freely accessible, actors with malicious intentions would also gain easier access to critical laboratory equipment.

Cyberattacks as a risk

Cyberattacks represent a significant threat to both cloud labs and SDLs. Control through software, which is frequently connected to the internet, means that laboratory equipment can be exploited for nefarious purposes (Martin et al., 2023; National Academies of Sciences, 2024). Robust precautions against such attacks are therefore necessary. This also includes the integrity of the data on which the experiment designs are based: experiments can be misdirected if these are faulty or deliberately manipulated. Subsequently, SDLs can pose a significant danger if they are entirely under the control of malicious actors. In this case, the efficiency gains of SDLs can also be capitalised on by them, for example, to synthesise novel viruses, poisons, drugs or otherwise dangerous materials (Maffettone et al., 2023; Martin et al., 2023).

Acceleration the invention of new pollutants

Danger of derailed experiments

Even a well-intentioned self-directed series of experiments can be derailed over time, i.e. deviate from the initial goal. The unintended result could be materials or proteins that possess unwanted and hazardous properties (Martin et al., 2023). How this risk can be mitigated remains unclear. Therefore, it is essential to benefit from the unique capabilities of both AI and human intelligence and intuition; it is necessary to explore the role of humans in the context of SDLs (Hysmith et al., 2024).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Regulatory framework for self-driving labs

SDLs can accelerate significant progress in discovering novel materials, molecules and proteins. On the other hand, SDL development is still relatively new, with many unanswered questions and challenges. This creates new opportunities, but it is also essential to control the associated risks. Therefore, the Austrian parliament must ensure that existing regulations consider these new opportunities or are updated accordingly. This includes rules relating to chemical and biological hazardous substances (e.g., Seveso III Directive[1] , System Regulation[2]). Furthermore, the question arises as to the extent to which laws that regulate process safety via employee protection[3] apply to self-driving labs or whether the absence of personnel can lead to a loophole in the law.

Austria is a location with a lot of relevant expertise.

The potential for accessing SDLs via the Internet is particularly significant for Austria. On the one hand, this could enhance Austria's reputation as a hub for corresponding SDLs and make it accessible to an international research community; on the other hand, Austrian researchers could utilise SDLs without needing to operate them themselves. Austria's strong position in SDL areas could provide a good starting point. Finally, AITHYRA, a new institute of the Academy of Sciences at the interface of AI and life sciences, is also being set up,[4] which is suitable for SDLs and could create excellent international visibility.

PROPOSAL FOR FURTHER ACTION

Better overview of the status quo in Austria necessary

There is still no comprehensive overview of the current status of SDLs in the Austrian research and development landscape. Accordingly, it would be essential to survey the status quo with the involvement of the relevant stakeholders and examine the current regulations. Furthermore, the development of AI tools that enable the establishment of SDLs should be kept in mind, as these may lower the access threshold for malicious actors (National Academies of Sciences, 2024).

REFERENCES

Abolhasani, M., & Kumacheva, E. (2023). The rise of self-driving labs in chemical and materials sciences. *Nature Synthesis*, *2*(6), 483-492.

Callaway, E. (2024a). Developers of AlphaFold win Chemistry Nobel. *Nature, 634*, 525-526.

Callaway, E. (2024b). 'Self Driving' Lab Uses AI And Robotics To Improve Proteins. *Nature, 625*, 436.

Hysmith, H., et al. (2024). The future of self-driving laboratories: from human-in-the-loop interactive AI to gamification. *Digital Discovery*, *3*(4), 621-636.

Maffettone, P. M., et al. (2023). What is missing in autonomous discovery: open challenges for the community. *Digital Discovery*, *2*(6), 1644-1659.

Martin, H. G., et al. (2023). Perspectives for self-driving labs in synthetic biology. *Curr Opin Biotechnol, 79*, 102881, ncbi.nlm.nih.gov/pubmed/36603501.

National Academies of Sciences, Engineering, and Medicine. (2024). *Artificial Intelligence and Automated Laboratories for Biotechnology: Leveraging Opportunities and Mitigating Risks: Proceedings of a Workshop-in Brief.*

Rosch, T. M., et al. (2024). AutoBioTech:– A Versatile Biofoundry for Automated Strain Engineering. *ACS Synth Biol, 13*(7), 2227-2237, ncbi.nlm.nih.gov/pubmed/38975718.

---

1 bmk.gv.at/themen/klima_umwelt/betrieblich_umweltschutz/anlagenbezogen_uws/seveso3.html.

2 ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen& Gesetzesnummer=.

3 E.g. the wide variety of legal standards that focus on safety when handling working materials: arbeitsinspektion.gv.at/Arbeitsstoffe/Allgemeines/Allgemeines.html.

4 oeaw.ac.at/aithyra/.

TEXTILE RECYCLING

© unsplash.com/Francois Le Nguyen

SUMMARY

Challenges: lack of infrastructure, mixed materials, high costs

The textile industry is characterised by overproduction and overconsumption ("fast fashion"), which leads to immense amounts of textile waste. The linear production method pollutes the environment through high water consumption, chemical pollution, CO_2 emissions and microplastics. Three-quarters of the textile waste produced in Austria is incinerated. Transitioning to a circular textile economy focusing on reuse, repair, and recycling is necessary. Mechanical recycling is widespread but only suitable for single-origin textiles, not synthetic fibres. Chemical recycling enables the reuse of mixed materials, but is only available to a limited extent. According to the EU, all textiles on the European market should be recyclable by 2030. Austria can potentially play a pioneering role in this area and benefit from the economic and environmental advantages.

OVERVIEW OF THE TOPIC

What is textile waste?

Textile waste is diverse; in addition to used clothing and shoes, including accessories (such as belts, scarves, and headwear), it also includes waste from household textiles (e.g., bed and table linen, towels) and home textiles (e.g. carpets, curtains, upholstery fabrics, mattresses). Used textiles" are separately collected textile waste from households and other sectors such as restaurants, hotels and hospitals that are similar in type and composition to households. Another category is technical/industrial textile waste, which covers various applications in various sectors, such as geotextiles, seat covers in transport vehicles, protective textiles, tents and nets. Used clothing, shoes and household and home textiles account for around 80 % of textile waste, while technical textiles and production waste play a subordinate role (Bernhardt et al., 2024).

Three-quarters of textile waste is incinerated

Across the EU, clothing accounts for the largest share (81%) of textile consumption (EC, 2022). In Austria, over 227,000 tons of textile waste are generated annually, and over three-quarters are incinerated. Only around a fifth is collected separately (as used clothing); the majority is mixed waste, mainly residual and bulky waste or from the medical sector. Only 3% of textile waste in Austria is generated during production, while 97% is generated after consumption, i.e. from households or businesses (Bernhardt et al., 2022). Over half of used textiles are collected for charitable purposes (57%), one-third in commercial and 12% in municipal collections.[1]

Problem (Ultra-)Fast Fashion

Today, around twice as many textiles are produced worldwide as twenty years ago, and the trend is rising (EEA, 2022). Worldwide, around 87% of these fibres end up in landfills or are incinerated, which alone causes an annual economic loss of 100 billion dollars (Lanz et al., 2024). A major driver of this development is fast fashion, an unsustainable pattern of overproduction and overconsumption. For decades, the trend of using garments for shorter and shorter periods before discarding them has been perpetuated, leading consumers to purchase more low-quality clothing produced rapidly to meet the latest trends. (Niinimäki et al., 2020). Recently, there has been a shift towards ultra-fast fashion, characterised by only a few days between design and mass production, making weekly changing collections feasible. This renewed acceleration is driven by digital technologies that collect and utilise vast amounts of data on consumer behaviour, personalising the customer's shopping experience and leveraging social media marketing influencers (Dzhengiz et al., 2023).

Environmental impact

Environmental Impacts occur throughout the entire value chain in the textile and fashion industry, from the production of raw materials to processing and consumption. The primary impacts are water consumption, chemical pollution, CO2 emissions, and textile waste (Niinimäki et al., 2020). In addition, the release of ***microplastics*** from synthetic textiles and footwear contributes to the sector's environmental impact, as around 35% of microplastics released into the environment come from textiles. Regarding European consumption, textiles have the fourth most significant adverse effect on the environment and climate - after food, housing and mobility (EEA, 2022). This is due to a linear production model characterised by short use cycles and little reuse, repair and little fibre-to-fibre recycling of textiles.

[1] *umweltbundesamt.at/news220207/grafiken-zu-textilabfaellen*.

The European Commission recently presented the "Strategy for Sustainable and Circular Textiles" with the primary objective that by 2030, all textile products on the EU market be recyclable, made from recycled fibres as far as possible, free from hazardous substances and produced in an environmentally and socially sustainable way (EC, 2022).

Quality, Durability and recyclability are often not.

Textiles comprise various fibres that must be recycled through different processes at the end of their life cycle. Used textiles must first be collected, sorted, and classified, with their quality assessed. The initial sorting is primarily conducted visually to determine the appropriate category, such as clothing or accessories. Subsequently, the textiles are divided into natural and synthetic fibres based on their composition. In certain instances, colours are sorted, and accessories are removed to aid subsequent processing. This reduces the material complexity of the textile fibres, thus enhancing the efficiency of recycling and reuse - a challenge given the wide variety of fabrics, colours, patterns, and contaminants present in the textile waste streams. (Lanz et al., 2024).

Different recycling technologies for various fibre types

Mechanical recycling is the most widespread and developed method; however, it has significant limitations as it is unsuitable for treating all fibres, particularly those of non-organic origin and blended textiles. For fibres that cannot be reused or mechanically recycled, thermal, chemical, or enzymatic recycling becomes necessary to prevent landfilling or incineration (Lanz et al., 2024).

Textile recycling technologies: ...

Mechanical recycling involves the physical breakdown of fibres using methods such as shredding, crushing or melting before the fibres are processed back into yarn. Mechanical processing results in weaker fibres and lower-quality textiles (downcycling) with limited use, e.g., as filling material for furniture or insulation. Mechanical recycling is most effective for textiles made from one material (e.g., 100 per cent cotton). It is less effective for mixed materials, as the processes used further deteriorate the quality of the resulting material (GAO, 2024).

... Mechanical recycling

Thermal recycling is a process based on heating that aims to recover either polymers or low molecular weight building blocks. A distinction is made between thermomechanical recycling and thermochemical recycling. Thermomechanical recycling is utilised to recycle thermoplastic textiles, such as polyester, polyamide, and polypropylene, and convert them back into granules or fibres through melting. In contrast, thermochemical recycling employs oxidation or heat to decompose polymers into monomers that can serve as feedstock for the chemical industry (Duhoux, 2021).

... Thermal recycling

In chemical recycling, textiles are broken down into their basic molecular building blocks using chemical solutions and then rebuilt to produce fibres of similar quality. Obtaining a high-quality product after the process (upcycling) is even possible. In the case of synthetic fibres, the polymer chains are broken down into monomers, which are then separated, purified and processed into new polymers. The additives are removed during the cleaning process. Chemical recycling can occur either in a closed loop (where the material is recycled into an identical product), such as in the case of pure polyester (PET) and nylon six materials, or in an open loop (where the material is recycled into another product category), such as in the case of cotton materials. The end product is cellulose pulp, which produces new fibres like viscose, lyocell, or rayon. (Lanz et al., 2024). Current chemical recycling processes are generally not suitable for mixed materials. Novel approaches using enzymes can separate some mixed materials (Kehl & Riousset, 2024), e.g., cotton and polyester (GAO, 2024). A pilot project in Austria is developing a process for the chemical separation and biotechnological upgrading of

... Chemical and bio-enzymatic recycling

mixed textiles[2]. Other innovative solutions are already being partially implemented, such as REFIBRA (Lenzing AG, AT), CIRCULOSE (Renewcell AB, SE), ONCEMORE (Södra, SE), SAXCELL (SaXcell BV, NL), WORNAGAIN (Worn Again Technologies Ltd., GB) and WOLKAT (Wolkat Group, NL).[3]

How are the recycling technologies?

Mechanical recycling technologies have existed since the Industrial Revolution but are limited due to modern challenges such as the extensive use of mixed materials. Improved labelling that includes various details (e.g., composition, production process and recyclability) could help solve this problem but has little implementation (GAO, 2024). *Thermochemical* recycling is considered a mature technology, even though producing raw materials for the chemical industry has only recently become possible (Duhoux, 2021). *Chemical* textile recycling is currently not available for widespread use. Theoretically, almost all polymers of synthetic fibres could be depolymerised, but an efficient, practical process suitable for all polymers has not yet been developed (Lanz et al., 2024). However, such technologies have already proven themselves in the laboratory and on a small scale, although some have high energy consumption.[4] They are also susceptible to fluctuations in the input material or impurities, which negatively impact the quality of the recyclates and the processing effort required, thus reducing the economic efficiency of the processes (Kehl & Riousset, 2024).

Automated sorting systems

Sorting is an essential prerequisite for all recycling technologies. Automated sorting systems have only recently been introduced, with the world's first plant opening in Malmö in 2021.[5] Infrared scanners could, for instance, recognise the composition of textiles and assist in sorting materials. Artificial intelligence and robotics could be employed to sort materials with high accuracy, though such technologies remain costly and are not yet widely adopted. (GAO, 2024; Tang, 2023).

Recycling is currently not competitive with incineration.

The production and consumption of textiles continue to increase, yet the management of textile waste in Europe is still suboptimal. Reuse is the most beneficial management pathway from both an environmental and socio-economic perspective. Mechanical recycling is the second most crucial pathway for most environmental impact categories. However, these recycling paths are currently not very economically competitive compared to incineration; either the price of CO2 would need to increase, or the costs of technology and processing would have to decrease (Solis et al., 2024).

Challenges

There is currently a lack of scalable fibre-to-fibre recycling solutions in particular, due to[6] (GAO, 2024):

- Mechanical and chemical textile recycling technologies are limited by a lack of supporting infrastructure and insufficient product information for sorting.
- Lack of mature and (economically) scalable recycling technologies; lack of technologies that can maintain the quality of textiles and separate mixed materials.

[2] *fti-ressourcenwende.at/de/projekte/kreislaufwirtschaft/PolyBacTex.php*.
[3] *umweltbundesamt.at/fileadmin/site/publikationen/dp184.pdf*.
[4] *umweltbundesamt.de/publikationen/chemisches-recycling*.
[5] *recyclingmagazin.de/2021/02/18/world's-first-fully-automated-textile-sorting-system-in-malmoe/*.
[6] *umweltbundesamt.at/fileadmin/site/publikationen/dp184.pdf*.

– Materials' suitability for recycling, lack of sufficient input quantities for recycling, low demand for recycled materials, high costs and high energy consumption.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

A switch to a circular production and consumption system for textiles with a longer useful life, more reuse, repair and recycling and a reduction in overall consumption is necessary. The Austrian textile, clothing, shoe and leather industry consists of 319 companies with more than 19,500 employees and an annual turnover of around 2.25 billion euros.[7] It is experiencing considerable competitive pressure and has been impacted by significant relocations of value chains to Asia in recent decades. Domestic companies primarily focus on quality to differentiate themselves, resulting in products from Austrian manufacturers often being found in higher-priced segments. Various instruments could be employed to establish a circular textile economy, and opportunities such as sustainable public procurement of textile products could be explored and exploited.[8] This relatively large lever could be utilised even more effectively in the future. Extended producer responsibility for textiles has also been proposed throughout the EU. Here, manufacturers must bear the costs associated with managing textile waste.[9]

PROPOSAL FOR FURTHER ACTION

Political context and pressing issues

A study focusing on Austria could help to clarify the following questions (see also GAO, 2024):

– What standards could enhance the suitability of textiles for recycling?
– What safety precautions should be implemented to minimise the environmental hazards associated with textile recycling? Which innovations for environmentally friendly recycling require further research or promotion?
– What technological advancements and infrastructures are necessary to facilitate comprehensive textile recycling?
– Which strategies and instruments can increase the use of recyclates increase (Kehl & Riousset, 2024)?

7 *wko.at/oe/industrie/textil-bekleidung-schuh-leder/factsheet-textil-bekleidungs-schuh-leder*, as of 2024.
8 *iwi.ac.at/wp-content/uploads/2021/11/BMK-Kreislaufwirtschaft-im-Textilsektor.pdf*.
9 *umweltbundesamt.at/fileadmin/site/publikationen/dp194.pdf*.

REFERENCES

Bernhardt, A., et al. (2024). *The Waste Management Inventory in Austria - Status Report 2024 for the Reference Year 2022*, ***bmk.gv.at/dam/jcr:7119f610-1180-4337-8837-f5c45e73b4b5/BAWP_Statusbericht_2024.pdf.***

Bernhardt, A., et al. (2022). Generation and treatment of textile waste in Austria, ***umweltbundesamt.at/fileadmin/site/publikationen/rep0788.pdf.***

Duhoux, T. et. al. (2021). Study on the technical, regulatory, economic and environmental effectiveness of textile fibres recycling. *Final Report to the European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs.* ***op.europa.eu/en/publication-detail/-/publication/739a1cca-6145-11ec-9c6c-01aa75ed71a1***.

Dzhengiz, T., et al. (2023). (Un)Sustainable transitions towards fast and ultra-fast fashion. *Fashion and Textiles, 10*(1), 19, ***doi.org/10.1186/s40691-023-00337-9.***

EC (2022). *EU Strategy for Sustainable and Circular Textiles*, ***environment.ec.europa.eu/document/download/74126c90-5cbf-46d0-ab6b-60878644b395_en?filename=COM_2022_141_1_EN_ACT_part1_v8.pdf.***

EEA (2022). *Textiles and the environment: the role of design in Europe's circular economy*, ***eea.europa.eu/publications/textiles-and-the-environment-the***.

GAO (2024). *Science & Tech Spotlight: Textile Recycling Technologies*, ***gao.gov/products/gao-24-107486***.

Kehl, C., & Riousset, P. (2024). *Strategies and instruments for improving the use of recyclates. With case studies on plastic packaging, electrical appliances and building materials. Final report on the TA project*.

Lanz, I. E., et al. (2024). A Mapping of Textile Waste Recycling Technologies in Europe and Spain. *Textiles, 4*(3), 359-390. doi:10.3390/textiles4030022.

Niinimäki, K., et al. (2020). The environmental price of fast fashion. *Nature Reviews Earth & Environment, 1*(4), 189-200, ***doi.org/10.1038/s43017-020-0039-9.***

Solis, M., et al. (2024). Management of textile waste in Europe: An environmental and a socio-economic assessment of current and future scenarios. *Resources, Conservation and Recycling, 207*, 107693.

Tang, K. H. (2023). State of the Art in Textile Waste Management: A Review. *Textiles, 3*(4), 454-467. doi:10.3390/textiles3040027.

GREEN CONCRETE

© unsplash.com/K8 Thomas Bayer

SUMMARY

Concrete must become more sustainable.

Conventional cement production, the main concrete component, causes around 8% of global CO_2 emissions and consumes immense amounts of natural resources. Given the increasing demand for concrete, finding more sustainable alternatives for concrete production is crucial. Green concrete encompasses various approaches to producing more environmentally friendly concrete. These include: Replacing conventional cement with industrial waste such as fly ash or granulated blast furnace slag, using recycled materials in concrete, or energy-efficient manufacturing processes. In addition, other innovations make concrete construction more environmentally friendly, such as self-healing, 3D-printed or photocatalytic concrete, electrified machines, carbon capture, utilization, and storage. The biggest challenges currently lie in the availability of alternative materials and technologies, the cost of renewable energy and recycled materials and the lack of incentives and subsidies for the use of green concrete.

OVERVIEW OF THE TOPIC

Concrete causes around 8 % of global CO_2 emissions

Due to its numerous applications, Concrete is the second most consumed material on Earth after water, with a global production of approximately 4.1 billion tonnes of cement in 2021 and an annual concrete consumption roughly seven times greater (Nilimaa, 2023). The concrete industry faces increasing pressure to take significant steps towards sustainability, as producing ordinary Portland cement, the primary binder of concrete, contributes approximately 8% of global anthropogenic carbon dioxide emissions. Furthermore, concrete production consumes vast natural resources. Billions of tonnes of concrete are anticipated to be needed in the coming years to address infrastructure demands, making it essential to render concrete production more environmentally friendly (Sivakrishna et al., 2020).

Conventional cement production

Alongside water and sand or gravel, cement is the leading concrete component. In conventional cement production, the initial step entails burning a finely ground mixture of limestone and clay at temperatures of 1,450 °C to produce Portland cement clinker. This releases CO_2 bound in the limestone, responsible for around two-thirds of the total emissions from cement production, while one-third is caused by operating the kiln with fossil fuels. In the second step, the clinker is ground into cement with limestone additives, granulated blast furnace slag, fly ash and gypsum. The composition determines the properties of the subsequent concrete, such as strength, setting behaviour and durability (Caviezel et al., 2023).

Current environmental trends and innovations in concrete construction

Current trends in sustainable concrete construction encompass green concrete, cementitious admixtures, permeable concrete, cooling concrete, and the utilisation of local and sustainable materials. Research is also being conducted into innovations such as self-healing concrete, 3D-printed concrete (see *Houses from the 3D printer*), self-purifying and air-purifying concrete, electrified machinery and carbon capture, utilisation and storage (CCUS, see *Negative emission technologies*) (Nilimaa, 2023).

Green concrete is a fuzzy concept.

The term *green concrete* is relatively vague. On the one hand, it partially replaces additives in conventional cement with industrial waste, such as fly ash from coal-fired power stations, granulated blast furnace slag from steel production, or silica fume. On the other hand, it also encompasses extending the useful life of concrete structures, using material-efficient construction methods, using recycled materials and recycled concrete, and overall reducing the carbon footprint and producing more energy-efficiently.

Low-clinker cements with new substitutes such as fly ash, granulated blast furnace slag, clay minerals or biochar

The production of new low-clinker standard types of cement also unavoidably generates CO_2, which can be partially avoided by reducing the proportion of clinker in the cement. In Germany, such new types of cement have been standardised since 2021, which can halve the clinker content to around 35 % compared to conventional Portland cement (Caviezel et al., 2023). The missing clinker must be replaced by larger proportions of additives, making the composition of low-clinker cements more complex. Additionally, the technical properties of concrete (and consequently, the application areas) increasingly rely on the additives' performance. However, these high-quality additives could become scarce in the future: blast furnace slag due to the transformation of the steel industry and fly ash due to the phase-out of coal-fired power generation (Caviezel et al., 2023). Great hopes are consequently pinned on new additives like clay minerals. Efforts are currently underway to standardise and introduce the corresponding cements. Nevertheless, questions remain about their performance and the conditions necessary for widespread use. (Caviezel et al., 2023). The addition of biochar (see *negative emission technologies*) to concrete also brings several advantages, such as improved strength and durability, improved thermal properties and the potential for longer-term carbon sequestration in building components (Barbhuiya, Bhusan Das, et al., 2024).

Used concrete recycling

In concrete recycling, attention is paid to separating materials by type during the demolition of buildings. After this, concrete residues are crushed and separated from the reinforcing steel, which is then melted down. Since 2024, mineral construction waste, which includes concrete, may no longer be landfilled in Austria. Old concrete is almost entirely recycled through downcycling, such as an unbound base layer in road construction. If concrete residues are classified—separated according to grain size—the material can substitute for natural aggregate in new concrete, significantly conserving resources in extraction and transportation.[1] Pilot plants can already produce Belit cement clinker, a high-quality aggregate for new concrete made from recycled concrete. The resulting CO2 emissions are captured in the process and bound again in the cement.[2]

New properties with effects on the sustainability of concrete structures:

There are also multiple methods for enhancing concrete with new properties to improve its sustainability during use. The maturity of these technologies varies significantly (Nilimaa, 2023):

... permeable concrete

- Permeable concrete is designed to allow water to pass through its structure, thereby reducing surface runoff of rainwater and promoting groundwater recharge. It could play a crucial role in mitigating the effects of urban heat islands, decreasing flooding risks, and enhancing water quality.

... cooling concrete

- Cooling concrete comprises reflective or light-coloured elements that decrease the surface temperature of concrete structures, thereby reducing heat loads and lowering the energy consumption of cooling in buildings.

... Air and self-cleaning concrete

- Photocatalytic materials like titanium dioxide provide concrete with self-cleaning and air-purifying properties, which can enhance air quality in urban areas.

... Ultra-high performance concrete

- Ultra-high-performance concrete (UHPC), a cement-based composite material, can significantly decrease the materials used while simultaneously prolonging the service life of components and buildings.

Self-healing concrete:

- Self-healing concrete, like other *self-healing materials*, is designed to improve durability and performance by repairing cracks and damage independently, reducing inspection, maintenance and repairs.

  ... with bacteria

  - Specific bacterial strains and nutrients are introduced, which, when moisture seeps through cracks, begin to excrete calcium carbonate as a by-product of their metabolism. This fills the cracks and restores the structural integrity of concrete.

  ... with microcapsules

1 *abfallwirtschaft.steiermark.at/cms/dokumente/10024917_46569/88d99351/2.3_Rec_Beton_V4.pdf*.

2 *vdi-nachrichten.com/technik/umwelt/kit-pilotanlage-fuer-klimafreundlichen-zement/*.

- The inclusion of microcapsules containing polymeric materials or mineral compounds. When the concrete cracks, the capsules break open, releasing the material inside to seal the cracks and harden.
- After deformation, such as due to heat or other external influences, shape-memory polymers can return to their original form. As fibres in embedded reinforcements, concrete can recover from deformations or rectify minor issues and cracks.

... with shape memory

- Superabsorbent polymers (SAPs) absorb significant amounts of water and subsequently release it. They help to minimise cracking during curing and aid in self-healing by releasing water at microcracks, which creates gels with unreacted cement particles to fill the gaps and cracks.

... with superabsorbent polymers

An open question with any composite material is its recyclability.

Key challenges for a net-zero concrete sector

Overall, there remains a considerable distance to cover to attain a net-zero concrete sector, and the primary challenges can be summarised as follows (Al-Otaibi, 2024; Barbhuiya, Bhusan, et al., 2024):

- *Technical:* availability of alternative energy sources, efficiency of existing plants and the lack of clear standards for recycled materials.
- *Economic:* e.g., non-uniform CO_2 taxes between countries or lack of emissions trading, which leads to support for the established carbon-intensive system. Cost and availability of renewable energy and recycled materials.
- *Implementation*: restrictive cement standards, equipment and operational issues, staff availability, and staff competence.
- *Support and promotion*: Lack of political support and *incentives* incentives for the use of recycled materials in construction

Reduction of unavoidable emissions through CCUS

From today's perspective, the goal of a (primarily) climate-neutral cement industry can only be achieved through CO_2 capture and storage or utilisation (see ***negative emission technologies***). CO2 should be captured directly at point sources, such as cement plants, and stored underground. To this end, the Austrian Carbon Management Strategy was adopted by the Council of Ministers in June 2024, which provides for, among other things, "the lifting of the ban on geological CO_2 storage in Austria and the simultaneous creation of the necessary legal framework for geological CO_2 storage through full implementation of the EU CCS Directive[3]. The legal framework for pipeline-based transportation also needs to be adapted. The strategy highlights the stringent safety and environmental standards under which CCS is to be executed. Numerous nations across the globe are pursuing storage projects, a few of which are commercially viable. However, as highly long storage periods are anticipated (spanning several centuries or millennia), uncertainties cannot be eliminated, particularly concerning how long the storage sites can endure without leaking (Bashir et al., 2024). Carbon captured at cement plants should also be usable for the primary industry (CCU, see ***CO_2 as a resource)***.

[3] *bmf.gv.at/themen/klimapolitik/carbon_management.html*.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

In Austria, several research institutions are developing and implementing green concrete[4]. There are nine cement plants with operational kilns across Austria, producing around 4.4 million tons of cement annually (2023)[5]. According to their information, some companies offer more climate-friendly concrete, with CO2- reductions of 10-70% compared to the industry standard, for example, through clinker substitutes and recycled concrete. The first steps towards sustainability have been taken with the standardisation of the assessment of concrete products in the production phase (from the cradle to the factory gate) or the entire life cycle (from the cradle to the grave).[6]

Diverse starting points for a strategy towards more sustainable concrete in Austria

Some starting points for implementing and promoting more sustainable concrete construction include establishing and enforcing rules and incentives to promote sustainability; forming public-private partnerships to share resources and responsibilities for sustainable projects; providing education and training to equip professionals with the necessary skills; supporting research and development efforts to drive sustainable innovation; and conducting pilot projects to test and refine sustainable practices in real-world scenarios (Khan & McNally, 2023).

PROPOSAL FOR FURTHER ACTION

Clear guidelines, improved standards

To overcome the obstacles identified, it is essential to understand the significance of making concrete construction more sustainable. This effort requires collaboration among all stakeholders in the construction industry. Additionally, research should urgently address unanswered questions related to sustainable concrete construction. All relevant stakeholders need to be involved in formulating clear guidelines, improving technical standards, and creating greater awareness of the benefits of green concrete (Al-Otaibi, 2024). An in-depth literature study, enriched by expert interviews on sustainability assessments of individual technologies mentioned above, can also provide a better basis for decision-making. A TA study could support political decision-makers in developing key strategies on the points mentioned above with all stakeholders. Strategies that could make a decisive contribution to making concrete construction more environmentally friendly.

---

4 i.e. *tugraz.at/tu-graz/services/news-stories/tu-graz-dossiers/sustainable-building-with-concrete*; *.klimaneutralestadt.at/resources/pdf/schriftenreihe-2024-26-rcc2.pdf.*

5 *zement.at/downloads/downloads_2024/Emissionen_aus_Anlagen_der_%C3%B6sterreichischen_Zementindustrie_Bilanzjahr_2023.pdf*.

6 *austrian-standards.at/de/shop/onorm-en-16757-2023-05-15~p2660618*.

REFERENCES

Al-Otaibi, A. (2024). Barriers and Enablers for Green Concrete Adoption: A Scientometric Aided Literature Review Approach. *Sustainability, 16*(12), 5093.

Barbhuiya, S., et al. (2024). Biochar-concrete: A comprehensive review of properties, production and sustainability. *Case Studies in Construction Materials, 20*, e02859, **sciencedirect.com/science/article/pii/S221450952400010X**.

Barbhuiya, S., et al. (2024). Roadmap to a net-zero carbon cement sector: Strategies, innovations and policy imperatives. *Journal of Environmental Management, 359*, 121052, **sciencedirect.com/science/article/pii/S0301479724010387**.

Bashir, A., et al. (2024). Comprehensive review of CO2 geological storage: Exploring principles, mechanisms, and prospects. *Earth-Science Reviews, 249*, 104672, **sciencedirect.com/science/article/pii/S0012825223003616**.

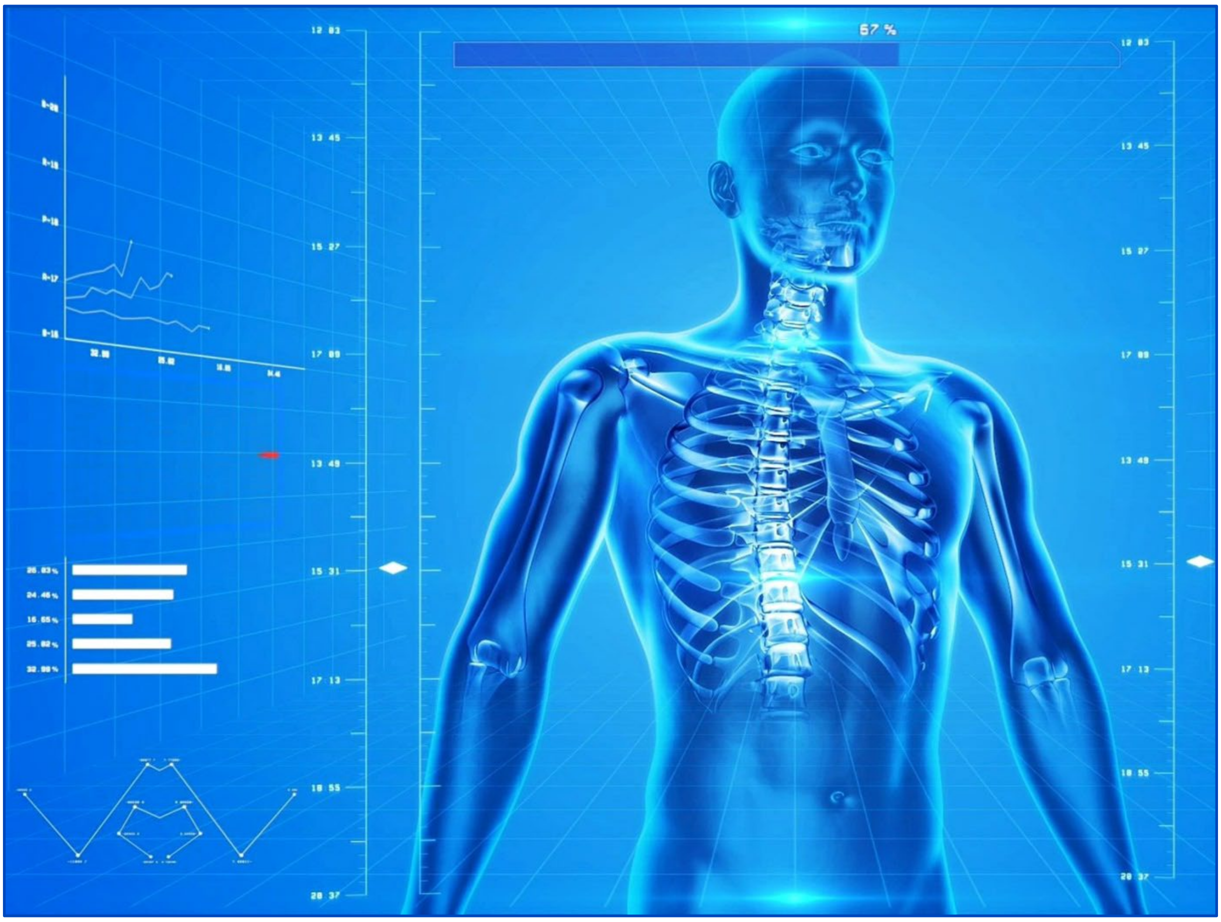
Caviezel, C., et al. (2023). Alternative technology pathways for emission reduction in the primary industry - Final report on the TA project (results report). *Office of Technology Assessment at the German Bundestag, Berlin*, **publikationen.bibliothek.kit.edu/1000170905/152949637.**

Khan, M., & McNally, C. (2023). A holistic review on the contribution of civil engineers for driving sustainable concrete construction in the built environment. *Developments in the Built Environment, 16*, 100273, **sciencedirect.com/science/article/pii/S2666165923001552**.

Nilimaa, J. (2023). Smart materials and technologies for sustainable concrete construction. *Developments in the Built Environment, 15*, 100177, **sciencedirect.com/science/article/pii/S2666165923000595**.

Sivakrishna, A., et al. (2020). Green concrete: A review of recent developments. *Materials Today: Proceedings, 27*, 54-58, **sciencedirect.com/science/article/pii/S2214785319331918**.

DIGITAL PATIENT TWINS



© pixabay.com/PublicDomainPictures

SUMMARY

Digital twins as a tool for overcoming many complex challenges

The concept of digital twins describes a representation of a real object in the virtual world and can be understood as a further development of existing modelling that makes it possible to monitor the state of the real object in real-time and, if necessary, intervene to control it. In addition, the effects of changes to the real object can be tested on digital twins. There are already many applications in laboratories, urban and traffic planning, and logistics. While digital twins have been in use in these areas for several years at an early stage of development, their application is now increasingly being researched for medical purposes. Digital twins of specific organs, such as the heart or liver, have been around for some time. However, the vision for the future is modelling the entire human organism.

OVERVIEW OF THE TOPIC

What are digital twins …

Digital twins are a concept for modelling real objects in digital systems. They are intended to enable a complete or partial representation of reality. The aim is to reproduce the relevant aspects of reality as accurately as possible to try out changes or adjustments to the model before making (costly or risky) fundamental changes. Controlling the real object through the digital twin based on sensor data related to the real object is often a key aspect of the relationship between the two twins. In some definitions, a temporal factor also plays a role, whereby one would only refer to a digital twin if the model exists throughout the entire life cycle of the real object and exchanges data with it (see also Singh et al. 2021).

… and how are these differentiated from similar concepts?

The concept is used in various areas: in medicine[1], in urban planning, in industrial manufacturing processes and many more. The most significant difference from previously used models is the (almost) real-time data exchange with the actual object the digital twin represents. In conventional static models, properties are drawn from reality, but there are no (bidirectional) continuous updates of the parameters; furthermore, there is no arrangement for controlling the real object through a static model. In comparison, digital shadow describes a virtual representation of a real object only supplied with data unidirectionally, from reality to the model.[2] However, merely measuring the parameters of an object or process and then visualising them is insufficient to define a digital twin, as this does not constitute a model. The distinction from a simulation may be fluid but is typically determined by the scale. For example, a simulation specialises in a particular variable aspect. In contrast, digital twins are intended to be more comprehensive, i.e. they can also carry out different or multiple simulations in parallel.[3]

e.g. digital shadow

e.g. simulation

Digital Patient: inside twins

Digital twins (digital patient twins or human/health digital twins, HDT) are frequently discussed and researched in medicine. This is primarily about the digital image of a person, with the possibility of simulating complex relationships and interactions; however, in contrast to the definition for other fields of application, it is not about the model controlling the real person (see Sun et al. 2023). However, targeted intervention in specific systems, such as pacemakers or insulin pumps, is conceivable.

1 See also: *Data-driven medicine* and *Automated health data monitoring*.
2 Sometimes the sum of all the data available about a person and stored in a profile is also referred to as the digital shadow.
3 On the relationship between smart spaces and digital twins, see here: *Smart Spaces and Digital Twins*.

Hopes in the areas of the fight against cancer

In the treatment of certain types of cancer, for example, it is hoped that data regarding the tumour, such as its tissue composition, will be integrated into a digital twin alongside other patient information, enabling the model to ultimately test which pharmaceutical or radiotherapy would have the most significant effect treatment. This could spare patients the ordeal of undergoing challenging treatment trials with severe side effects. According to initial findings from a research project in this field, it is believed that the current models are already capable of determining more effectively than humans the appropriate therapy for particular types of cancer (75% to 53% probability that the proposed treatment will be successful). The researchers believe that if AI systems are further developed successfully, they could be implemented in hospitals within a few years.[4] Diabetes patients could also benefit from digital twins. Drawing on individual data, it ought to be possible to identify secondary damage from the disease early, thereby preventing further complications damage.[5] Other promising areas are dermatology and cardiology.

diabetes

dermatology and cardiology

Drug development

Digital twins are already being used in medicine to develop medicines, where they are intended to reduce the resources required to create new products, in this case, pharmaceutical therapies, in a similar way to virtual prototyping in the industry. The digital twin of an organ or organ system allows the interaction with the drug to be tested in advance under different conditions. The aim is to reduce the number of preparations entering clinical trials to a few promising ones, lowering the rejection rate (e.g., by the Federal Drug Administration in the USA, where it is 90%). There are also plans to use fewer people and more digital twins for control groups in clinical trials, so-called "in silico clinical trials" (Venkatesh et al 2024).

Naturally, these initial objectives of using digital patient twins do not yet cover what many anticipate from the concept. Clarifying the *most suitable form of therapy for certain types of cancer* is a start. Ultimately, however, there is hope that one day, it will be possible to model a person's entire organism in real time using suitable sensors (Tang et al 2024). This should enable considering genetic factors alongside environmental influences, prior illnesses, or interactions with other substances. However, a more precise understanding of the human body's functions and its complex interactions remains lacking in many areas. It would be the pinnacle of personalised medicine, so to speak - from the patient's perspective view.

The implementation of the concept in medicine is picking up speed but is not yet able to fulfil all the promises attributed to it

Another vision for the future would be, for example, *preparation for complicated operations*. Doctors could use the model data to understand the specifics of the person to be operated on, explore different approaches, and, for example, have prostheses tailored in advance. This would lead to a higher quality surgical outcome and quicker recovery. In prevention, the digital twin could integrate all of a person's available measurement data with statistical population data, individual disease progression, information on specific clinical presentations, and the success of treatments for others. It could then derive preventive measures that might contribute to significantly lower treatment costs and a healthier population overall.[6]

---

4 *science.orf.at/stories/3227296/*.

5 *pwc.de/en/healthcare-and-pharma/pwc-study-the-digitale-zwilling.pdf*.

6 *siemens-healthineers.com/en/perspectives/digital-patient-twin*.

Vision: fully digitised population

The next step would involve a digitised population composed of all the digital twins of a country's inhabitants. Hopefully, this would offer a better foundation for decision-making during disease outbreaks, pandemics, and the like, as new findings could be immediately applied to the population. For instance, pre-existing conditions, comorbidities, or genetic predispositions that render an individual part of a vulnerable group would become apparent. (Venkatesh et al 2024).

Is this possible in compliance with data protection regulations?

From the perspective of data protection experts, the assessment is not wholly positive. Significant risks arise from the volume of sensitive personal data required and the continuous monitoring of bodily functions, which facilitate a broad range of improper uses. The unresolved issues in this context primarily relate to access to the data and its purpose limitation. Who stores the data? Will all "healthcare providers" have access to it? How will this be regulated in future in the European Health Data Space[7]? Will insurance companies also have access to the data? Will they be permitted to offer lower premiums if granted access to their digital twin? Will this transform privacy into a luxury good for the rich? The principle of data economy[8] would probably also be almost impossible to fulfil in such a case because, from today's perspective, the system will deliver better results if as much data as possible is fed in - incredibly as long as the relevant processes or the criteria responsible for certain developments in the human body are still unknown.

New collections of sensitive personal data are to be expected.

Generally speaking, it should be noted that the functioning of digital twins requires a lot of data that does not yet exist (apart from the small contribution made by fitness trackers and smartwatches), which would, therefore, have to be collected specifically for this purpose. At the same time, various players would very much like access to the data, not always for noble motives. So, how can this enormous mountain of sensitive health data be protected from unauthorised access, misuse, and exploitation modification?
The responsible use of data is crucial in the medical field to ensure that fundamental rights are not compromised for improved efficiency in the healthcare system. The trade-off between interventions under data protection law and the potential increase in effectiveness in prevention and treatment should be discussed in a broader social context debate. Aspects such as fairness and non-discrimination should also be considered. Access to the benefits of digital twins should be available equally. Furthermore, it is essential to ensure that a bias in the AI training data, such as an underrepresentation of specific population groups, does not lead to the benefits being exclusively realised by the majority population.

New dependencies

It is also worth considering what a plan B might entail and how we would prepare for it. Given the extensive integration of these systems into the healthcare system, it is essential to consider the fall-back position if these systems function unreliably.

---

7 European Commission on the EHDS: *European Health Data Space*.

8 Only as much data is collected and processed as is absolutely necessary to achieve the purpose.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Better quality of life for patients and lower healthcare costs

Austria can benefit from the possibilities of digital twins and their development. There are already applications that are productively used in many other areas in Austria. The Austrian Research Promotion Agency also promotes research in this area. If the high expectations are met, the healthcare system will become just as powerful and efficient as it would benefit patients individually. Thanks to its high expertise in the field, Austria would also become more attractive as a production and research location. This would provide an opportunity to combine expertise in AI, medical research and system modelling. This work might also reveal which data is available and usable, where further surveys may be needed or where there is a lack of standardisation in collection and processing.[9] The strong molecular-biological/medical research field in Austria could also benefit significantly from focusing on developing digital twins.

Parliament is affected on two levels here. On the one hand, promoting development more strongly, if necessary, and initiating research funding and innovation incentives is important. On the other hand, it is essential to ensure that the processing of the data used by the respective players in the development and operation of these systems only takes place in compliance with all data protection regulations. To this end, it may be necessary to strengthen the competencies and resources of the supervisory authorities.

PROPOSAL FOR FURTHER ACTION

The existing knowledge and potential on this topic in Austria could be surveyed as a first step. Improved networking of the relevant players would also seem sensible.

Recording the current status and deployment guidelines would be crucial for further development …

In processing sensitive personal health data from medicine or for medical purposes, developing guidelines that support developers in achieving data protection-compliant implementation of their projects in market-ready products is essential. However, a fundamental prerequisite for this would be first to develop ways of implementing digital twins that meet social expectations and the regulatory framework. This involves ethical issues such as the limits of the use of digital twins, equal access for all people to the benefits of this technology, data protection and non-discrimination. The specific conditions under which applying these concepts to health data by fundamental rights is acceptable could be developed in an in-depth study of Austria with the involvement of all stakeholders. Should the legislator or the administration wish to make the topic a research focus in Austria, drawing up a strategy for digital twins and an associated roadmap for achieving the goals set in all areas would also make sense.

… factors for the effectiveness and acceptance of digital twins could also be researched

[9] Cf. the situation during the Covid-19 pandemic: It can be assumed that in some other areas, too, there is no uniform nationwide strategy for data collection that goes beyond what is collected by Statistics Austria.

However, to increase the chances of acceptance and success of the concept, it is not only necessary to find a solution to the emerging data protection problem. Standardising digital twins that enable interoperability and sustainable operation would also be essential. The operation and development of current AI systems require a great deal of energy. Therefore, until the vision of a complete digital twin for all is achieved, either consumption should be drastically reduced, or CO_2-neutral production from renewable sources should increase accordingly.

REFERENCES

Grieves, M.W. (2005). Product lifecycle management: the new paradigm for enterprises. *Int. J. Product Development*, vol. 2:1, 2.

Singh, M., Fuenmayor, E., Hinchy, E.P., Qiao, Y.; Murray, N., Devine, D. (2021). Digital Twin: Origin to Future. *Appl. Syst. Innov.*, 4, 36, ***doi.org/10.3390/asi4020036.***

Sun T., He X., Li Z. (2023). Digital twin in healthcare: Recent updates and challenges. *Digital Health* 2023/9. ***doi:10.1177/***20552076221149651.

Tang, C., Yi, W., Occhipinti, E. et al. (2024). A roadmap for the development of human body digital twins. *Nat Rev Electr Eng* 1, 199-207. ***doi.org/10.1038/s44287-024-00025-w***.

Venkatesh, K.P., Brito, G., Kamel Boulos, M.N. (2024). Health Digital Twins in Life Science and Health Care Innovation. *Annual Review of Pharmacology and Toxicology*, Vol. 64, 159-170. ***doi.org/10.1146/annurev-pharmtox-022123-022046***.

ARTIFICIAL WOMB AND SYNTHETIC EMBRYOS (UPDATED)

© unsplash.com/85GB photo

SUMMARY

Techniques to enable the development of embryos or foetuses (including humans) outside the body in artificial systems (ectogenesis) have developed considerably in recent years. In addition to these advances, recent ground-breaking experiments on the creation of embryos without egg or sperm cells, so-called "synthetic embryos", as well as their in vitro cultivation, have made it possible to decipher fundamental processes of embryo (self-) organisation and development. Such embryo models are already raising profound legal questions. In the short to medium term, developments in the creation and cultivation of embryos, in particular, will likely require a social discussion of the opportunities and ethical challenges to develop and use new knowledge and potential biomedical applications responsibly.

OVERVIEW OF THE TOPIC

Research to develop embryos or foetuses[1] outside the body - so-called ectogenesis - has made significant progress in recent years. Sensational results of such work have been reported at both ends of the "development spectrum" from fertilisation to birth.

Artificial womb systems - possible care for premature babies

Partridge et al. (2017) showed that the development of lamb foetuses, in which the umbilical cord was connected to an artificial circulatory system (artificial placenta), can be continued in an "extra-uterine system" for several weeks until birth maturity. This artificial womb or uterus consisted of a kind of fluid-filled [2] Previously, foetuses in such systems - which have been worked on in various forms since the late 1950s (initially with human foetuses; Westin, Nyberg, & Enhorning, 1958) - could only survive for hours to a few days. This was mainly due to problems (such as circulatory failure) caused by the artificial placenta systems used (Bie et al., 2021; Partridge et al., 2017). The experiments were carried out to improve the chances of survival of extremely premature babies and avoid[3] Currently, children born before the 22nd week of pregnancy have no real chance of survival. From the 22nd to the 25th week, the survival rate increases from approximately 24% to 76%. However, the risk of retaining severe health damage remains considerable (AWMF, 2020), as the lungs of extremely premature babies are too immature to allow sufficient gas exchange (and without damaging the lungs) through ventilation procedures. This problem appears to be solvable using artificial womb systems, in which the foetuses are supplied with oxygen (in the blood) via the umbilical cord. Accordingly, highly premature babies, in particular, could benefit from such systems. Additionally, a health economic benefit in the form of cost savings due to reduced long-term impairment in such children also seems feasible. It remains unclear when and under what medical-ethical or regulatory conditions—such as in clinical trials or experimental treatments—these systems could be tested or utilised for the first time. In both cases, (differently) strict regulations and ethical guidelines would apply (Romanis, 2020). In the USA, the responsible authority, the FDA, has recently looked at possible clinical trials (Hunter, 2024).

Ever more extended cultivation of embryos in vitro

At the other end of the development spectrum, so to speak, there have recently been several groundbreaking experiments on the generation and cultivation of mouse, monkey and human embryos in vitro ("in the test tube"). On the one hand, these show that embryos can be cultivated beyond the stage at which they would implant in the uterus (in humans approx. one week after fertilisation). Mouse embryos could be grown in a nutrient solution in rotating glass vessels (with a

[1] Embryos are referred to as fetuses from the end of the 8th week after fertilization, a time when the organ systems (for further maturation) have formed.

[2] *youtube.com/watch?v=dt7twXzNEsQ*.

[3] A 5-year research project in the EU to develop prototypes for an artificial uterus system has been funded by the Horizon 2020 program since 2019; *perinatallifesupport.eu/project/*.

unique gas exchange system)[4] up to stages that correspond to those after more than half of the standard gestation period (of 19 days) and that have formed all organs (Aguilera-Castrejon et al., 2021). Development beyond 14 days seems quite possible in humans - an internationally recommended period that is the legal limit for culturing human embryos for research purposes in some countries (e.g. France, United Kingdom)[5] (Powell, 2021, and ref. therein). From this point onwards, the embryo forms a body axis and different tissue layers from which the organs develop.

Embryos without fertilisation - synthetic embryo models

On the other hand, it was shown that synthetic embryos or embryo models, which are highly similar to natural embryos, can be created independently of germ cells or fertilised eggs. Synthetic mouse embryos were produced from embryonic stem cells, sometimes in combination with other stem cells (e.g. for the later placenta), and developed into stages of organ formation, including the central nervous system (Amadei et al., 2022; Tarazi et al., 2022). In humans, so-called blastoids correspond to the blastocyst stage (the stage at which the embryo implants in the uterus) (e.g. Kagawa et al., 2022)[6] and embryo models have been generated in this way, which in many aspects correspond to embryo stages after uterine implantation of up to 14 days after fertilisation (Mallapaty, 2024 and ref. therein). Synthetic monkey blastoids were transferred into mother animals but stopped developing after 20 days (Li et al., 2023). In vitro cultured stages corresponding to those occurring after implantation in the uterus could, for instance, facilitate the investigation of the causes of pregnancy losses and congenital malformations that frequently arise at this stage of development. Furthermore, synthetic embryos could be employed to assess drugs' impact and generate tissue or organs for transplantation. As synthetic embryos are created without fertilised egg cells, these approaches could represent a less ethically problematic alternative to research with ***natural embryos***. However, the further such embryos develop (up to the development of the nervous system), the more ethical and associated legal and regulatory issues are likely to arise (e.g., Mallapaty, 2024).

Complete ectogenesis - currently only a vision

Although progressively longer segments of the prenatal developmental spectrum can thus occur outside the body, complete ectogenesis (which would require small and swiftly developing stages to be linked to artificial placental systems) is deemed unrealistic by experts in the foreseeable future (Bie et al., 2022, and references therein). Complete ectogenesis is associated with the vision of reproduction without pregnancy. Accordingly, the broader social implications discussed in this context, particularly concerning reproductive and associated social inequalities among women as well as access to such technologies (e.g., Bie et al., 2022), are unlikely to become relevant over a longer period of time.

---

[4] *youtube.com/watch?v=mKh6wYDsTBg*. Due to the small dimensions of the embryonic stages (a few millimeters), oxygen and nutrients can be supplied purely via diffusion processes.

[5] In May 2021, the International Society for Stem Cell Research (ISSCR) relaxed the so-called 14-day rule. Projects to cultivate embryos beyond 14 days are to be examined on a case-by-case basis.

[6] The generation of blastoids by Kagawa et al. (2022) took place at the Institute of Molecular Biotechnology in Vienna and was approved by the Austrian Academy of Sciences' Commission for Scientific Ethics.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Challenges and opportunities for synthetic embryo models

Neither complete ectogenesis, which is likely to remain a vision for a long time, nor possible artificial womb systems for the care of extremely premature babies, which would only be testable or applicable under strict existing regulations and, in special exceptional cases, are likely to lead to genuinely new ethical or legal challenges in the foreseeable future. In contrast, such challenges arise from the rapid developments and advances in synthetic embryo generation and in vitro cultivation (e.g., Rivron et al., 2023). In particular, possible implications for the scope of the Austrian Reproductive Medicine Act, which apparently does not cover synthetic embryos or leaves their legal status unclear, are already foreseeable today (e.g., Körtner, 2022). In addition, a significant social challenge is the question of what ethical status possible synthetic embryo models (with potentially more far-reaching development potential than before, or even those that could only develop specific organs) should have - and how their use for research purposes and applications, such as the generation of organs or possibly in reproductive medicine, could or should be regulated. The creation of appropriate ethical and legal certainty and public trust would also be relevant given Austria's existing potential - with cutting-edge research in this area and the commitment of leading pharmaceutical companies in the country – to translate findings from such research into biomedical applications with social benefits.

PROPOSAL FOR FURTHER ACTION

Clarification of legal issues and national dialogue process

Clarifying current and possible future legal implications should, in particular, require an exchange between legal experts and parliament to determine the need for legislative action. A social dialogue process involving the public could be initiated for the ethical classification of possible synthetic embryo models and questions regarding the conditions of their future use for research and potential applications. On the one hand, this should enable mutual learning processes - particularly about different values, perspectives or interests - by involving as many relevant stakeholders as possible from areas such as science, medicine and ethics, authorities and politics, civil society organisations and the general public. Secondly, results could be regularly fed back to parliament. Ideally, such a process should be able to go beyond isolated events, e.g., as part of various research projects, and be initiated and organised nationally (possibly under the auspices of parliament).

REFERENCES

Amadei, G., et al. (2022). The embryo model completes gastrulation to neurulation and organogenesis. *Nature*, *610*(7930), 143-153. *doi.org/10.1038/s41586-022-05246-3*.

AWMF (2020). *Preterm infants at the limit of viability*. AWMF Guidelines Register No. 024/019. Association of the Scientific Medical Societies in Germany. *register.awmf.org/assets/guidelines/024-019l_S2k_Frühgeburt_Grenze_Lebensfähigkeit_2021-01.pdf*.

Bie, F. R. de, et al. (2021). Artificial placenta and womb technology: Past, current, and future challenges towards clinical translation. *Prenatal Diagnosis*, 41(1), 145-158. *doi.org/10.1002/pd.5821.*

Bie, F. R. de, et al. (2022). Ethics Considerations Regarding Artificial Womb Technology for the Fetonate. *The American Journal of Bioethics: AJOB*, 1-12. *doi.org/10.1080/15265161.2022.2048738.*

Hunter P. (2024). Exogestation for treating premature births and congenital diseases: Artificial womb technology edges towards first trials in humans. EMBO Rep, 25(1),17-20. *doi.org/10.1038/s44319-023-00022-4.*

Kagawa, H., et al. (2022). Human blastoids model blastocyst development and implantation. *Nature*, *601*(7894), 600-605. *doi.org/10.1038/s41586-021-04267-8*.

Körtner, U. H. (2022). Synthetic embryos. Unsettled legal status. Austrian Broadcasting Corporation (ORF), August 26, 2022. *science.orf.at/stories/3214803/.*

Li, J., et al. (2023). The Cynomolgus monkey embryo model captures gastrulation and early pregnancy. *Cell Stem Cell*, *30*(4), 362-377.e7. *doi.org/10.1016/j.stem.2023.03.009*

Mallapaty S. (2024). Human embryo models are getting more realistic - raising ethical questions. *Nature, 633* (8029), 268-271. *doi.org/10.1038/d41586-024-02915-3*.

Partridge, E. A., et al (2017). An extra-uterine system to physiologically support the extreme premature lamb. *Nature Communications*, *8*(1), 15112. *doi.org/10.1038/ncomms15112.*

Powell, K. (2021). What's next for lab-grown human embryos? *Nature*, *597*(7874), 22-24. *doi.org/10.1038/d41586-021-02343-7.*

Rivron, N.C. et al. (2023) An Ethical Framework for Human Embryology with Embryo Models, *Cell* 186(17), 3548, *cell.com/cell/fulltext/S0092-8674(23)00807-3?dgcid=raven_jbs_etoc_email*.

Romanis, E. C. (2020). Artificial womb technology and clinical translation: Innovative treatment or medical research? *Bioethics*, *34*(4), 392-402. *doi.org/10.1111/bioe.12701.*

Tarazi, S., et al. (2022). Post-gastrulation synthetic embryos generated ex utero from mouse naive ESCs. *Cell*, *185*(18), 3290-3306.e25. *doi.org/10.1016/j.cell.2022.07.028*.

Westin, B., Nyberg, R., & Enhorning, G. (1958). A technique for perfusion of the pre-viable human fetus. *Acta Paediatrica*, *47*(4), 339-349. *doi.org/10.1111/j.1651-2227.1958.tb07643.x.*

MEDICATION AGAINST OBESITY (UPDATED)

© unsplash.com/Dennis Klicker

SUMMARY

Obesity is a significant global health issue that can lead to diabetes, cardiovascular disease, and cancer. It is estimated that over 4 billion people could be affected by obesity by 2035. For several years now, there has been a promising pharmaceutical treatment option involving the active ingredient semaglutide, which is being hailed as a breakthrough in the battle against obesity. The active ingredient has now been approved in the European Union. To date, there have been no studies on its long-term effects. Beyond questions of safety and efficacy, the use of these drugs also raises significant concerns about the social implications of drug treatment options, necessitating a comprehensive discussion of the opportunities, social and ethical challenges, and potential risks involved. It is essential not to overlook the socio-economic and cultural factors related to obesity in this context.

OVERVIEW OF THE TOPIC

Obesity - a serious health problem worldwide

Obesity affects a large proportion of the world's population. The World Obesity Federation (WOF) estimates that more than 4 billion people could be affected by 2035 (2020: 2.6 billion) (WOF 2023). A sharp increase is expected in children and adolescents in particular (WOF 2023). In addition, the prevalence of overweight and obesity[1] will continue to rise in both industrialised and developing countries (WHO 2021). Obesity is linked to several serious health issues, including a heightened risk of strokes, heart attacks, cancer, and type 2 diabetes. In addition to health consequences, there are also significant economic consequences for both individuals and society: the global economic impact[2] amounted to USD 1.96 trillion in 2020, which could rise to over USD 4 trillion by 2035 (Okunogbe et al. 2022; 2021; cited from WOF 2023).

Complex causes - multi-layered approach required

Obesity has many causes (e.g., NIH 2021), including genetics, lifestyle and socio-economic factors. For example, studies show that low-income people are more frequently affected (see, among others, WOF 2023; McLaren 2007). Food marketing also plays a role, as (more) unhealthy/processed foods are advertised (see Chester, Montgomery & Kopp 2021). Government measures also influence the availability and affordability of healthy food (e.g., subsidies for unhealthy food vs. support for local agriculture) (e.g., Hawkes et al. 2012).

Combating obesity thus necessitates a multi-faceted approach that includes public health initiatives, political reforms, and actions at an individual level. For an extended period, medical treatment was restricted primarily to diets and, in severe instances, stomach reduction procedures. In addition, prescription drugs were approved (such as appetite suppressants with amphetamines or so-called lipase inhibitors; see Schäffler & Raether-Buscham 2020; Wirth et al. 2017; Lenzen-Schulte 2016), although their effectiveness is controversial, and some of them were withdrawn from the market due to side effects. In the meantime, however, the active ingredient semaglutide has emerged as a viable pharmaceutical treatment option (see Spektrum 2022, among others). Initially developed for treating type 2 diabetes, so-called glucagon-like peptide-1 (GLP-1) agonists[3] increase insulin production and affect fat metabolism and the feeling of satiety, which can lead to a substantial weight reduction. Studies funded by the drug manufacturers indicate a weight loss of up to 13.8 % within one year (control group: 2.3 %) (Wilding et al. 2021). Recent studies also suggest cardiovascular benefits, as semaglutide can reduce the risk of chronic heart attacks and strokes by 20%, regardless of weight loss (Price 2024). Further developments include research into tirzepatide (Lenharo

---

[1] People are generally considered overweight from a body mass index (BMI) ≥ 25 kg/m^2 and obese from a body mass index ≥ 30 kg/m^2, whereby the BMI is calculated from body weight/height^2. To arrive at an accurate assessment, the individual body composition (ratio of muscle mass to fat mass) must be taken into account, as well as age and gender.

[2] The economic impact includes both the healthcare costs of treating overweight and obesity and their consequences, and the impact of high BMI on economic productivity, where high BMI can lead to absenteeism, presenteeism (reduced productivity at work) and premature retirement or death.

[3] The active ingredients mimic the intestinal hormone GLP-1.

2024; 2023). According to the latest studies, it shows positive results in sleep apnea and appears to reduce chronic kidney disease, among other things.[4]

New pharmaceutical treatment option for obesity

In the USA, Wegovy (active ingredient semaglutide) received approval from the Food and Drug Administration (FDA) in 2021 for weight management in adults who are overweight or obese and have at least one weight-related condition (such as high blood pressure, type 2 diabetes or high cholesterol) (FDA 2021), and in 2023 also for 12-18-year-olds above a certain BMI.[5] The active ingredient is now also approved in the EU despite some side effects, including vomiting and diarrhoea, although no long-term studies are available. Animal studies even indicate an increased risk of thyroid cancer (Lenharo, 2024; Medline Plus, 2023). Further studies on the long-term safety of the supplements are necessary, as ongoing use is needed for long-term benefits and efficacy.

Social consequences unclear

The costs of currently several hundred euros per month for drugs such as Ozempic (Tagesspiegel 2023), which are injected weekly, are only reimbursed if medically indicated. This raises questions about fair distribution and access, as eating disorders and obesity are heavily dependent on psychological factors and subjective body perceptions. There is also a risk that the widespread availability of medication could increase the social pressure to conform to an ideal of beauty and that overweight people could become even more stigmatised (see Phelan et al. 2015). In the UK, for instance, there are discussions regarding the prescription of "weight loss injections" for overweight unemployed individuals to enhance their prospects in the job market.[6]

A drug becomes a lifestyle product.

This is also indicated by the fact that GLP-1 antagonists are increasingly being used by individuals of normal weight and those who are underweight (with eating disorders) to achieve even slimmer, in addition to their regulated use in a medical context[7]. There is a real hype surrounding the "weight loss injection".[8] Success stories are shared on social media, while side effects are often complained about. In some countries, off-label use—meaning use without approval—has resulted in people with diabetes no longer receiving adequate care.[9] Furthermore, there appears to be no systematic oversight in the USA regarding the adherence to access criteria, such as a specific BMI. Consequently, drug regulatory authorities in several countries are now examining more stringent regulations (Price 2024). In addition, according to the Austrian Chamber of Pharmacists,

4 *economist.com/briefing/2024/10/24/glp-1s-like-ozempic-are-among-the-most-important-drug-breakthroughs-ever*.
5 *diatribe.org/fda-approves-weight-loss-drug-wegovy-teens*.
6 *spiegel.de/ausland/grossbritannien-abnehmspritze-fuer-arbeitslose-regierung-will-nhs-entlasten-a-f226bcbb-6cb1-4fb5-9098-6c674f79aed2*
7 Diet drugs are also being investigated for their anti-ageing effects (*parlament.gv.at/dokument/fachinfos/zukunftsthemen/123_laenger_leben.pdf*).
8 *derstandard.at/story/2000144566185/experts-praised-take-off-injection-and-disguised-payment-from-manufacturer*.
9 *tagesspiegel.de/gesellschaft/schlank-per-spritze-was-den-hype-um-das-medikament-ozempic-gefahrlich-macht-9627842.html* and *tagesschau.de/ausland/ozempic-101.html*.

"fake stores are currently springing up on the internet that illegally offer supposed slimming products".[10]

In general, it should be noted that these drugs only address the physical symptoms of obesity rather than the causes, which are often socially determined as well. Consequently, there is a risk that socio-economic and cultural factors, as well as prevention, will be overlooked due to the increased use of these drugs treatment. The social treatment of obesity, the standardising effect of body images and indicators such as the BMI ("The Bizarre and Racist History of the BMI"[11]) and the medical definition of overweight and obesity (see, for example, BMJ 2006 on the controversial change in the definitions of overweight and obesity in children, which some researchers believe could exaggerate the problem and unnecessarily label children as sick) should also be debated.

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Challenges and opportunities presented by anti-obesity drugs

Obesity is a significant public health issue in Austria. In 2019, approximately 3.8 million individuals aged 15 and over were classified as overweight, with 16.6% of the population being obese (BMSGPK 2020). *The age-standardized proportion of overweight and obese people rose from 48.7% in 2006/07 to 50.8% in 2019* (ibid). Consequently, alongside a strategy to address overweight, obesity, and eating disorders in children and adolescents,[12] medication to combat obesity is also being discussed in Austria. A consensus paper published by the Austrian Obesity Society in 2023, for instance, highlights drug therapy as a significant element of obesity treatment (Itariu 2023; Brix et al. 2023). The Austrian Parliament could tackle issues of safety, efficacy, and equity of access. Furthermore, a framework should be established for systematically analysing the risks and the ethical, social, and legal issues involved. It is equally important to address the socio-economic and cultural aspects of the obesity issue. Attention should also be paid to legislation or policy measures that guarantee unrestricted access to health information and resources and promote healthy lifestyles. Lifestyle and behavioural interventions (e.g. increased physical activity, dietary changes, psychotherapy), as well as control of food supply and marketing and improving public awareness of the risks of obesity, should not be lost sight of.

PROPOSAL FOR FURTHER ACTION

Inter- and transdisciplinary examination of open questions

The fight against obesity is a complex global issue that necessitates the collaboration of various actors and sectors, including public health, research, health professionals, politics, and the pharmaceutical industry etc.). Technology assessment can involve all relevant stakeholders in inter- and transdisciplinary processes and focus public attention on the problem of obesity and the opportunities and

[10] *apothekerkammer.at/aktuelles/aktuelle-themen/schlankheitsmittel*.

[11] *elemental.medium.com/the-bizarre-and-racist-history-of-the-bmi-7d8dc2aa33bb.*

[12] *parlament.gv.at/aktuelles/pk/jahr_2022/pk0316*.

possible consequences of the use of medication. A detailed report on the state of research and development, challenges and research needs and a risk analysis of current developments with the involvement of experts and stakeholders would be an essential contribution to the socio-political debate.

REFERENCES

BMJ (2006). Obesity task force linked to WHO takes "millions" from drug firms. News June 15, 2006, 332, 1412. ***bmj.com/content/332/7555/1412.2***.

Brix, J.M., *et al. (2023).* Overweight and obesity in adults: general principles of treatment and conservative management. *Vienna Klin Wochenschr* 135 (Suppl 6), 706-720.

Federal Ministry of Social Affairs, Health, Care and Consumer Protection (2020). Austrian Health Interview Survey 2019. Main results of the Austrian Health Interview Survey and methodological documentation. ***statistik.at/fileadmin/publications/Oesterreichische-Gesundheitsbefragung2019_Hauptergebnisse.pdf***.

Chester, J., Montgomery, K.C., Kopp, K. (2021). Big Food, Big Tech, and the Global Childhood Obesity Pandemic. Executive Summary. Center for Digital Democracy.

Delcan, P. (2023). A new class of drugs for weight loss could end obesity. The Economist. 02.03.2023. ***economist.com/briefing/2023/03/02/a-new-class-of-drugs-for-weight-loss-could-end-obesity***.

FDA (US Food and Drug Administration) (2021). FDA Approves New Drug Treatment for Chronic Weight Management, First Since 2014. Press Announcement. ***fda.gov/news-events/press-announcements/fda-approves-new-drug-treatment-chronic-weight-management-first-2014***.

Finkelstein, E. A., et al. (2009). Annual medical spending attributable to obesity: Payer-and service-specific estimates. *Health Affairs*, 28(5), w822-w831.

Hall, K. D., et al. (2019). Ultra-processed diets cause excess calorie intake and weight gain: An inpatient randomised controlled trial of ad libitum food intake. *Cell Metabolism*, 30(1), 67-77.

Hawkes, C., et al. (2012). Linking agricultural policies with obesity and noncommunicable diseases: A new perspective for a globalising world, *Food Policy*, 37(3), 343-353.

Itariu, B.K. (2023). Consensus paper of the Austrian Obesity Society On the diagnosis and treatment of people with obesity. *Vienna Klin Wochenschr*, 135 (Suppl 6), 705.

Lenharo, M. (2024). Why do obesity drugs seem to treat so many other ailments. *Nature*. 633, 858-760.

Lenharo, M. (2023). What Scientists are learning about potent new obesity drugs. *Nature*. 618, 17+18.

Lenzen-Schulte, M. (2016). Appetite suppressants: The "magic bullet" for losing weight is still utopia. *Deutsches Ärzteblatt*, 113(43): A-1922/B-1619/C-1607.

McLaren, L. (2007). Socioeconomic status and obesity. *Epidemiologic Reviews*, 29, 29-48.

MedlinePlus (2023). Semaglutide Injection. Article from 15.02.2023. MedlinePlus is a service of the National Library of Medicine (NLM), the world's largest medical library. ***medlineplus.gov/druginfo/meds/a618008.html***.

NIH (National Institutes of Health) (2021). What causes obesity & overweight? ***nichd.nih.gov/health/topics/obesity/conditioninfo/cause***.

Okunogbe, A., et al. (2022). Economic impacts of overweight and obesity: current and future estimates for 161 countries. *BMJ Global Health*, 7(9), e009773.

Okunogbe, A., et al (2021). Economic impacts of overweight and obesity: current and future estimates for eight countries. *BMJ Global Health*, 6(10), e006351.

Phelan, S.M., et al. (2015). Impact of weight bias and stigma on quality of care and outcomes for patients with obesity. *Obesity Reviews*, 16(4), 319-326.

Price, K. (2024). 'Beyond weight loss': what is the future of semaglutide *The Pharmaceutical Journal*, 312(7986), 312.

Schäffler, A., Raether-Buscham, K. (2020). Prescription drugs for weight loss. ***apotheken.de/krankheiten/hintergrundwissen/12564-rezeptpflichtige-medikamente-zur-gewichtsreduktion***.

Schienkiewitz, A., et al (2017). Overweight and obesity in adults in Germany. *Journal of health monitoring*, 2(S2), 21-27.

Stöckl, D., Horvath, K., & Rieder, A. (2019). Obesity and its impact on healthcare utilization and costs in Austria. *Obesity facts*, 12(1), 71-80.

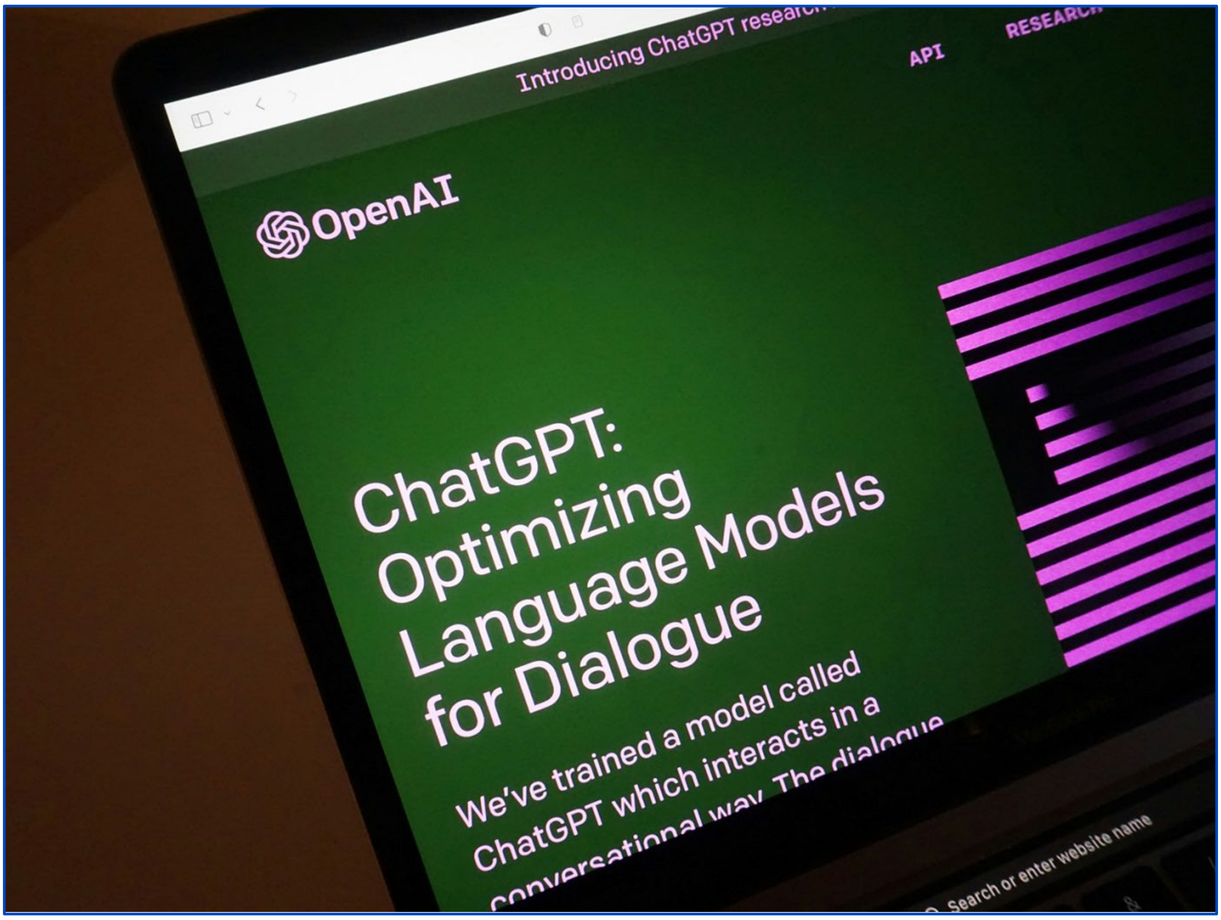
WHO (World Health Organization) (2021). Obesity and overweight. Fact Sheets. ***who.int/news-room/fact-sheets/detail/obesity-and-overweight***.

Wilding, JPH, Batterham, RL, Calanna, S., Davies, M., et al. (2021). Once-Weekly Semaglutide in Adults with Overweight or Obesity. *New England Journal of Medicine*, 384:989-1002.

Wirth, A., Krause, J., Riedel, O., & Schmidtmann, M. (2017). Appetite suppressants - drugs for the treatment of overweight and obesity. *German Medical Journal*, 114(21), 375-382.

WOF (World Obesity Federation) (2023). World Obesity Atlas. ***data.worldobesity.org/publications/WOF-Obesity-Atlas-V5.pdf.***

GENERATIVE AI AND DEMOCRACY (UPDATED)



© unsplash.com/Rolf van Root

SUMMARY

Since the publication of ChatGPT in November 2022, generative AI systems have stirred considerable interest, reviving old dreams, hopes, and fears regarding the capabilities of artificial intelligence (AI) and specific concerns about their impact on democratic societies. Generative AI promises enormous simplification of work and unrestricted access to information. However, a closer look reveals that many unresolved difficulties still make its use in most professional environments inadvisable. In addition, experts see a significant security problem facing society, as generative AI systems could also be used, for example, to write slightly varied malicious code thousands of times over or to launch individually tailored fraud attempts on millions of citizens.

Generative AI - hype, game changer or danger to society?
Hype, game changer or danger for society?

OVERVIEW OF THE TOPIC

The desire for thinking and serviceable machines has existed for a long time.

The possibilities of simulating understanding and thought have improved significantly since the Enlightenment, when the "Schachtürke," a purportedly self-thinking chess automaton with a hidden human player, was presented in Vienna in 1769. Joseph Weizenbaum's ELIZA program from 1966, which was able to represent different conversation partners using various scripts, can be seen as the predecessor of current generative AI systems. The concept of thinking intelligent machines has always been linked to high expectations, dreams, and utopias, but also to threatening scenarios and fears. It often centred on enhancing human capabilities, compensating for their "flaws", and even saving them if we consider current ideas on how AI systems should liberate us from the repercussions of climate change.[1] Is this now the generation of artificial intelligence that everyone has been waiting for since ELIZA? Or is it, as Bareis and Katzenbach (2021) write, more "Talking AI into Being", i.e. more the narrative than the actual possibilities of artificial intelligence that are fuelling the hype?

Who do we trust?

Trust is closely linked to considerations about the usefulness of thinking systems. Do we trust machines when it comes to vital decisions? At the same time, people tend to recognise human traits in technology. This is evident in our dealings with digital assistants (Schaber et al., 2019). It is assumed that machines, mainly calculating machines and computers, cannot make mistakes, that their results are therefore undoubtedly correct and - applied to AI systems - that their decisions are also accurate.[2] This is because people cannot understand how these systems work and, therefore, perhaps trust where trust is inappropriate. These systems are designed and built by humans, and AI is trained with specific data that is not neutral. We now know that technology is generally not neutral. It carries the values and values of its developers within it. This realisation is particularly relevant when it comes to automation and AI. These systems reproduce the (discriminatory) structures from which they (re)learn.

Fears around (generative) AI systems

There are also warning voices that a learning, self-optimising machine, with its consciousness (perhaps even a personality), could accelerate the development of intelligent and thinking machines to such a degree that humans would no longer have a place in such a scenario world. Machines would outperform humans in all respects and gradually replace them. This point, at which machines would be far better than humans in everything, is known as the "technological singularity" (see also the books by Kurzweil 2005 or Bostrom 2016). Moreover, if this notion were not already alarming enough, some fantasies view these machines as hostile and malevolent towards humanity. Nevertheless, considering the current state of research, we are still far from this development.

How it works …

The AI systems that have fascinated people worldwide since the introduction of chat GPT are so-called generative AI systems that use text input to create further

1 *derstandard.at/story/2000142852407/how-artificial-intelligence-helps-in-the-fight-against-the-climate-crisis*.

2 More information on the so-called automation bias, for example, from Kate Goddard (2014).

texts or produce other audiovisual content. They use probabilities and vast training data to simulate intelligence and understanding.[3] Statistical methods and (training) data, as well as the resulting probability information, are used in a stochastic process to process queries and develop answers that string together parts of words or sentences (or combine image elements, program code, etc.) based on statistical distributions and probabilities. This leads to sentences, images, videos, or sections of code that appear meaningful about the task at hand. Consequently, users feel that they have been understood and received a suitable response in terms of content. However, the system has never developed an understanding, contemplated, or formulated an answer. As tests have demonstrated, the answers are frequently not factually correct. They can sometimes seem fabricated, although this creative act does not occur; instead, it is a product of statistical chance.

... and the resulting dangers

This mode of operation is challenging for individuals who typically think in deterministic frameworks and cannot be relied upon to provide accurate information on scientific questions, for example. However, the strictness and middling accuracy of the generated answers are enough to create responses that seem deceptively authentic to most individuals, including fake news. This poses a significant threat to society, its negotiation processes and democracy, as fake news produced by the machine is not recognised as such, opening the door to manipulating public opinion.

Further abuse scenarios

Even if language or text has been used abusively, manipulatively, or with the intent to deceive, and ***images and videos are also falsified***, both are still the central basis of our communication. Images, in particular, are seen as evidence of the truthfulness of a claim. Experts believe society is moving towards a "security catastrophe of unprecedented proportions."[4] On the one hand, there is still a lack of practice in dealing with content created by machines; on the other hand, it has become almost unconditional on the user side to produce fake news in high quality, quantity and/or individuality. The first publications that humans did not create are also appearing in science. Failure to "unmask" these would have catastrophic consequences for science (Haider et al. 2024). Moreover, chatbots powered by generative AI are increasingly being utilised as a cost-effective alternative to psychotherapy (Kahwaja et al., 2023) and for simulating conversations with the deceased.[5] (see also ***Social agents***).

Dangers for liberal democracies

In addition to other dangers, it is also crucial, from a democratic policy perspective, to understand on an individual level whether you are communicating with another person or a machine. This understanding lets you classify their responses and identify whom to confide in. Due to their functioning, it is only possible for a select few - if any - to comprehend the biases that systems receive through programming and training. In tension, due to their operational methods, only a limited number of individuals—if any—can comprehend the bias that systems acquire through programming and training. In the context of tensions between geopolitical and economic interests and power struggles, AI systems that act as

3 Examples of such systems are: ***Bard, ChatGPT*** (login required), ***Dall-E2, Jasper, Kaiber, LaMDA*** (description) and ***Midjourney***.

4 ***heise.de/hintergrund/Drei-Gruende-warum-KI-Chatbots-eine-Sicherheitskatastrophe-sind-8933941.html***.

5 The documentary "Eternal You" (2024) describes this in detail: ***de.wikipedia.org/wiki/Eternal_You_%E2%80%93_Vom_Ende_der_Endlichkeit.***

black boxes (Udrea et al., 2022) and a dependency on them can also be gateways for the enforcement of foreign interests through the deliberate manipulation of results, which means that their use should also be questioned for reasons of ***digital sovereignty***.

Regulation

Specifically, the lack of knowledge regarding the management of data collected by ChatGPT—which can be linked to identifiable individuals through mandatory registration—has resulted in the application undergoing closer examination by data protection authorities in Germany, for example.[6] In China, interim regulations for the use of AI were issued in 2023, which are to be adapted in the future.[7] At the EU level, a passage on "general purpose AI models" has been added to the AI Regulation.[8]

Generative AI and education

Due to concerns that pupils and students may use the software to write essays, falsely presenting them as their own, and that teachers might overlook such deceit, some schools and universities have prohibited utilising this software, irrespective of the enforceability of these regulations. In Austria, as a reaction, the preparation of the so-called pre-scientific paper for the Matura at an AHS was replaced by a final paper that need not be textual and includes high requirements regarding the documentation of the preparation.[9] As a result, an essential social discussion about how to deal with generative AI systems has been postponed indefinitely. At other educational institutions, students are encouraged to use the software to promote a critical examination of the results.
Positive potential uses for such systems would arise (mainly if they function reliably and transparently) in journalism/research, summarising texts, curating content, advertising and marketing, creating program code or ***making diagnoses in healthcare*** (see also Albrecht, 2023).

New opportunities to simplify specific work processes

For instance, the realm of generic illustration in publications would also transform significantly, necessitating new business concepts for imagery databases. Collaboration between humans and machines seems to be the most promising way forward. However, the necessary skills would have to be taught in educational institutions yesterday rather than today.
Products and services centred around generative AI are also evolving in this direction. The exploration focuses on how AI can assist individuals and where it can generate revenue.

Ethical requirements

The ethical requirements for generative AI systems are comparable to those for other AI systems. The focus should be on people, and decisions should be transparent, comprehensible, justifiable and reproducible.[10] There is specific criticism

---

6 ***faz.net/aktuell/feuilleton/medien/datenschuetzer-haben-fragen-an-open-ai-18839095.html***. The conference of independent data protection supervisory authorities in Germany has now published its first ***guidelines*** on the use of LLMs in companies.

7 ***nzz.ch/technology/china-adopts-world's-first-rules-for-chat-gpt-and-co-ld.1747327***.

8 ***artificialintelligenceact.eu/article/51/***.

9 ***orf.at/stories/3361802/***.

10 The statement by the German Ethics Council is representative of many statements on this topic: Mensch und Maschine - Herausforderungen durch Künstliche Intelligenz, ***ethikrat.org/fileadmin/Publikationen/Stellungnahmen/ deutsch/stellungnahme-mensch-und-maschine.pdf***.

regarding the power imbalances that emerge from a lack of transparency concerning the operation of the system and the use of data, as well as the accumulation of power stemming from extensive data collections and proprietary systems from American IT companies. Equally problematic are the working conditions under which people in low-wage countries train the systems, the systems' unsustainable operation, and high resource consumption.[11]

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Setting priorities in research policy by the Parliament

In order not to lose touch with the topic, a regular evaluation of the scope and use of funds in national research funding for AI must be carried out to avoid undesirable developments that emerged in 2023 and further promote the strengths of Austrian AI development. However, it should not be forgotten that, despite all efforts to assert national locational advantages, only a coordinated approach at the European level can lead to the emergence and maintenance of a counterweight in Europe to developments in North America and China. Research into AI and the associated changes in research and society is at least as important as research into developing AI systems and their applications. Here, it would be possible for Parliament to intervene in a guiding manner by setting appropriate budgeting priorities and supporting this critical area, which contributes significantly to understanding and reflecting on the changes taking place and ultimately makes the successful use of AI systems possible in the first place.

PROPOSAL FOR FURTHER ACTION

New research projects

In addition to the ongoing study commissioned by parliament on the effects of generative AI systems on democracy in Austria, research projects on other specific aspects could be considered to prepare the knowledge-based foundation for future political decisions on the prioritisation of research funding on the criteria for the successful use of AI in state administration; or in the education sector. It would also be essential to evaluate ongoing efforts in education and research, such as the projects launched as part of the AIM-AT initiative, and their results promptly so that adjustments can be made in research and education if necessary. In the future, it will be essential to provide the workforce in Austria with the knowledge required to work with AI systems, to use them productively, and to be able to assess their advantages and disadvantages better.

Education as the key to the successful use of AI

[11] A good summary of the literature on this can be found in the TA-Swiss paper on ChatGPT: *ta-swiss.ch/chatgpt*; summary on the topic of water consumption: ***heise.de/news/Wasserbilanz-von-KI-Modellen-Halber-Liter-Wasser-per-Unterhaltung-mit-ChatGPT-8973680.html***.

REFERENCES

Albrecht, St. (2023). ChatGPT and other computer models for language processing - basics, application potentials and possible effects. TAB Background Paper No. 26. ***publikationen.bibliothek.kit.edu/1000158070/150614893.***

Bareis, J., & Katzenbach, C. (2022). Talking AI into Being: The Narratives and Imaginaries of National AI Strategies and Their Performative Politics. Science, Technology, & Human Values, Vol. 47 (Issue 5), pages 855-881.

Bostrom, N. (2016). Superintelligence. Scenarios of a coming revolution. Suhrkamp, Frankfurt am Main.

Goddard K, Roudsari A, Wyatt JC (2014). Automation bias: empirical results assessing influencing factors. International Journal of Medical Informatics. 2014 May; Vol 83 (Issue 5): pages 368-75. ***doi: 10.1016/j.ijmedinf.2014.01.001***.

Haider, J., et al. (2024). GPT-fabricated scientific papers on Google Scholar: Key features, spread, and implications for preempting evidence manipulation. Harvard Kennedy School Misinformation Review.

Helberger, N., Diakopoulos, N. (2023). ChatGPT and the AI Act. Internet Policy Review (2023) 12 (1). ***doi.org/10.14763/2023.1.1682***.

Khawaja Z, Bélisle-Pipon JC. (2023). Your robot therapist is not your therapist: understanding the role of AI-powered mental health chatbots. *Front Digit Health*, 5:1278186.

Kurzweil, R. (2005). The Singularity Is Near. When Humans Transcend Biology. Viking, New York.

Schaber, F., Krieger-Lamina, J., Peissl, W. (2019). Digital assistants. ITA Report 2019-01. ***epub.oeaw.ac.at/ita/ita-projektberichte/2019-01.pdf.***

Udrea, T. et al. (2022). Artificial Intelligence - Understandability and Transparency. ITA Report 2022-01. ***epub.oeaw.ac.at/ita/ita-project-reports/ITA-2022-01.pdf***.

LARGE HEAT PUMPS (UPDATED)

© Wien Energie

SUMMARY

Heat pumps are central to the necessary heating transition and corresponding phase-out strategy. Until now, however, they have primarily been utilised in new constructions and single-occupancy households. With the advancement of large heat pumps with outputs reaching several megawatts, it is now feasible to harness numerous (waste) heat sources from the industry as well as ambient heat from geothermal energy and bodies of water, thereby allowing for the use of heat pumps in existing buildings and heating networks. Research initiatives aimed at qualitatively and quantitatively assessing the potential uses in Austria, along with stable framework conditions that guarantee investment security and social cushioning during the transition, seem necessary.

Large heat pumps as an important element in the heating transition

OVERVIEW OF THE TOPIC

To achieve the climate targets, as expressed in the Austrian federal government's commitment to climate neutrality by 2040 in its government program, it is vital to make the energy supply in electricity, industry, mobility and heating climate-neutral as quickly as possible. In addition, the political goal of energy independence, especially from gas, has become more critical due to the war of aggression against Ukraine. The corresponding solutions for electricity are largely clear through generation using renewable energy sources such as water, solar, and wind power, and for mobility through the transition to e-mobility, integrated mobility concepts with the expansion of public transport, and the reduction of private transport. These solutions are already being implemented in some cases. Heat pumps are central to heat supply but have mainly been utilised in private households.

Heat pumps as a central element in the heating transition

Recent calculations published for Germany indicate that replacing gas heating systems with heat pumps would most rapidly decrease gas consumption, potentially reducing up to 60% of the gas volume previously supplied by Russian sources by 2025. (Altermatt et al., 2023). In Austria, around 1 million or 27% of households use gas as their most common energy source. This is followed by district heating (25%), firewood (16%) and heating oil (16%). Electricity is in 5th place (7%). Wood pellets (5%), alternative energy sources (3%) and coal (0.5%) are used least frequently (Lechinger & Matzinger, 2020, p. 3).

While newly built single-family homes can generally be supplied with heat pumps, it is much more challenging to ensure a reliable heat supply for more significant and older buildings, which is done primarily by gas or oil today. It is generally recognised that heating networks are usually the best choice, as they use different heat sources and can transport the energy from the source directly to the individual buildings in the form of heat. Decarbonised heat supply can be achieved in appropriate locations using various types of geothermal energy and biomass power plants. However, these utilisation options are not feasible everywhere. Using large heat pumps is an option for closing the heat gap. These systems, with thermal outputs ranging from 100 kW to several MW, use waste heat from hot exhaust gases from industrial plants, wastewater, data centres, industrial processes and also ambient heat from lakes and rivers. In the UK[1], Germany, and Switzerland[2], such plants are being built or used. Sweden has been a pioneer in this field since the 1980s and now has seven large heat pumps with a total output of 225 MW from wastewater in operation in Stockholm.[3]

Large heat pumps with an output of up to several MW as the next step

Pilot projects with large heat pumps have also been tested in Austria for some time. In Vienna, one of Europe's most powerful heat pumps has been operating in an initial expansion stage since December 2023. It is located at the Simmering wastewater treatment plant and extracts 6°C from the already treated wastewater. It can thus provide around 90°C hot water for the Vienna district

Pilot projects in Austria

1 *bbc.com/future/article/20230131-can-city-dwellers-ever-have-heat-pumps.*

2 *aew.ch/publications/magazine-aew-on/fruehling-2020/waermeverbund-uetikon-am-see.*

3 *heatpumpingtechnologies.org/annex47/wp-content/uploads/sites/54/2018/12/annex-47hammarbyverket.pdf.*

heating system. The electricity required for operation comes directly from the nearby Freudenau Danube power plant via a dedicated line. A predecessor model has been operating at this location since 2019; the new system currently supplies 55 MW to 56,000 households and is expected to supply up to 112,000 households with heat when fully expanded in 2027 with an output of 110 MW.[4]

Large heat pumps are essential for sector coupling.

Heat pumps are highly efficient, typically delivering over three times the input electrical energy as heat. They also utilise a diverse range of previously untapped heat sources to produce warmth. These include environmental heat sources such as ambient air, geothermal energy or bodies of water, and waste heat sources from industrial processes. Large heat pumps can, therefore, contribute to sector coupling.[5] Research into and development of large heat pumps is progressing, and the aim is to avoid using climate-damaging refrigerants and achieve higher system temperatures.[6] The so-called temperature swing – the difference between the temperature of the heat source and the output temperature of the heat pump – is becoming ever more significant, so that heat pumps with a process temperature of up to 160°C are now in operation.[7]

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Austrian heating strategy

The Austrian heating strategy[8] is intended to create a joint framework for the federal and provincial governments to decarbonise Austria's entire heating supply in a phased plan by 2040. The use of heat pumps plays a central role in this. Large heat pumps are considered an important element in making the replacement of fossil heating technology climate-neutral through the expansion of heating networks (Gerhardt et al., 2021). With over 1,300 kilometres, Vienna's district heating network is one of the largest in Europe. Wien Energie supplies around 440,000 Viennese households and 7,800 large customers with district heating.[9] There are also large district heating networks in nine cities in Austria, where Linz is considered the "district heating capital". Almost three-quarters of all homes are connected here, making it the densest district heating network in Austria. The aim is to increase this share to 80% by 2030.[10]

---

4 *infothek.bmk.gv.at/umweltfoerderung-im-inland-staerkste-grosswaermepumpe-europas-entsteht-in-wien/* and*positionen.wienenergie.at/projekte/waerme-kalte/grosswaermepumpe/*.

5 *agfw.de/technik-sicherheit/erzeugung-sektorkopplung-speicher/aktuelles-aus-dem-bereich/newsdetail/agfw-veroeffentlicht-praxisleitfaden-zu-grosswaermepumpen-in-zweiter-auflage*.

6 *gruene-fernwaerme.de/gruene-fernwaerme/erneuerbare-energien/grosswaermepumpen*.

7 *dryficiency.eu*.

8 *bmk.gv.at/themen/klima_umwelt/energiewende/waermestrategie/strategie.html*

9 *ots.at/presseaussendung/OTS_20230203_OTS0044/baufortschritt-europas-leistungsstaerkste-grosswaermepumpen-in-wien-angekommen*. Details of the comprehensive strategy can be found here: *wien.gv.at/stadtentwicklung/energie/pdf/waerme-und-kaelte-2040.pdf*.

10 *orf.at/stories/3266222/*.

In 2022, natural gas was the second most important source of energy for district heating at 33%, after biogenic energies at 53% (BMK, 2024, p. 16). This shows a corresponding expansion potential for (large) heat pumps, considering ambient heat, for instance, has only made a minor contribution of 1.2%. However, since almost 70% of the population in Austria lives in smaller towns and municipalities with up to 100,000 inhabitants, the expansion of local heating networks using large heat pumps poses a particular challenge. Regarding energy sources, the smaller the city, the more frequently firewood, heating oil or wood pellets are used for heating, and the larger the municipality, the more regularly gas and district heating are used (Lechinger & Matzinger, 2020, p. 8f).

Settlement structure as a challenge

The heat pump has already established itself in newly built single-family homes. The Renewable Heat Act has been in force since February 29, 2024.[11] It prohibits (with transitional provisions) using fossil fuels as a heating source and for hot water preparation in building construction. Consequently, it can be assumed that the expansion of heat pumps will accelerate.

Particular attention must also be given to the social aspects of the heating transition. Modifications to the heating system often alter dependencies or diminish individual autonomy. Furthermore, the essential investments for the transition are scarcely affordable for lower-income sections of the population, even if energy consumption and costs are reduced throughout use. An extended subsidy policy and possibly tax adjustments must be considered, including stable framework conditions as a basis for investment security. The "Clean Heating for All" campaign has promoted the transition from fossil fuels to a wood-fired central heating system or heat pump for households that lack a connection to local or district heating since the beginning of 2024.[12]

Heat transition in existing buildings, taking social aspects into account

PROPOSAL FOR FURTHER ACTION

As a next step, it is proposed that a TA study be conducted to assess the potential use of large heat pumps in Austria in both qualitative and quantitative terms, compare alternatives, and compile a list of criteria that could serve as the basis for possible funding in the area of large heat pumps and (local) heating networks. In addition to the necessary framework conditions for potential investors, local and regional conditions and social aspects (heating as a basic need) should also be considered in implementation funding. In addition, research funding for sector coupling and the role of large heat pumps as a flexibility technology could be highlighted.

TA study on large heat pumps

---

[11] *bmk.gv.at/themen/klima_umwelt/energiewende/waermestrategie/ewg.html*.
[12] *umweltfoerderung.at/privatpersonen/sauber-heizen-fuer-alle-2024*.

REFERENCES

Altermatt, P. P., et al. (2023). Replacing gas boilers with heat pumps is the fastest Way to cut German gas consumption. *Communications Earth & Environment*, *4*(1), 56, **doi.org/10.1038/s43247-023-00715-7.**

BMK (2024) (Federal Ministry for Climate Action Environment Energy Mobility Innovation and Technology) (2024). *Energy in Austria - facts, figures and data*.

Gerhardt, N., et al. (2021). *Transformation paths of district heating in feedback with the energy system and necessary framework conditions*.

Lechinger, V., & Matzinger, S. (2020). *How Austria Heats - Heating Types and Energy Sources in Austrian Households in a Social Context*.

ENVIRONMENTAL IMPACT OF SPACE TRAVEL (UPDATED)

© unsplash.com/Bill Jelen

SUMMARY

There are currently more than 5,500 active satellites in orbit, and this figure is set to rise to 58,000 by 2030 - a trend primarily driven by commercial activity. In the foreseeable future, there will be rocket launches to planned space stations, exploration missions to the Moon and Mars, space tourism, mining in space, anti-satellite weapons, and solar power plants. The effects of these activities are manifold. Satellites provide essential services, but have problematic environmental impacts that have so far received little attention due to the relatively low launch density: These include ozone-depleting emissions (aluminium, chlorine) in the upper atmosphere; enormous amounts of fuel with greenhouse gas emissions (CO_2, water vapor, soot particles), including near the ground during launch; space debris, with risk of collision and emissions during re-entry; hazards from re-entering rocket parts/broken satellites; impairment of astronomy. While there are international agreements regarding outer space, they address these emissions no more than environmental agreements (e.g., Montreal Protocol).

Increased use of space of space has increasing environmental consequences on the earth

OVERVIEW OF THE TOPIC

Rocket launches are on the rise ...

There are currently more than 5,500 active satellites in orbit around the Earth, and it is estimated that a further 58,000 satellites will be launched by 2030. As the cost of satellites and rocket launches has fallen, private companies, in particular, are deploying large constellations of satellites into orbit, which is currently the primary reason for this increase in launches (GAO 2022). Although the number of objects launched in recent decades has remained steady at a few hundred per year, by 2023, there were already over 2,600 objects.[1] However, more rocket launches are also expected due to the construction and supply of space stations (ISS, China, etc.), lunar and Mars exploration missions, space tourism, ***mining in space***, the construction of solar power plants and the removal of ***space debris***.[2] The increased use of space also increases the risk of conflict, whereby the use of anti-satellite weapons (ASAT) and militarised space travel could become a further reason for increased rocket launches.[3] So far, four countries have destroyed their satellites during tests of anti-satellite weapons (USA, China, Russia and India[4]). Austria and numerous other countries have spoken out against testing ASAT missiles, but the development of ASAT capabilities is constantly being driven forward.[5]

... with previously overlooked environmental consequences

Satellites provide critical, sometimes essential services (GPS, internet, civil and military ***remote sensing***, control of wind turbines, etc.), but space debris is not the only environmental problem of space travel. Greenhouse gas emissions, particularly ozone-depleting exhaust gases, have so far been deemed negligible because of the limited number of rocket launches, and little research has been conducted on them. However, this situation could change in the future if the trend continues. One study shows, for example, that just one decade of a space tourism boom is enough to damage the ozone layer to such an extent that the entire recovery of the layer since the Montreal Protocol would be wiped out (Ryan, Marais, Balhatchet, & Eastham, 2022). Even if today's emissions appear small compared to other industrial sectors, the future CO_2 footprint is difficult to estimate but will be non-negligible (Dallas, Raval, Gaitan, Saydam, & Dempster, 2020; Ross & Jones, 2022).

Overall, environmental impacts arise not only during rocket launch but at many points throughout the entire life cycle: (a) mining of raw materials; (b) use of rare earths; (c) satellite manufacturing; (d) satellite calibration facilities; (e) horizontal launch of satellites; (f) vertical satellite launch ; (g) atmospheric pollution from launch; (h) ground segment activities; (i) satellite validation campaigns; (j) effects of night sky brightness on astronomy; (k) effects of night sky brightness on ecology; (l) increase in space debris; and (m)rising collisions of space objects (Gaston et al., 2023).

---

1 *ourworldindata.org/grapher/yearly-number-of-objects-launched-into-outer-space*.
2 *esa.int/Space_Safety/ClearSpace-1.*
3 *tagesschau.de/ausland/amerika/krieg-satelliten-101.html*.
4 *space.com/anti-satellite-weapons-asats*.
5 *verteidigungspolitik.at/documents/475963/0/%C3%96sterreichische+Milit%C3%A4rische+Weltraumstrategie+2035%2B.pdf/2681f00c-2458-64b4-958a-0b93b3ebc806?version=1.0&t=.*

Ozone-depleting effect during launch and re-entry into the atmosphere

As early as the 1990s, a study showed that US space shuttles' auxiliary engines (boosters) create small holes in the ozone layer (Ko et al. 1994). When burning aluminium perchlorate, solid propellant engines disperse fine particles that catalyse ozone decomposition when traversing the stratosphere. The alteration in atmospheric chemistry was subsequently classified as negligible, primarily due to the relatively few launches and because it was assumed that the small holes would promptly close again.

The protection of the ozone layer was regulated under international law with the ban on chlorofluorocarbons (CFCs) in the Montreal Protocol. Research in the 1980s showed that the Antarctic ozone hole occurred seasonally. A thinned ozone layer allows more ultraviolet radiation from sunlight to pass through the atmosphere, which has a carcinogenic effect on living organisms. Life on Earth as we know it today would not be possible without the ozone layer. Even though the ozone layer is slowly recovering, ozone holes now occur seasonally at both poles: Although CFCs have been banned, a large number of other ozone-depleting substances (e.g. nitrous oxide) continue to be emitted or remain in the environment as ***persistent pollutants*** for a long time after the ban. In addition to solid-fuel engines, today's rockets often use kerosene, hydrogen or methane. The environmental impact of solid-fuel engines has been better studied, and they contribute more to ozone loss than other engines (Dallas et al., 2020). However, all engines, including liquid propellants, emit a range of particles and gases (such as nitrogen oxides) directly into the middle and upper atmosphere, where they have been shown to harm the ozone layer (Brown, Bannister, & Revell, 2023).

There is also a trend towards reusable components in modern rockets, but these, like re-entering debris, produce nitrogen oxides when heated by re-entry into the atmosphere. These emissions then contribute to total ozone depletion in the stratosphere to the same extent as chlorine from solid propellant engines (Ryan et al., 2022). The incinerating debris produces nitrogen oxides and aluminium oxide, as aluminium is a significant component of many components. This, in turn, is suspected of triggering chemical processes in the atmosphere. An international industry standard states that satellites must disintegrate no later than 25 years following the conclusion of their mission, which is a considerable amount of material considering the significant rise in satellite launches.

Rocket launches and global warming

Greenhouse gas emissions from space travel have always been regarded as negligible. However, the overall impact of particle and gas emissions on the ozone layer and the greenhouse effect remains unknown. However, chlorine and particle emissions, such as soot, are considered to be more worrying than gas emissions, such as water vapour and carbon dioxide. However, this only applies to the current take-off volume. Overall, the magnitude of the potential climate impact of particulate emissions is unknown, as there is little observational data that can be used to validate modelling studies for rocket emissions, and these data have often only been collected in the lower stratosphere (GAO, 2022). Soot particles from rocket emissions significantly impact as they are released at altitudes where they warm the atmosphere nearly five hundred times more per unit than all other sources of soot from the ground and aviation combined (Ryan et al., 2022).

International law does not cover missile emissions

Given the projected growth of the space industry, atmospheric impacts have not received sufficient study and international environmental agreements, like the Montreal Protocol, currently do not account for rocket emissions; at the national level, only isolated measures exist, such as taxes on space tourism in the US. (Sirieys, Gentgen, Jain, Milton, & de Weck, 2022). This underscores the need for appropriate environmental management of the upper atmosphere (Brown et al., 2023). Creating a sustainability index for launch vehicles could provide a foundation for future regulations or motivate the sector to embrace more sustainable designs by establishing emissions reduction as a competitive advantage (Sirieys et al., 2022).

The risk of falling parts

The trend towards ever-larger rockets also increases the risk that the main rocket stage will not burn up entirely after burning out during uncontrolled re-entry. In the case of the largest Chinese rocket, the "Long March," around 20 tons of scrap metal crashed into the sea near the Maldives, passing over numerous population centres from Europe to India. The world's largest rocket to date (Space-X-Starship) exploded during several launches in recent years.

The trend towards reusable missile systems

However, it is designed so that the main stage returns to the launch pad and can be reused. A successful return was achieved for the first time in October 2024. Overall, there is a trend towards reusable rocket systems. Blue Origin also successfully returned to Earth in 2015, and the national space programs in the USA and China are also working on RLVs (reusable launch vehicles). [6]

Interference with Earth and space observation due to sunlight reflections and radio transmission

Satellites also reflect sunlight after sunset and can appear as bright streaks in night sky images. Satellites can also disrupt remote sensing data from other satellites in higher orbits as they pass beneath them. Communication with satellites relies on radio signals significantly stronger than those emitted by astronomical phenomena. Therefore, satellites can obscure the weak signals necessary for radio astronomy and thus interfere with observations of distant objects such as black holes or faraway galaxies. While the effects may be minimal for individual satellites, the cumulative impact of numerous satellites functioning within large constellations can be significant or even uncertain in some instances. (GAO, 2022).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Space strategy: researching the environmental impact of increased rocket launches

Austria's 2030+ space strategy[7] has six overarching goals, the first of which is "Sustainable development on Earth and in space", and is committed to the UN Sustainable Development Goals. If the use of space, including by Austrian space Research and industry, should be sustainable, addressing open questions such as damage to the ozone layer by aluminium and other particles and gases must be scientifically clarified, as must the question of how many launches are tolerable for the atmosphere. In addition to agenda-setting for these topics in research funding, adapting the sustainability indicators outlined in the strategy can also create

[6] *researchgate.net/publication/383181934_Overview_on_Reusable_Space_Launch_System*.

[7] *austria-in-space.at/resources/pdf/V4_EN_Accessibility__Austrian-Space_Strategy_2030_v6_23_PAC2021_Approved.pdf.*

opportunities for action regarding Austria's national space commitment. Moreover, Austria could facilitate the "greening" of European and international space law through the ESA and at the UN level.

PROPOSAL FOR FURTHER ACTION

In addition to scientific, ethical and legal questions to be clarified

In addition to the urgently needed consolidation and expansion of the body of knowledge regarding emissions and other environmental impacts of space travel, as well as political options for action in a comprehensive TA study, an agenda-setting initiative with stakeholder participation could establish the foundations for a research agenda in this regard, which could then anchor the questions to be clarified in research funding. For instance, it must be legally clarified to what extent the precautionary principle should be applied in the face of uncertain knowledge and to what degree (private) polluters would need to compensate for the damage inflicted on the atmosphere, which is a common good. Furthermore, significant ethical questions arise, such as the inequitable distribution of benefits and burdens associated with (private) space travel, particularly if space tourism, accessible only to a select few wealthy individuals, substantially harms the global climate and ozone layer.

REFERENCES

Brown, T. F., Bannister, M. T., & Revell, L. E. (2023). Envisioning a sustainable future for space launches: reviewing current research and policy. *Journal of the Royal Society of New Zealand*, 1-17.

Dallas, J., Raval, S., Gaitan, J., Saydam, S., & Dempster, A. (2020). The environmental impact of emissions from space launches: A comprehensive review. *Journal of Cleaner Production, 255*, 120209.

GAO (2022). *Technology Assessment - Large Constellations of Satellites. Mitigating Environmental and Other Effects*. ***gao.gov/products/gao-22-105166***.

Gaston, K. J., et al. (2023). Environmental impacts of increasing numbers of artificial space objects. *Frontiers in Ecology and the Environment, 21*(6), 289-296, ***esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2624.***

Ross, M. N., & Jones, K. L. (2022). Implications of a growing spaceflight industry: Climate change. *Journal of Space Safety Engineering, 9*(3), 469-477. ***doi.org/10.1016/j.jsse.2022.04.004.***

Ryan, R. G., Marais, E. A., Balhatchet, C. J., & Eastham, S. D. (2022). Impact of rocket launch and space debris air pollutant emissions on stratospheric ozone and global climate. *Earth's Future, 10*(6), e2021EF002612.

Sirieys, E., Gentgen, C., Jain, A., Milton, J., & de Weck, O. (2022). Space sustainability isn't just about space debris: On the atmospheric impact of space launches: MIT Science Policy Review.

DROUGHT RESILIENCE (UPDATED)

© Krieger-Lamina

SUMMARY

Droughts are on the increase and cause great damage

Rain-spoiled regions such as Austria are little prepared for droughts. However, droughts in Austria now inflict more damage than all other natural disasters combined. Drought damage is expected to quadruple by 2050. It is no longer only agriculture that is impacted by low rainfall, declining groundwater levels, and diminishing river levels; drinking water, industry, and energy production are affected, as well as transportation. Each subsequent drought uncovers competing uses and conflicting objectives. Given the limited historical experience with drought, the current plans are only partially suitable for the future. Monitoring systems are in place, but adaptation and coping strategies must be improved. Research and development of drought resilience and a national water strategy are urgently needed to make Austrian regions future-proof.

OVERVIEW OF THE TOPIC

Droughts are increasing, with significant economic and ecological damage

Climate variability has increased significantly in Europe, resulting in climate-related extreme events such as hot droughts, significant heatwaves, persistent flooding and flash floods (Kempf, 2023). In 2019, 38% of the EU population and 29% of the EU territory were affected by water scarcity.[1] While awareness of a potential rise in drought risk is widespread, drought is often not considered a significant threat in Central, Northern, and Eastern Europe (Blauhut et al., 2022).

In Austria, too, naturally occurring fluctuations in dry phases are significantly amplified by global warming.[2] Since the 1880s, Austria has recorded an increase in the average temperature of 2 °C, significantly higher than the global average of 0.85 °C (Hanger-Kopp & Palka, 2022). The study "Water Resources Austria" provides a comprehensive basis for the sustainable management of groundwater resources and states: "Due to the effects of climate change, the available groundwater resources in Austria could decrease by up to 23% from the current 5.1 billion m³ to 3.9 billion m³ by 2050."[3] While the severity and frequency of past drought events have been studied thoroughly, little is known about the effects of coping strategies and how the relevant interest groups perceive the risk (Blauhut et al., 2022).

Austria was long considered a water paradise

Given that there is significantly less historical drought experience than floods, existing plans are only partially equipped for the future. Regions affected by rain are poorly prepared for droughts. Climate in the Danube region has changed so much that annual droughts have become the norm in the last decade. Droughts are increasingly causing more damage than all other natural disasters combined, and drought damage is expected to quadruple by 2050.[4] According to initial estimates, the flood of the century in 2024 caused around 1.3 billion euros in damage[5]. Drought and flooding problems are closely linked through the (inadequate) protection of unsealed soils and river straightening. In Austria, drought caused damage of 170 million euros in the warmest year in the 256-year history of the fair, according to the insurance company. In contrast, hail, storms, and flooding caused 45 million euros, and frost damage was 35 million euros. In the extreme drought year of 2018, 230 out of 270 million euros in losses were due to drought[6]. Annual drought losses in the European Union and the United Kingdom currently stand at €9 billion and could rise to over €65 billion annually by the end of the century (Naumann, Cammalleri, Mentaschi, & Feyen, 2021).

Definition of drought

Drought is an extreme, prolonged condition in which less water is available than required from a hydrological, agricultural or ecological perspective[7]. A distinction is made between the following levels: meteorological drought (one to two months drier than usual), agricultural drought (two months or longer of dryness resulting in crop losses), hydrological drought (four months or longer, with

---

1 *environment.ec.europa.eu/topics/water/water-scarcity-and-droughts_en*.
2 *zamg.ac.at/cms/en/climate/news/new-study-on-droughts-in-the-alps*.
3 *info.bml.gv.at/service/publikationen/wasser/wasserschatz-oesterreichs.html*.
4 *science.apa.at/power-search/10251405872317897922*.
5 *wifo.ac.at/news/floods-caused-13-mrd-e-damage/*.
6 *hagel.at/press-releases/annual-balance-sheet-2023/*.
7 *gerics.de/products_and_publications/publications/detail/062858/index.php.en*.

groundwater and water levels being affected), and socio-economic drought (one year or longer, where a lack of water hampers productivity) economy).[8]

Cascading effects lead to far-reaching consequences in agriculture and forestry, industry, energy production, drinking water and recreation

Droughts cause a chain reaction: For instance, droughts and heat waves frequently happen together and may provoke secondary events like forest fires. A spreading meteorological drought results in low water levels in reservoirs and rivers, impacting public water supplies, causing partial shutdowns of nuclear power plants, and triggering massive fish die-offs. A shortage of feed for livestock usually follows crop losses and, as a result, premature slaughter of animals (de Brito, 2021). Acute drought is also essential to favouring bark beetle infestation, leading to significant forest damage (Netherer, Panassiti, Pennerstorfer, & Matthews, 2019). Lowering river water levels hinder transportation and energy production in run-of-river power plants. Meanwhile, decreasing groundwater levels highlight conflicts among drinking water supply, industrial and agricultural use, and tourism (e.g., ***artificial snow***). Glaciers in the Alps have stored vast amounts of water to alleviate water shortages in hot years partially. However, the significant reduction of these glaciers is advancing rapidly, placing further strain on the water balance and likely leading to serious consequences in the future. This interconnectedness also highlights the inadequate state of research, as the effects of droughts have been studied in the past using isolated approaches that focused on individual impact categories. Hence, new methodological approaches are necessary to understand the complex interactions of drought impacts that extend across different sectors and regions (de Brito, 2021).

Rising risk does not affect everyone equally

Modelling shows that winter and spring could become wetter in Austria in the future, while at the same time, the risk of moderate and extreme drought events in summer increases (Haslinger et al., 2022). In agriculture, the consequences of increasing risk and uncertainty hit small farmers the hardest; in this case, assistance is particularly important (Birghila, Pflug, & Hochrainer-Stigler, 2022). However, farmers are also currently affected by winter droughts, and southern and western Europe are already experiencing severe droughts before summer.[9] In principle, numerous agricultural adaptation strategies exist beyond irrigation and crop failure insurance, such as adjusting ploughing intensity, mulching, or crop resilience (Hanger-Kopp & Palka, 2022).

Urban and rural areas are also affected differently and sometimes require different strategies. In principle, the water retention capacity of landscapes and urban areas must be increased. Measures such as the renaturation of rivers, moors and floodplain landscapes not only help store more water for drought but are also highly relevant for flood protection as they provide floodplains. In urban development, concepts such as the sponge city have been under discussion for some time and are beginning to be applied.[10] Sponge cities can absorb, filter, retain, and purify water during rainfall, releasing it during dry periods. A sponge city comprises wetlands, forests, lakes, green roofs, biological retention systems, and permeable pavements, among others (Guan, Wang, & Xiao, 2021).

---

8 *dwd.de/DE/service/lexikon/Functions/glossar.html?lv2=100578&lv3=603288*.

9 *orf.at/stories/3309655/*.

10 *wien.gv.at/environment/parks/schwammstadt.html*.

Adaptation and coping strategies needed

Due to persistent greenhouse gas emissions and rising temperatures, Europe is expected to face growing drought challenges, necessitating quick action and efficient adaptation and coping strategies (Shah et al., 2022). National coping strategies are essential, but they reach their limits regarding shared water resources, such as transboundary rivers. Joint management of shared water resources among riparian states is a common practice in the EU to prevent conflicts and serves as an exemplary model in a global context.[11] However, the question remains regarding the effectiveness of such sharing during an extreme crisis. The coronavirus pandemic, for instance, has shown how quickly it can revert to a national focus of interest.

Strategic and systematic use of water as a resource

Satellite-based ***remote sensing*** is used to monitor soil moisture in the Danube region.[12] EU-wide monitoring has also been launched in the "European and Global Drought Observatories" (EDA/GDO) project, which aims to improve drought resilience and adaptation throughout the EU.[13] There is a distinct monitoring system for the Alpine region.[14]
A comprehensive national strategy for Austria is currently lacking; it remains to be seen to what extent the Ministry of Agriculture's future platform for water[15] can contribute to this direction. There are examples of new strategies in Germany and France, for example. Germany has recently adopted a new water strategy that establishes a foundation for a refreshed strategic approach to water resources. This change is partly due to increasing public awareness of competition for usage and conflicting objectives in water utilisation during the recent summer drought:[16] "A regional water balance that is as close to nature as possible will be an important prerequisite for a stable water supply and for safeguarding ecological interests." France has also recently declared a climatic state of emergency for certain regions due to the extreme winter drought and introduced a new water plan that regulates the distribution of scarce water resources.[17]

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Uniform drought management called for in Europe

There is an urgent need to further reduce the impact of droughts by developing and implementing a European approach to drought management, such as through a directive that strengthens national drought management and mitigates

11 *read.oecd-ilibrary.org/governance/international-regulatory-co-operation-case-studies-vol-3/transboundary-water-management_9789264200524-4-en#page3*.
12 *droughtwatch.eu*.
13 *drought.emergency.copernicus.eu/*.
14 *ado.eurac.edu*.
15 *info.bml.gv.at/service/presse/wasser/2022/sicherung-des-wasserschatzes.html*, see also the plans and initiatives here *info.bml.gv.at/themen/wasser/nutzung-wasser.html*.
16 *bmuv.de/fileadmin/Daten_BMU/Download_PDF/Binnengewaesser/nationale_wasserstrategie_2023_bf.pdf*.
17 *zeit.de/wissen/umwelt/2023-04/frankreich-duerre-wassermangel-strategie?utm_source=pocket-newtab-global-en-EN&utm_referrer=https%3A%2F%2Fgetpocket.com%2Frecommendations*.

damage to both people and nature (Blauhut et al., 2022). An overarching EU strategy is already driving adaptation to global warming;[18] emergency measures can be implemented at short notice as part of the Union's Civil Protection Mechanism. The EU Commission's ongoing initiative is to promote the broader use of drought management plans, measures to improve the water capacity of soils, and the safe reuse of water.[19]

Nature-based solutions– synergies from drought and flood protection

The interplay between flood and drought protection and the use of nature-based solutions, such as near-natural river and floodplain landscapes that act like a sponge and keep water in the landscape for a long time, is essential. Improved protection of unsealed surfaces can also be used to tackle both problems simultaneously.[20] In the longer term, nearly all river catchment areas will be impacted, necessitating both organisational and technical adaptation solutions. In agriculture, it is essential to promote sustainable (re) water use, effective soil management, vegetation cover, drought-resistant crops, vertical farming, and adjustments in land use planning. In the energy and transport sectors, preparations must be made for disruptions to the transportation of goods on waterways, hydroelectric power plants, and power plant cooling. In the drinking water supply sector, the promotion of water conservation in households and industry, along with additional supply and storage infrastructures, is necessary.[21] Experts advocate for more consistent drought risk management across Europe: (a) the inclusion of a precise definition of drought in the Water Framework Directive that encompasses various types of drought and their spatial and temporal patterns; (b) the establishment of impact-driven, regional, and sector-specific guidelines for drought indices; and (c) the creation of an interdisciplinary collaborative EU working group to tackle drought risk management and evaluate the potential advantages and disadvantages of a European drought directive. (Blauhut et al., 2022).[22].

Various adaptation strategies are necessary

PROPOSAL FOR FURTHER ACTION

Harmonised drought resilience at EU level, specific regional strategies

While acute emergency aid during droughts is essential, various proactive coping and adaptation strategies that enhance resilience to droughts in urban and rural areas could be developed and regionally adapted. Learning from other regions with extensive experience of drought, such as California, Singapore, or Spain, could also be encouraged. A forward-looking TA project that fosters the exchange among all relevant stakeholders from business, science, and civil society could be a starting point here.

---

18 *climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en*.

19 *op.europa.eu/en/publication-detail/-/publication/0bdb11d0-4322-11ef-865a-01aa75ed71a1*

20 *donau-uni.ac.at/en/news/2023/praeventionsstrategien-fuer-extreme-ueberschwemmungsereignisse.html*.

21 *eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:82:FIN*.

22 *environmentalrisks.danube-region.eu/workshop-towards-a-better-understanding-of-drought-impacts-and-risks-in-water-management-sector-april-4-2023/*.

REFERENCES

Birghila, C., Pflug, G. C., & Hochrainer-Stigler, S. (2022). Risk-layering and optimal insurance uptake under ambiguity: With an application to farmers exposed to drought risk in Austria. *Risk Analysis*, *42*(12), 2639-2655. doi:/10.1111/risa.13884.

Blauhut, V., et al. (2022). Lessons from the 2018-2019 European droughts: a collective need for unifying drought risk management. *Natural hazards and earth system sciences*, *22*(6), 2201-2217.

de Brito, M. M. (2021). Compound and cascading drought impacts do not happen by chance: A proposal to quantify their relationships. *Science of The Total Environment*, *778*, 146236. doi:10.1016/j.scitotenv.2021.146236.

Guan, X., Wang, J., & Xiao, F. (2021). Sponge city strategy and application of pavement materials in sponge city. *Journal of Cleaner Production*, *303*, 127022.

Hanger-Kopp, S., & Palka, M. (2022). Decision spaces in agricultural risk management: a mental model study of Austrian crop farmers. *Environment, Development and Sustainability*, *24*(5), 6072-6098. doi:10.1007/s10668-021-01693-6.

Haslinger, K., et al. (2022). Contradictory signal in future surface water availability In Austria, there is an increase on average vs. a higher probability of droughts. *EGUsphere*, *2022*, 1-28. doi:10.5194/egusphere-2022-191.

Kempf, M. (2023). Enhanced trends in spectral greening and climate anomalies across Europe. *Environmental Monitoring and Assessment*, *195*(2), 260.

Naumann, G., Cammalleri, C., Mentaschi, L., & Feyen, L. (2021). Increased economic drought impacts in Europe with anthropogenic warming. *Nature Climate Change*, *11*(6), 485-491. doi:10.1038/s41558-021-01044-3.

Netherer, S., Panassiti, B., Pennerstorfer, J., & Matthews, B. (2019). Acute Drought Is an Important Driver of Bark Beetle Infestation in Austrian Norway Spruce Stands. *Frontiers in Forests and Global Change*, *2*. doi:10.3389/ffgc.2019.00039.

Shah, J., et al. (2022). Increasing footprint of climate warming on flash droughts occurrence in Europe. *Environmental Research Letters*, *17*(6), 064017.

RESILIENT FERTILIZER SUPPLY

© CC0 (Craig Cooper/unsplash)

SUMMARY

Mineral nitrogen, phosphorus, and potash fertilizers are both a blessing and a curse. They increase agricultural productivity but simultaneously cause climate and environmental problems and make food security dependent on a few countries and fossil fuels. Research and application of alternative approaches and technologies are necessary for a resilient, decarbonized, sustainable nutrient supply. Examples of this include the development of new processes for nitrogen production, the use of secondary phosphorus sources, in particular sewage sludge, and polyhalite as a substitute for chloride-containing potash salts, but also the breeding of new plant varieties that can mobilize nutrients from the soil, the use of biochar and efficient nutrient fertilization through AI and precision agriculture. The coherent combination of various approaches requires a context-specific evaluation of the nutrient supply technologies and measures suitable for Austria and the development of a national strategy for a resilient, climate-neutral, and efficient nutrient management system.

Technology assessment and development of a national nutrient strategy for a resilient, climate-neutral and efficient fertiliser supply in Austria

OVERVIEW OF THE TOPIC

Mineral fertiliser supply is neither resilient nor sustainable

Mineral fertilisers with the nutrients nitrogen, phosphorus and potassium essential for plant growth have led to considerable increases in agricultural yields. However, the production and use of mineral fertilisers is not sustainable. Nitrogen is produced on an industrial scale by chemically synthesising ammonia from atmospheric nitrogen and hydrogen using the Haber-Bosch process. Ammonia synthesis occurs on an iron-containing catalyst at approximately 150 to 350 bar and 400 to 500 °C, contributing to around 5% of global greenhouse gas emissions (Gao & Cabrera Serrenho, 2023).

Decarbonisation and transformation of the nutrient supply are essential for agricultural production

Nutrient losses due to fertilisation pollute air, soil and water and endanger climate and biodiversity

EU "Farm to Fork" strategy to Fork" strategy reduces fertiliser use by 20%

Phosphorus and potassium are limited in space and quantity, as they occur bound in mineral deposits (especially apatite and sylvite). Phosphorus has been on the EU list of critical resources since 2017,[23] as the supply depends on a few producing countries such as North Africa, Jordan, Russia and China, as well as their geopolitical stability. Phosphorus extraction presents ecological issues, as the minerals include toxic metals and radioactive materials like cadmium and uranium (Issaoui et al., 2021). These are increasingly restricting their use as fertilisers. The application of mineral fertilisers also results in environmental issues. In contemporary agricultural practices, plants only use 14% nitrogen and 16% phosphorus (Daneshgar et al., 2018). Most nutrients are lost, resulting in air, soil, and water pollution, climate impacts due to ammonia and nitrous oxide emissions, and a decline in biodiversity. Especially in areas with high livestock populations, the significant amount of farm manure often leads to excessive nitrogen application to the land, which exceeds the crops' ability to absorb it. Over-fertilization also impacts health, as high nitrogen levels in leaf and root vegetables can be converted into nitrite during digestion, which harms health.[24] With the "Farm to Fork Strategy", the EU Commission aims to improve nutrient management and reduce the use of mineral fertilisers by 20% and nutrient losses by 50% by 2030.[25]

Price increases of fertilisers make food more expensive

Efficient circulation system is necessary

The utilisation of mineral fertilisers also encompasses a socio-economic aspect. This is due to supply constraints and rising prices for mineral fertilisers, mainly due to increased energy costs, affecting consumer food prices. In light of the economic, ecological, and socio-economic repercussions of mineral fertiliser production and usage, along with the limited options for substitution, it is vital to transform the nutrient supply into an efficient circular system to advance sustainable, biodiversity-enhancing, and health-promoting value chains. This requires a long-term nutrient policy concept and a national strategy encompassing various political goals, technologies and strategies from fertiliser production to application and nutrient recycling.

Hope for polyhalite as a substitute for potash fertiliser

Mining polyhalite, a mineral containing potassium chloride, calcium, sulphur, and magnesium, can help improve the supply of potash fertilisers. However, mining and utilisation are challenging and limited due to the mineral composition, the depth (200 to 1,000 m), and the relatively low level of purity (Tan et al., 2022).

23 *eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:52020DC0474*.
24 *landeszentrum-bw.de/Lde/Startseite/wissen/nitrat-im-gemuese-wirklich-so-bedenklich*.
25 *food.ec.europa.eu/document/download/472acca8-7f7b-4171-98b0-ed76720d68d3_en?filename=f2f_action-plan_2020_strategy-info_en.pdf*.

In a nature park in North Yorkshire, UK, Sirius Minerals is planning the world's largest extraction of high-quality polyhalite and has commissioned the Austrian construction company STRABAG.[26] Polyhalite can be marketed as a low-chloride potash fertiliser but is not a complete substitute for potash fertiliser due to its lower potassium content.

Research for improved plant uptake of potassium and phosphorus

Research is being conducted to enhance the uptake of potassium and phosphorus from the soil, as the typically abundant soil reserves are largely unavailable to plants. By breeding specific genotypes, the release of organic acids from plant roots can be increased, thereby improving the availability of phosphorus and potassium bound in the soil[27] (Zörb et al., 2014). Microbes such as the nitrogen-fixing bacterium Pseudomonas chlororaphis, which make bound phosphorus bioavailable to plants, are also the subject of research. However, producing and transporting these microbes poses challenges due to their sensitivity to stress factors like temperature and humidity, complicating large-scale agricultural introduction problematic (Burke et al., 2023).

Phosphorus recycling from sewage sludge has great potential

Another option is to recycle phosphorus from sewage sludge.[28] In Austria, approximately 237,000 tonnes (t) of sewage sludge were produced by municipal sewage treatment plants in 2018, with the majority (53%) subjected to thermal treatment. Roughly 20% of this sewage sludge was applied directly to agricultural land, while about 27% was sent for further processing (e.g. composting). By utilising phosphorus from municipal sewage sludge (6,700 t/a) and animal waste (5,500 t/a), it is theoretically possible to substitute 75% of mineral fertiliser imports (Leonhardt & Pinkl, 2020). Thermochemical treatment can lower the phosphorus content in sewage sludge to below 2%, producing by-products such as struvite, which is suitable for producing phosphorus fertiliser (Clemens & Teloo, 2020). However, the processes are neither established on an industrial scale nor competitive (Leonhardt & Pinkl, 2020). In addition, recyclates such as struvite require professional marketing, which is not economical due to the comparatively small quantities of fertiliser (Clemens & Teloo, 2020). Instruments to promote recycling include recycling quotas for the fertiliser industry or phosphorus recovery requirements for sewage treatment plants, as will be mandatory in Germany from 2029 for sewage treatment plants with more than 50,000 inhabitants (Kind, 2020). Similar legal framework conditions and incentives for efficient recycling are also being considered in Austria.

Research into alternative processes for production

In nitrogen production, the energy-intensive Haber-Bosch process for synthesising ammonia from nitrogen and hydrogen can become climate-neutral through technical modifications to utilise green hydrogen and renewable energy electricity. The first commercial plant demonstrates this for the production of green ammonia in Puertollano (Spain).[29] Alternative approaches are power-to-ammonia processes that work with new catalysts at significantly lower temperatures and pressures and with new heat integration strategies as a steam substitute. They

26 *strabag.com/databases/internet/_public/content.nsf/web/861E4C21EBCAF2C1C125825F002C32A1*.

27 *d-nb.info/964804751/34*.

28 *parlament.gv.at/dokument/fachinfos/zukunftsthemen/118_phosphorrecycling.pdf*.

29 *fertiberia.com/en/greenammonia/h2f-project/*.

enable flexible and decentralised ammonia reactors and energy savings of up to 50 % (Torrente-Murciano & Smith, 2023). Others are researching catalytic systems that use light as an energy source for ammonia production (Ashida et al., 2022). However, processes in which nitrogen is produced at room temperature using light, water and molybdenum catalysts are still far from industrial maturity (Durrani, 2024).

Improving nutrient efficiency through precision farming

In addition to alternative methods for producing mineral fertilisers, the resilience of the fertiliser supply can be enhanced by improving efficiency in agricultural practices. Conventional agriculture often operates with excessive nitrogen and phosphorus surpluses due to the regional concentration of livestock farming. These surpluses can be reduced without any loss of yield. Appropriate methods to enhance nutrient efficiency include techniques for analysing the nutrients in farm manure and technologies to optimise application distribution. Precision farming technologies can further increase the efficiency of fertiliser use.[30] With the help of AI and data, e.g., from nitrogen sensors and satellites, fertiliser application maps are created, and fertiliser application is adjusted in a targeted manner. However, despite the benefits, precision farming in agriculture is still hesitant.

A higher proportion of organic farming reduces the need for mineral fertilisers by using organic fertilisers and biochar

The planned expansion of organic farming in the EU to 25% of agricultural land, as part of the "Farm-to-Fork" strategy, can also contribute to a resilient fertiliser supply. Although the proportion of organically farmed land in Austria is already 27%, there is still room for expansion.[31] In organic farming, organic fertilisers are utilised, while mineral fertilisers are largely avoided. The nutrient supply is ensured by cultivating nitrogen-fixing legumes and introducing atmospheric nitrogen into the soil with root nodules bacteria. Biochar from the pyrolytic carbonisation of plant residues is also produced in Austria as a nutrient store to increase fertiliser efficiency and as a component of Terra Preta, which is considered a *negative emission technology*.[32] However, there are gaps in knowledge about the effect of biochar.[33]

RELEVANCE OF THE TOPIC FOR PARLIAMENT AND FOR AUSTRIA

Legislation and funding policy for a resilient, sustainable, and nutrient supply and food security based on the circular economy principle

The regulation of plant nutrients is enshrined in European and national legislation. However, despite their central importance for agriculture and food security, the sustainable provision and use of fertilisers are not guaranteed. There is a lack of political and public awareness of this highly relevant issue and a lack of a coherent strategy for fertiliser management (Brownlie et al., 2021) as well as economic instruments to compensate for the governance deficits of regulatory law (Garske et al., 2020). A wise funding policy is needed to increase individual technologies' investment incentives and market maturity and exploit economies of scale. In addition, whether the processes and technologies can add value to

[30] *tab-beim-bundestag.de/projekte_digitalisierung-der-landwirtschaft.php*.
[31] *landwissen.at/wp-content/uploads/2023/11/BML_Broschuere_Biologische_Landwirtschaft_231108_BF.pdf*.
[32] *parlament.gv.at/dokument/XXV/AB/8575/imfname_538434.pdf*.
[33] *bafu.admin.ch/dam/bafu/en/dokumente/klima/fachinfo-daten/faktenblatt-pflanzenkohle-2022.pdf.download.pdf/D_Faktenblatt_Pflanzenkohle.pdf*.

achieving sustainability goals must be examined. In this context, practical requirements must also be considered. An analysis of the economic, ecological and socio-economic opportunities and challenges of transforming fertiliser supply and use, e.g., through AI and precision farming (Rösch, 2006) and their trade-offs for agriculture, climate and the environment, is required. This analysis could establish the knowledge base necessary to sustainably enhance the intricate production and consumption patterns and develop refined strategies for increasing acceptance among farmers and consumers (Kurniawati et al., 2023).

PROPOSAL FOR FURTHER ACTION

Evaluation of technologies and processes as the basis for an Austrian strategy for a resilient and climate-neutral fertiliser supply

To develop appropriate strategies and measures for Austria to reduce fertiliser use by 20% (farm-to-fork strategy) and ensure efficient and climate-neutral nutrient management, a comprehensive analysis of the current state of research and knowledge and the legal framework is necessary. This includes closing national and regional nutrient cycles and a social discussion on the future of nutrient supply and use. A prerequisite is creating an up-to-date knowledge base to evaluate the various technologies and processes for a resilient and climate-neutral supply of mineral and organic nutrients. Economic, ecological, and socio-economic aspects, along with the opportunities and risks along the value chain, should be considered, and stakeholders and citizens ought to be involved to enhance the study's relevance and the application of the results in practice.

REFERENCES

Ashida, Y., et al 2022. "Catalytic Nitrogen Fixation Using Visible Light Energy". *Nature Communications* 13(1):7263. ***doi.org/10.1038/s41467-022-34984-1.***

Brownlie, W. J., et al. 2021. "Global Actions for a Sustainable Phosphorus Future". *Nature Food* 2(2):71-74. ***doi.org/10.1038/s43016-021-00232-w.***

Burke, B., et al. 2023. "Self-Assembled Nanocoatings Protect Microbial Fertilizers for Climate-Resilient Agriculture". *JACS Au* 3(11):2973-80. ***doi.org/10.1021/jacsau.3c00426.***

Clemens, J., and Teloo. 2020. "Requirements for phosphorus recyclates from the treatment of sewage sludge from the perspective of a fertiliser manufacturer".

Daneshgar, Saba, Arianna Callegari, Andrea Capodaglio, and David Vaccari. 2018. "The Potential Phosphorus Crisis: Resource Conservation and Possible Escape Technologies: A Review". Resources 7(2):37. ***doi.org/10.3390/resources7020037.***

Durrani, J. 2024. ammonia production "Beyond "Haber-Bosch". *Spectrum der Wissenschaft*, (2.24), pp. 66-72.

Gao, Y. and A. Cabrera Serrenho. 2023. "Greenhouse Gas Emissions from Nitrogen Fertilizers Could Be Reduced by up to One-Fifth of Current Levels by 2050 with Combined Interventions". *Nature Food* 4(2):170-78. ***doi.org/10.1038/s43016-023-00698-w.***

Garske, B., et al. 2020. "Sustainable Phosphorus Management in European Agricultural and Environmental Law". *Review of European, Comparative & International Environmental Law* 29(1):107-17. ***doi.org/10.1111/reel.12318.***

Issaoui, R., et al. 2021. "Cradle-to-Gate Life Cycle Assessment of Beneficiated Phosphate Rock Production in Tunisia". *Sustainability Management Forum | NachhaltigkeitsManagementForum* 29(2):107-18. ***doi.org/10.1007/s00550-021-00522-8***.

Child, S.. 2020. *sustainable phosphorus supply*. ***doi.org/10.5445/IR/1000133950***.

Kurniawati, Ari, Petra Stankovics, Yahya Shafiyuddin Hilmi, Gergely Toth, Marzena Smol, and Zoltan Toth. 2023. "Understanding the Future of Bio-Based Fertilizers: The EU's Policy and Implementation". Sustainable Chemistry for Climate Action 3:100033. ***doi.org/10.1016/j.scca.2023.100033.***

Leonhardt, C., and J. Pinkl. 2020. Strategy process for future crop production challenges. Vienna.

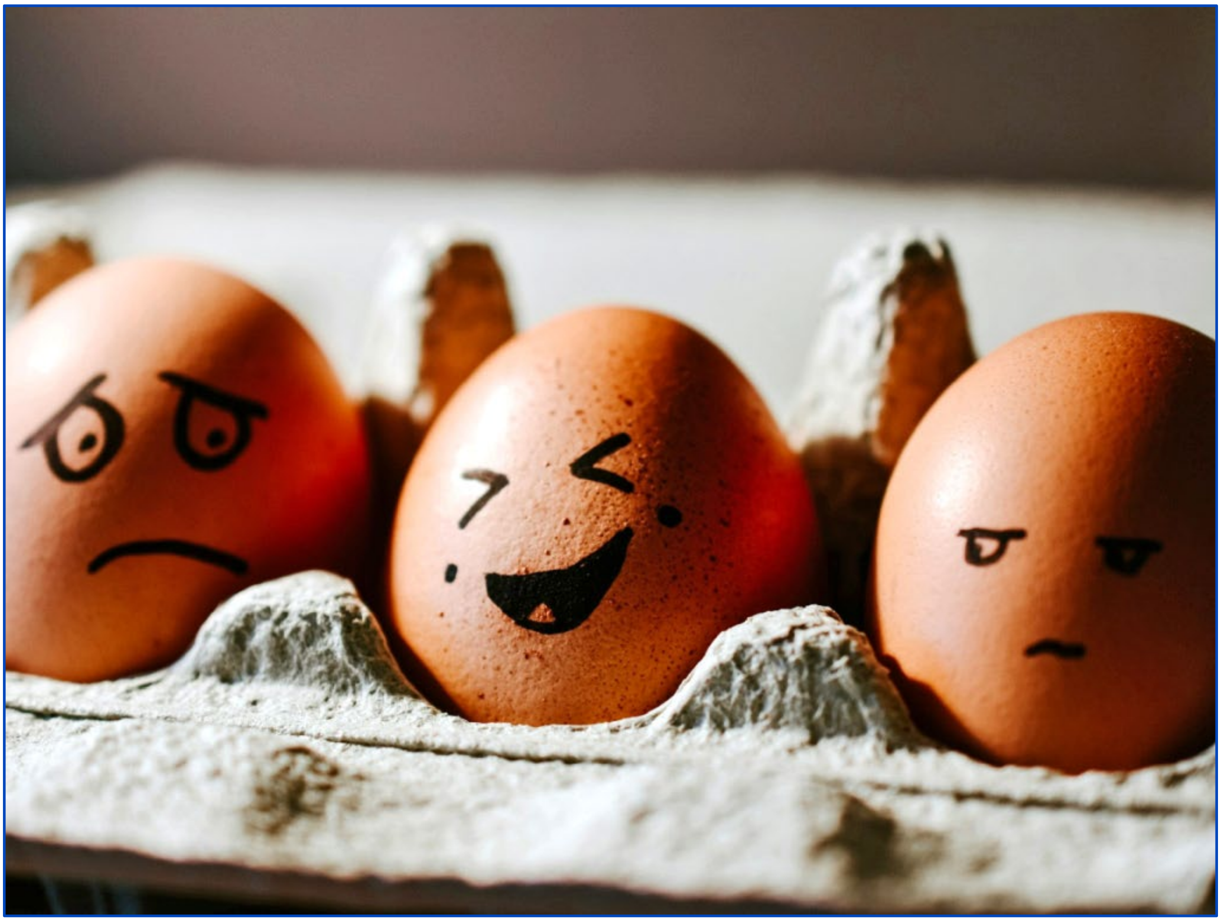
Rösch, C. 2006. "Precision Agriculture – Landwirtschaft per Satellit und Sensor" ISBN: 978-3-86641-080-0. KITopen-ID: 1000103648

Tan, H., et al. 2022. "Toward the Replacement of Conventional Fertilizer with Polyhalite in Eastern China to Improve Peanut Growth and Soil Quality". *Chemical and Biological Technologies in Agriculture* 9(1):94. ***doi.org/10.1186/s40538-022-00363-7.***

Torrente-Murciano, L., and C. Smith. 2023. "Process Challenges of Green Ammonia Production". *Nature Synthesis* 2(7):587-88. ***doi.org/10.1038/s44160-023-00339-x***.

Zörb, C. et al. 2014. "Potassium in Agriculture - Status and Perspectives". *Journal of Plant Physiology* 171(9):656-69. ***doi.org/10.1016/j.jplph.2013.08.008***.

EMOTION RECOGNITION AS A FIELD OF PROMISE FOR AI?



© CC0 (Nik/unsplash)

SUMMARY

AI is increasingly used to recognize patterns in faces, speech, texts, body signals and behaviour and to create analyses and predictions about people's emotional states, preferences and personality traits. The systems can be utilised in various areas—such as by security authorities at borders and in public spaces, for therapeutic care in medicine, to support pupils in education, personalised marketing, or for personnel development in the workplace. However, the reliability of the systems must be critically evaluated due to the underlying models and psychological assumptions. Additionally, there are numerous challenges regarding discrimination, data protection, and ethical responsibilities, particularly for vulnerable groups. These include structural changes in political public spheres and the exacerbation of social inequality in the workplace.

OVERVIEW OF THE TOPIC

Emotion recognition: new possibilities with AI

Advances in artificial intelligence are opening up new possibilities for *assigning emotion category* human behaviour to a specific and drawing further conclusions about emotional states, character traits or behavioural patterns of people.[1] Corresponding AI systems can draw on various data types such as biometric signals, images, texts, interaction, audio and video data. One has already tried and tested variant analyses and predicted character traits and preferences on social media platforms. Interaction patterns are used as data traces to create user profiles (Kosinski, Stillwell & Graepel 2013). Another possibility is the collection of visual data through facial recognition systems, where facial expressions are employed to capture individuals' emotional states. Contemporary facial recognition systems predominantly rely on so-called holistic approaches. In contrast to feature-based approaches, in which actual biometric data and the distance between the eyes are measured, holistic systems only capture brightness distributions in an image (Meyer 2019, p. 321-359). Additionally, biometric data such as heart rate, pupil diameter, or muscle activity can be employed for emotional recognition. The necessary sensors can now also be utilised on the go - for instance, in wearables like smartwatches (Khare et al. 2024). The spread of large language models (LLM), in particular, is also making it possible to recognise emotions from texts more and more effectively. In some cases, emotions are named directly; in others, they are determined from descriptions, exclamations or other rhetorical phrases (Yang, 2023).

Diverse areas of application: Security, public services, marketing ...

AI for recognising emotions can be applied in various fields. For example, car assistance systems that monitor drowsiness based on steering behaviour, pedal use, head posture, and gaze behaviour through a camera system are already available.[2] The Fraunhofer EMOBIO project, for example, aims to develop further AI-based systems that use physiological data to recognise (micro) emotions to determine different driver states.[3] Emotional facial recognition systems have been employed by border authorities in the USA and the UK, as well as by Interpol, for several years to identify suspicious individuals during immigration checks (Crawford et al. 2019). AI systems designed for emotion recognition could also find applications across various areas of public services. In psychological care, chatbots such as Woebot[4] or Wysa[5] based on AI language models have been offered in recent years, particularly by private providers. The applications aim to enhance access to therapeutic services amid a shortage of therapy placements and provide immediate assistance for depression or anxiety disorders through structured exercises and self-help materials (Swartz, 2023). In the care sector, the use of care robots is being discussed (Korn 2019). The systems could recognise the emotions of individuals requiring care to regulate the interaction behaviour of robots. Online marketing on social media and marketplace platforms presents another area of application. In this context, product recommendations can be tailored to individuals'

1 *t3n.de/news/emotion-ai-maschinen-lernen-1149606/*.
2 *bussgeldkatalog.org/muedigkeitserkennung*.
3 *hci.iao.fraunhofer.de/en/Human-Centered-AI/feinfuehlige-technik/KI-gestuetzte-Emotionserkennung.html*.
4 *woebothealth.com*.
5 *wysa.com*.

emotional states to encourage purchasing decisions (Zeng et al. 2016). Visual emotion recognition also aims to bridge the gap between the digital and analogue realms in personalised advertising. For instance, video surveillance is intended to capture customers' faces in retail stores, analyse their reactions to specific products, and subsequently play tailored advertising (Meyer 2021, p. 42).

High-risk applications: The world of work and education

In principle, both the world of work and the education sector offer various applications. In education, technology could enhance learning environments - from supporting individuals with learning disabilities and flexibly adapting content to their emotional reactions to monitoring the concentration levels of pupils or students. In principle, both the world of work and the education sector offer various applications. In education, technology could enhance learning environments - from supporting individuals with learning disabilities and flexibly adapting content to their emotional reactions to monitoring the concentration levels of pupils or students (Büchling et al. 2019). In the world of work, AI systems for emotion recognition can be used for job application processes, internal personnel development, and performance monitoring. Video-recorded job interviews could be automatically evaluated according to facial expressions, gestures, and language, thus providing information about the applicants' personalities.[6] Companies could also use them to assess employees internally and make personnel decisions based on personality and performance analysis. Such systems are already in use in the USA, for example. In the European Union, however, applications related to the workplace or the education sector will be prohibited in future under the new AI Act. They are considered high-risk AI systems, as their use in job interviews or the school environment, for example, harbours the risk of discrimination. Furthermore, they could serve as surveillance technologies focusing on employees' or students' intimate interpersonal or physical expressions. This could undermine rights enshrined in law, such as the freedom to strike, the right to associate with trade unions, and the right to establish a works council.

Challenges:

- Reliability of the models
- Bias
- Discrimination
- Data protection

For all AI systems for emotion recognition, neural networks are trained with existing material, such as images or texts, to recognise patterns to which emotions are assigned. However, deriving emotions and personality traits from observable variables of people's behaviour and appearance is problematic and controversial. Emotions are not empirically verifiable, so their replacement by measurable proxy features cannot be verified and evaluated. This fundamentally calls into question the reliability of the models. On the one hand, training data must often be classified by people with specific emotions to train an AI. For this purpose, classification approaches are usually used, in which a distinction is made between six so-called basic emotions - sadness, joy, fear, disgust, surprise and anger - to which a specific typified form of expression - such as facial expressions - is assigned (Ekman 1971). The systems, therefore, primarily abstract from the diversity of emotional states, their representation in facial expressions, modes of interaction or texts, and their connection with stable personality traits in favour of a schematic assignment of stereotypical expressions. For facial recognition models in particular, it has been found that the ascribed emotions often do not do justice to the diversity of emotional expressions in real everyday situations and different cultural spaces (Feldman Barrett et al. 2019). This presents a risk of discrimination.

[6] *algorithmwatch.org/de/sprachanalyse-hr/*.

The dominant models underpinning emotional pattern recognition are often stereotypical and typically trained on historical data. This may lead to discrimination against demographic groups and emotional expressions deemed abnormal or not adequately represented in particular data sets. When used to monitor public spaces or for border controls, the systems run the risk of attributing negative emotions to the facial expressions of non-white people in particular, thereby marking them as dangerous (Rhue 2018). Data protection presents a challenge, as in many cases, the processing (including storage and analysis) of sensitive personal data occurs within a context of power imbalance between the surveillant and the surveilled.

Emotionalisation of political publics

Regardless of the reliability of the models and training data, fundamental socio-political questions arise, especially in economic application areas. In online marketing, the personalisation of products and services through AI-based emotion recognition systems can result in the manipulation of social behaviour, as customers are influenced to make consumption decisions by analysing unconscious emotional states. The data for emotional analysis is often collected in digital services that users use for entirely different purposes - such as social and political participation or information procurement. This harbours the risk of cultural and political public spheres being structured by economic purposes, which can affect the functioning of democratic exchange and social cohesion. For instance, it has been demonstrated that the algorithmic sorting of content on social media platforms driven by advertising can affect users' emotional state (Kramer et al. 2014) and thus influence political mobilisation.

RELEVANCE OF THE TOPIC FOR THE AND FOR AUSTRIA

Grey areas of legal regulation

In the European Union's AI Regulation (AI Act), a legal framework was presented in 2023 that also regulates the use of AI-based emotion recognition systems for Austria.[7] Regulation is conducted in line with the risk-based approach of the AI Act, employing various regulatory instruments classified by risk category. The category of unacceptable risks encompasses emotion recognition systems intended for use in the workplace and educational institutions. These systems are prohibited unless employed for medical and safety purposes. High-risk AI systems include those used in employment, personnel management, access to essential public services, certain areas of law enforcement and border control. Such systems are permitted, but numerous regulatory requirements exist, such as the continuous operation of a risk management system. As a result, the use of AI systems for emotion recognition in Austria is already prohibited or subject to strict conditions in some of the sensitive areas described above. However, their use is generally permitted in all other areas. There are also grey areas, such as prohibited use in the workplace and permitted use in HR management. For example, which data may be collected by HR departments for personnel management purposes, which falls within the scope of the workplace, is likely to be the

7 See version of March 13, 2024, *europarl.europa.eu/RegistreWeb/search/simpleSearchHome.htm?references=P9_TA(2024)0138&language=en*.

subject of legal rulings and social negotiations in the coming years. The interpretation of the regulation will be clarified through delegated acts, standard specifications, standardisations, guidelines, and other means by various actors at different levels within the EU. However, it can also be assumed that court decisions will ultimately clarify questions of validity and interpretation in the long term or that regulatory gaps will persist.

PROPOSAL FOR FURTHER ACTION

The limitations of AI-based emotion recognition systems should be critically examined in a TA study. Given the wide range of potential applications for such systems and the emerging regulations from the EU, it would also be worthwhile to investigate the legal grey areas in which they can be employed, even though this could lead to ethical or social issues. For instance, the often ambiguous regulations in the workplace present opportunities for disputes regarding the areas in which such AI systems can and cannot be employed. Subsequently, it should be examined where those affected have limited opportunities to enforce relevant laws due to specific dependency relationships and vulnerabilities. This applies, for example, to use border authorities but also in precarious employment relationships with little social security.

REFERENCES

Büching, C. et al. (2019). Learning analytics at universities. In: Wittpahl, V. (ed.): Artificial Intelligence. Berlin/Heidelberg, 142-160, *doi.org/10.1007/978-3-662-58042-4_9.*

Crawford, K. et al. (2019). AI Now 2019 Report, New York, *ainowinstitute.org/publication/ai-now-2019-report-2* (22.04.2022).

Ekman, P. (1971): Universal and cultural differences in facial expression of emotion. In: Cole J. (ed.): Nebraska Symposium on Motivation. Lincoln, 207-282.

Feldman Barret, L. et al. (2019). Emotional Expressions Reconsidered: Challenges to Inferring Emotion From Human Facial Movements. Psychological science in the public interest 20(1), 1-68. *doi.org/10.1177/1529100619832930.*

Khare, S. K. et al. (2024). Emotion recognition and artificial intelligence: Asystematic review (2014-2023) and research recommendations. Information Fusion 102, 102019. *doi.org/10.1016/j.inffus.2023.102019.*

Korn, O. (2019): Social robots - introduction and potential for care and health. Wirtschaftsinformatik & Management 11, 126-135. *doi.org/10.1365/s35764-019-00187-5.*

Kosinski, M. et all (2013). Private traits and attributes are predictable from digital records of human behavior. PNAS 110 (15), 5802-5805, *doi.org/10.1073/pnas.1218772110.*

Kramer, Adam D. I. et al. (2014). Experimental Evidence of Massive-Scale Emotional Contagion through Social Network. Proceedings of the National Academy of Sciences of the United States of America 111 (29), 8788-8790, *doi.org/10.1073/pnas.1320040111.*

Meyer, R. (2019). Operative portraits. A pictorial history of identifiability from Lavater to Facebook. Konstanz University Press: Konstanz.

Meyer, R. (2021). Face recognition. Digital image cultures. Klaus Wagenbach publishing house: Berlin.

Rhue, L. (2018). Racial Influence on Automated Perceptions of Emotions, *dx.doi.org/10.2139/ssrn.3281765.*

Swartz, H. A. (2023). Artificial Intelligence (AI) Psychotherapy: Coming Soon to a Consultation Room Near You? American Journal for Psychotherapy, (76) 2nd, 55-56, *doi.org/10.1176/appi.psychotherapy.20230018.*

Tursunbayeva, A. et al. (2018). People analytics-A scoping review of conceptual boundaries and value propositions. International Journal of Information Management 43, 224-247. *doi.org/10.1016/j.ijinfomgt.2018.08.002.*

Yang, Tao et al. (2023): PsyCoT: Psychological Questionnaire as Powerful Chain-of-Thought for Personality Detection. In: Bouamor, H. et al. (eds.): Findings 2023. Singapore. *doi.org/10.18653/v1/2023.findings-emnlp.216.*

Zheng Y. et al. (2016). Emotions in context-aware recommender systems. In: Tkalci, M. et al. (eds.): Emotions and Personality in Personalized Services. Springer International Publishing, 311-326, *dx.doi.org/10.1007/978-3-319-31413-6_15*.

SOLAR STORMS AND SPACE WEATHER

© CC0 (Chris Henry/unplash)

SUMMARY

What impact would massive solar storms have on Austria?

Space weather phenomena, such as solar storms, can severely impact human life on Earth for weeks or even months due to our reliance on critical infrastructure that is vulnerable in this regard. In particular, the networks for electricity and communication, known as cross-sectional infrastructure, which form the foundation for the operation of all other areas of critical infrastructure, would be significantly affected. The field of research has been gaining relevance for several years due to the growing reliance on these technologies. What issues might arise, and what measures can be implemented in Austria to enhance resilience?

OVERVIEW OF THE TOPIC

What are sunspots, and what do they have to do with the earth?

Sunspots, associated with strong magnetic fields on the sun's surface and the intensity of its radiation, follow an approximately eleven-year cycle. We are currently in sunspot cycle 25, with its maximum expected to occur between January and October 2024, following a correction to the forecasts made last November. A significant increase in solar activity is anticipated during this maximum, which is evident in the number of sunspots. The forthcoming maximum is expected to surpass the maximum of cycle 24, yet, like the maxima of previous cycles, it will remain below the average of all recorded cycles.[1]

What are solar storms, eruptions, solar wind …

The sun continuously emits radiation and particles into space. This stream of particles also reaches the Earth and is known as solar wind. If this becomes unusually strong for a brief period in a specific area, it is termed a solar flare (Jaswal et al., 2023).

This occurs due to alterations in the sun's magnetic field, which typically contains hot plasma. However, the plasma can be expelled into space if the magnetic field is reorganised. This results in interference between the magnetic fields of the sunspots and particle streams. As a result, high-energy particles (primarily protons) are shot away at high speed, which can cover the distance to Earth in around an hour.

When particles are created outside the sun (flares[2]), they initially fly towards the sun, are slowed down there, and correspondingly slow down. The lost energy is visible as an X-ray flash. These propagate at the speed of light and can be measured on Earth before the proton showers.

A coronal mass ejection usually follows the flares. The magnetic fields of the flares interact so that a plasma cloud is separated from the sun's surface and propelled into space by altering the magnetic field lines. The coronal mass ejection consists of charged particles (electrons, protons and atomic nuclei) and moves away from the sun at around 1,000 km/h. This cloud is responsible for the majority of the flares.[3] This cloud is responsible for most of the phenomena observed on Earth, including the temporary disruption of a planet's magnetosphere.

… and what do they do with our earth's magnetic field?

Although the Earth's magnetic field shields us from the effects of eruptions, the impact of the current (comprising protons, electrons, and ions, along with short-wave radiation in the UV and X-ray range) in the ionosphere causes a visible interaction in the upper atmosphere layer, known as the aurora borealis, and interferes with broadcast radio communications. As the intensity of the particle stream increases, the Earth's magnetic field deforms and becomes weaker. Above a particular strength, the earth's magnetic field is deformed and weakened, protons that penetrate further increase the electron density in the atmosphere, which leads to growing adsorption for short waves and VHF up to 300 MHz. More intense storms can also negatively affect critical infrastructure on Earth. As our dependence on vulnerable systems increases, the importance of research into various space weather phenomena is likewise growing. The aim is to enhance forecasting accuracy and extend warning times to avert or, at the very least, contain potential damage.

[1] *heise.de/news/Sun-now-more-active-and-with-probably-more-sunspots-than-predicted-9350207.html*.

[2] Simple plasma magnetic field arcs on the surface of the sun.

[3] *mps.mpg.de/sonnenstuerme-sonnenaktivitaet-faq/1* and *de.wikipedia.org/wiki/Sonneneruption.*

Massive impairments in the past

Due to the shape of the earth's magnetic field, interference occurs between the sun's radiation and our atmosphere, which is increasingly visible as auroras in the polar regions. If the intensity of the radiation increases, the Earth's magnetic field deforms to such an extent that this optical phenomenon may also be observed in areas nearer to the equator. However, auroras in Central Europe are extremely rare. The best-known and strongest observed event of this kind was the so-called Carrington Event in 1859.[4] Reports indicate that auroras were even visible in Rome during that time. The primary infrastructure available on a large scale in the 19th century was the telegraph network. There was no reliance on electricity grids or other communication systems. The flow of charged particles induced high direct current voltages in the telegraph lines. As the lines were unprotected against such events, many telegraph stations experienced electric shocks, overvoltage, sparks, and fires alongside burnt-out lines and significant damage to the infrastructure. For a time, it was even feasible to telegraph between certain stations without a power supply, as the DC voltage induced by the solar storm was nearly equivalent to the power supply of the battery-powered telegraph lines.

What damage can currently be expected?

Experts agree that an event of this intensity today would cause massive damage, particularly to power and communication networks (Hayakawa, 2023). Air traffic, radar, radio broadcasting and government radio would also be affected.[5] The electronic components of satellites could also sustain damage. This and altered signal propagation times could impact positioning systems such as GPS or Galileo, potentially leading to total failure. Of course, navigation instruments would not be affected only. Many systems utilise the GPS signal for accurate time determination or synchronisation, such as in high-frequency trading or within the power grid (Strauß et al. 2017).

Weaker solar storms have previously resulted in power grid outages due to burnt-out transformers and line failures. The factors that influence the extent of damage include, on the one hand, the geographical latitude and length of the lines, their north/south/east/west orientation, and finally, the conductivity of the ground (in terms of material and moisture). Especially in the case of very long lines, the rotation of the Earth and the angle of incidence of the solar storm mean that both ends of the line are affected simultaneously. This results in induced stresses and creates a significant voltage gradient between the endpoints, which can be more or less balanced through the ground. This is particularly problematic because the failure of high-voltage transformers, such as in 1989 in the Quebec region of Canada,

---

4 The particles of the coronal mass ejection hit the earth at a speed of approx. 2,000 km/s, taking only 17.5 hours (with an average transit time of 24-36 hours) to cover the distance between the sun and earth: *en.wikipedia.org/wiki/Carrington_Event*. Another such strong event occurred in 1872 (the so-called Chapman-Silverman storm), when auroras could be seen as far away as Sudan and the Caribbean: *mps.mpg.de/polarlichter-ueber-der-der-karibik*. In 2012, a solar storm that would have been comparable in intensity to the Carrington event narrowly missed the Earth: *spiegel.de/wissenschaft/weltall/sonnensturm-2012-fast-katastrophe-auf-erde-plasma-verfehlt-planet-a-982652.html*. The high intensity does not only seem to be a question of timing and interference of individual flares, but, as was observed in 2012, also due to multiple shock waves hitting the Earth one after the other. The later ones find an already strongly deformed magnetic field and can therefore penetrate much further.

5 *de.wikipedia.org/wiki/Sonneneruption*.

cannot be repaired easily/quickly. Repairs are assumed to take weeks to months, depending on the availability of the necessary parts in the global market. If a damaging event similar to the Carrington event were to occur, many regions worldwide would be impacted, significantly worsening the availability of spare parts (Strauß et al. 2017).

Are there preventive measures?

The installation of DC circuit breakers could be regarded as a preventive measure. While this would still briefly cause the lines to fail—which can also lead to large-scale power outages—there would be less physical damage. The situation is similar with satellites. The systems can be shut down if the warning time is sufficiently long. This prevents significant damage to the electronic components. A power failure with all its ramifications would also need to be considered. Still, physical damage could be minimised, which is particularly important for satellites due to their poor accessibility repairs.

When considering the internet, it is anticipated that events as destructive as the Carrington event would result in a widespread internet outage accompanied by physical damage that could not be swiftly repaired. Given our society's heavy reliance on electricity, particularly on the internet, which continues to grow, it is evident that there would be a significant impact on social life both globally and in Austria, rendering life as we know it unimaginable for months to come.[6]

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Support for research efforts and the development of a national strategy

Research activities on this topic are carried out in Austria, for example, at the Institute of Space Research of the Austrian Academy of Sciences, at GeoSphere Austria, at the Graz University of Technology and also in cooperation with operators of critical infrastructures such as the Austrian Power Grid (APG). Austria is well-positioned to significantly contribute to international research in terms of expertise and research resources, such as the Conrad Observatory (Schachinger et al. 2020). Many countries are consolidating and institutionalising their research efforts in this area.

The risk has been significantly underestimated to date.

The findings from such projects are essential for Austria's critical infrastructure. Even if Austria would not be directly affected by the impacts of smaller solar storms due to its geographical location, intense solar storms hold enormous potential for damage, irrespective of their severity rarity. Furthermore, drawing on the observations outlined above from 2012, along with recent research findings (O'Hare et al. 2019), it is suggested that events of the intensity of the Carrington event occur far more frequently than previously believed (approximately once every ten years). Moreover, significantly more severe damaging events may also be possible, suggesting that the risk in Austria could have been substantially underestimated as well. To prevent duplication in research and resource use, it would also be sensible to establish a national strategy for addressing the issue.

6 Details on the consequences of a large-scale internet outage in Austria can be found in Schachenhofer et al 2022.

PROPOSAL FOR FURTHER ACTION

Space weather action plan

In preparation for a national strategy regarding "space weather phenomena," a comprehensive review of the current state of research and research requirements should be conducted. Based on such a study, emergency plans should be developed in collaboration with the State Crisis and Disaster Management (SKKM) and the operators of critical infrastructures. Knowledge from other countries that have addressed this issue for some time (e.g., the USA, Canada, Scandinavia, etc.) can also be applied here. Prevention (such as shielding, early warning systems, and procedures in the event of a disaster) and enhancing international cooperation in this area seem particularly important.

REFERENCES

Hayakawa, H., Cliver, E., Clette, F. et al. (2023), The extreme space weather event of 1872 February: Sunspots, Magnetic Disturbance, and Auroral Displays, The Astrophysical Journal, Vol 959, No 1, DOI 10.3847/1538-4357/acc6cc.

Jaswal, P., Saha, C., Nandy, D. (2023), Discovery of a relation between the decay rate of the Sun's magnetic dipole and the growth rate of the following sunspot cycle: a new precursor for solar cycle prediction, Monthly Notices of the Royal Astronomic Society, 528, L27-L32, ***doi.org/10.1093/mnrasl/slad122.***

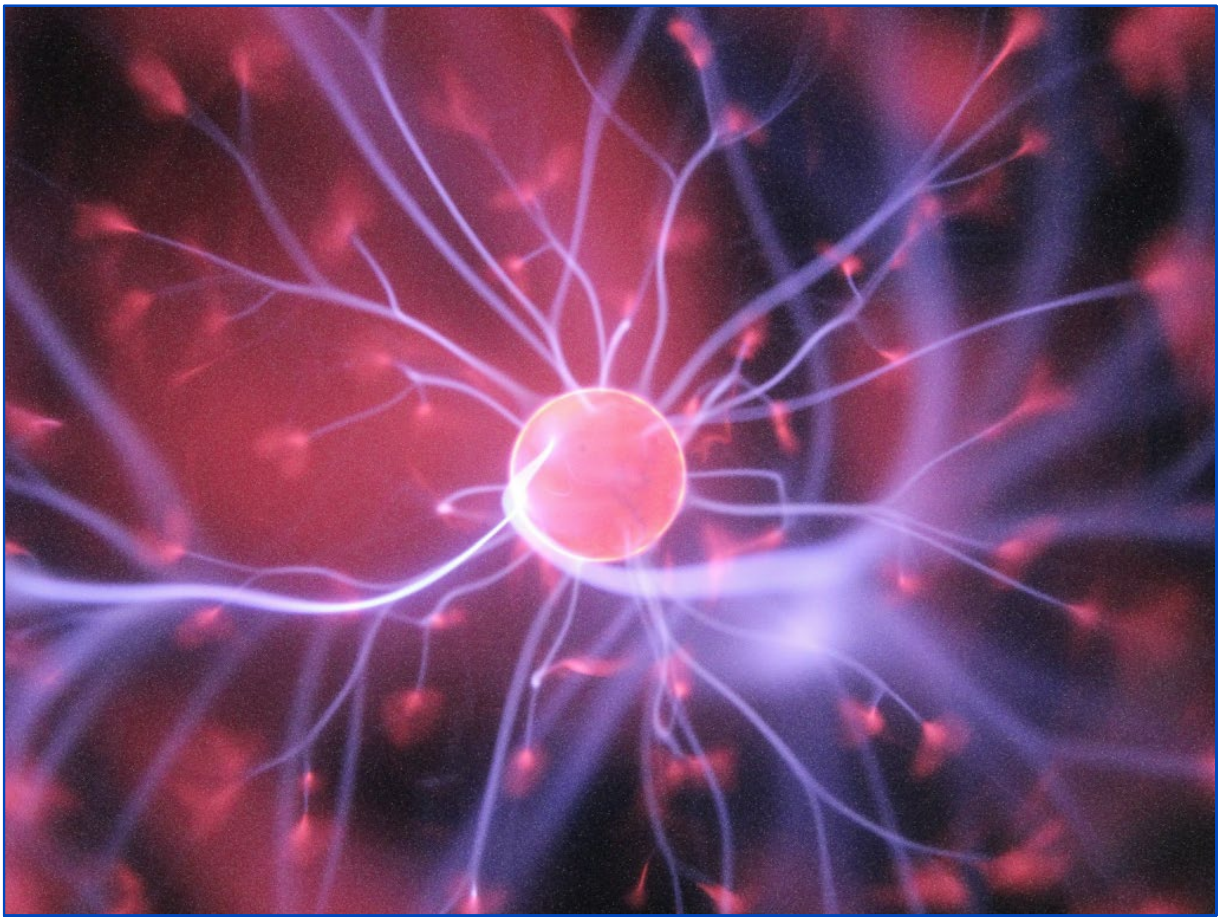
O'Hare, P., Mekhaldi, F., Adolphi, F. et al. (2019), Multiradionuclide evidence for an extreme solar proton event around 2,610 B.P. (~ 660 BC), PNAS 116 (13) 5961-5966, ***doi.org/10.1073/pnas.1815725116.***

Schachenhofer, L., Gronalt, M., Krieger-Lamina, J. et al. (2022), ISIDOR - Folgen einer langandauernden und großflächigen Einschränkung der internetbasierten Dienste und Infrastrukturen (Endbericht), Vienna, doi:/10.1553/ITA-pb-2022-04.

Schachinger, P., Albert, D., Renner, H. et al. (2020), Niederfrequente Sternpunktströme im Übertragungsnetz: Ein Überblick über aktuelle und zukünftige Forschung in Österreich, Tagungsband EnInnov 2020, p. 205f, ***tugraz.at/fileadmin/user_upload/tugrazExternal/4778f047-2e50-4e9e-b72d-e5af373f95a4/files/allg/EnInnov2020_Tagungsband.pdf***.

Strauß, S., Krieger-Lamina, J. (2017), Digitaler Stillstand - Die Verletzlichkeit of the digitally networked society - Critical infrastructures and system perspectives, Vienna, PB 2017/01, ***epub.oeaw.ac.at/ita/ita-projektberichte/2017-01.pdf***.

BIOCOMPUTERS



© CC0 (Hal Gatewood/unsplash)

SUMMARY

The human brain possesses unique abilities that technology can only partially replicate. However, the structure of contemporary AI software, known as neural networks, is modelled on the functioning of neural structures. Efforts are also underway to replicate the physical architecture of the brain in hardware (neuromorphic engineering). Produced from human stem cells or bacterial cells, biological systems, such as ***brain organoids,*** can already be used for computing power, while DNA is a long-term storage medium. Biocomputers present an opportunity to replace resource- and energy-intensive conventional computing systems in the long term, as merely a few grams of cells can deliver significant parallel computing power. However, developments are still in their infancy despite the impressive progress made in recent years.

Alternative Biocomputer

OVERVIEW OF THE TOPIC

The silicon transistor—and, with it, the information age—has fundamentally transformed the lives of billions in just a few decades. One of the cornerstones of the digital revolution is the density of transistors per area on a chip, commonly referred to as Moore's Law, which doubles approximately every 20 months. Silicon technology appears to be gradually reaching its physical limits, as the necessary reduction in circuit size does not seem to be sustainable much longer, even though there is still some capacity for higher transistor densities. Consequently, today's improvements in computer performance are primarily attributable to efficiency gains in software, the development of algorithms for new problems (e.g. machine learning), and innovative machine models (parallel and vector processing) that utilise new hardware more effectively than the old conventional model (serial random-access) (Leiserson et al., 2020).

Neuromorphic systems, organoid intelligence and cells as computers

For this reason, alternative computing technologies are becoming increasingly appealing for future development because of the immense resource and energy demands of conventional data processing. In addition to systems that use quantum effects to process information (see ***Future of quantum technology***), significant progress is being made in various areas that can be summarised under *biocomputers*. These aim to mimic biological structures, such as brain architecture (neuromorphic), or directly utilise biological cells and systems, such as organoids, for computing power.

Neuromorphic computers: Computer architecture based on the brain

One promising approach to alternative computing technologies is utilising the inherent dynamics of individual components, such as memristors. Memristors are components that facilitate complex data processing through their internal electrophysical processes, enabling each element to replace intricate digital circuits. These components support new computer architectures based, for instance, on the brain's structure (neuromorphic systems), allowing for both high energy efficiency and substantial computing capacity (Kumar et al., 2022). In simple terms, neuromorphic systems differ from conventional systems, comprising "neurons and synapses" rather than computing and memory elements, allowing them to process and store data (Aimone et al., 2022). Several approaches are being pursued: artificial synaptic components, such as mem transistors, optical or electrolytic-neural synapses, or ferroelectric components (Seok et al., 2024). Currently, neuromorphic computers are primarily utilised for machine learning and neuroscience applications (often called cognitive applications). Nonetheless, they also hold promise for various other computational challenges, including composition, graph algorithms, constrained optimisation, and signal processing. Overall, neuromorphic computing is considered essential for the next generation of artificial intelligence (AI), as traditional computer systems constrain the potential of AI applications due to their high energy consumption and limited efficiency in information processing (Ajayan et al., 2022).

Organoid intelligence

While neuromorphic computers aim to replicate biological components and functions, an alternative approach involves utilising cell systems to conduct genuine computing operations. ***Organoids***, i.e. highly simplified and miniaturised versions of organs derived from stem cells, are only a few millimetres in size. Specific signalling molecules can trigger the maturation of nerve cells (neurons), which, as a conglomerate, exhibit certain brain functions. These are combined with electronic components and can already perform simple arithmetic operations. Initial experiments show that neuronal cultures can be taught to play video games[1] or to exhibit characteristics of reservoir computing, a specific form of machine learning. In this process, a brain organoid is placed on a high-density multi-electrode array, which facilitates the sending and receiving of information. This configuration has proven successful in speech recognition and more complex, non-linear computations (Cai et al., 2023).

Mini brains derived from human stem cells combined with electronics

Organoid intelligence (OI) describes an emerging, multidisciplinary field of research focused on developing biological data processing through 3D cultures of human brain cells and technologies for brain-machine interfaces (Smirnova et al., 2023). There is also hope that such biocomputing could be faster, more efficient and more potent than silicon-based computers and artificial intelligence while requiring only a fraction of the energy (Smirnova et al., 2023). Some hurdles remain. For instance, more complex and durable brain organoids are required, enriched with cells and genes related to learning. Furthermore, new mathematical models, algorithms, and interface technologies are necessary for improved communication with brain organoids. Additionally, a deeper understanding of their learning and computational processes and how to handle and store the vast quantities of data they will generate is still lacking (Smirnova et al., 2023). As systems become more significant and intelligent, ethical issues become apparent, mainly when organoids exhibit aspects of consciousness. It is also essential to protect cell donors' personal rights and interests (Hartung et al., 2024).

Cells as computers

Genetic circuits and bacterial colonies as neuronal networks

Computer science generates an output from a series of inputs and rules. Biological systems, such as human or bacterial cells, perceive physico-chemical stimuli and respond to them to create a reaction according to their internal configuration, for example, to produce certain proteins. With the help of *synthetic biology* tools such as CRISPR-Cas9, it can be modified to allow the programming of information processing in living matter. (Goñi-Moreno, 2024). Both computational paradigms (digital and analogue) have been implemented in living cells to construct genetic circuits. Many circuits operate based on two discrete, binary-coded levels (digital: 0,1), including memory elements, counters, state machines, toggle switches, digitisers, and highly complex logical functions. Conversely, the analogue paradigm computes with a continuous set of numbers and is suggested as an alternative for tasks that do not require decision-making (Rizik et al., 2022).

Various signalling pathways within each cell facilitate parallel information processing. It is, therefore, also possible to combine multiple circuits in a single cell—much like multi-core processors—resulting in enormous computing capacity (Kim et al., 2019). The communication pathways between biological cells also facilitate new forms of distributed data processing. Drawing inspiration from the structural similarity between artificial neural networks (the basis of AI) and cellular networks, computations can already be conducted in bacterial consortia to recognise patterns (Li et al., 2021). As logarithmic computations can already be performed, an efficient implementation of artificial neural networks using E. coli

[1] *spektrum.de/news/intelligence-neurons-in-the-petri-dish-learning-pong-play/2078757*.

cells is feasible, which is regarded as neuromorphic computing (as noted above) involving cell assemblies (Rizik et al., 2022).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

High demand for low-resource computer systems

The applications of biocomputers are conceivable for various challenges, including environmental remediation, drug research, the production of novel materials, and medical diagnosis. However, considerable improvements are still needed in the manipulation of biological processes, the enhancement of interfaces, and the understanding and measurement of cell states.[2] Obstacles include limited cellular resources, significant random variation in cell responses, and undesirable interactions between synthetic components and host cells (Rizik et al., 2022). Biocomputers possess the potential for high computational power while utilising minimal resources. Research into alternative, low-resource computer systems is crucial given the substantial and ever-increasing energy consumption of conventional IT infrastructure and the simultaneous necessity to significantly reduce greenhouse gas emissions (see ***digitalisation for climate***). Commercialising the first processes and individual components is expected in the next five years. As research into biocomputers remains relatively new, an innovative research and development infrastructure can be established here with foresight, allowing for parallel work on standardisation to simplify system integration.

PROPOSAL FOR FURTHER ACTION

"Embedded ethics" and forward-looking impact assessment

While theory development was the primary focus of cellular computers for decades due to the limited experimental possibilities, the situation is now reversed. New methods such as CRISPR have opened up a vast experimental space, making the expansion of fundamental research in overlapping fields of theoretical computer science and (synthetic) biology worthwhile (Goñi-Moreno, 2024). For organoid intelligence technology to develop responsibly in ethical and social contexts, an "embedded ethics" approach is necessary. This involves transdisciplinary teams of ethicists, researchers, and public members identifying, discussing, and analysing ethical issues, aiming to incorporate these insights into future research and practice (Smirnova et al., 2023).

[2] *radar.gesda.global/sub-topics/cellular-computing*.

REFERENCES

Aimone, J. B., et al. (2022). A review of non-cognitive applications for neuromorphic computing. *Neuromorphic Computing and Engineering, 2*(3), 032003, ***dx.doi.org/10.1088/2634-4386/ac889c.***

Ajayan, J., et al. (2022). Advances in neuromorphic devices for the hardware implementation of neuromorphic computing systems for future artificial intelligence applications: A critical review. *Microelectronics Journal, 130*, 105634, ***sciencedirect.com/science/article/pii/S0026269222002634***.

Cai, H., et al. (2023). Brain organoid reservoir computing for artificial intelligence. *Nature Electronics, 6*(12), 1032-1039, ***doi.org/10.1038/s41928-023-01069-w.***

Goñi-Moreno, Á. (2024). Biocomputation: Moving Beyond Turing with Living Cellular Computers. *Commun. ACM*, 11, ***doi.org/10.1145/3635470.***

Hartung, T., et al. (2024). Brain organoids and organoid intelligence from ethical, legal, and social points of view. *Frontiers in Artificial Intelligence, 6*, ***frontiersin.org/articles/10.3389/frai.2023.1307613***.

Kim, H., et al. (2019). A CRISPR/Cas9-based central processing unit to program complex logic computation in human cells. *Proceedings of the National Academy of Sciences, 116*(15), 7214-7219, ***pnas.org/doi/abs/10.1073/pnas.1821740116.***

Kumar, S., et al. (2022). Dynamical memristors for higher-complexity neuromorphic computing. *Nature Reviews Materials, 7*(7), 575-591, ***doi.org/10.1038/s41578-022-00434-z***.

Leiserson, C. E., et al. (2020). Plenty of room at the Top: What will drive computer performance after Moore's law? *Science, 368*(6495), eaam9744, ***science.org/doi/abs/10.1126/science.aam9744***.

Li, X., et al. (2021). Synthetic neural-like computing in microbial consortia for pattern recognition. *Nature Communications, 12*(1), 3139, ***doi.org/10.1038/s41467-021-23336-0***.

Rizik, L., et al. (2022). Synthetic neuromorphic computing in living cells. *Nature Communications, 13*(1), 5602, ***doi.org/10.1038/s41467-022-33288-8.***

Seok, H., et al. (2024). Beyond von Neumann Architecture: Brain-Inspired Artificial Neuromorphic Devices and Integrated Computing. *Advanced Electronic Materials, n/a*(n/a), 2300839, ***doi.org/10.1002/aelm.202300839.***

Smirnova, L., et al. (2023). Organoid intelligence (OI): the new frontier in biocomputing and intelligence-in-a-dish. *Frontiers in Science, 1*, ***frontiersin.org/journals/science/articles/10.3389/fsci.2023.1017235***.

NEGATIVE EMISSION TECHNOLOGIES

© CC0 (Wander Fleur/unplash)

SUMMARY

Negative emissions: no simple solutions in sight

Even if measures to reduce greenhouse gases take precedence, additional methods to remove CO_2 (negative emission technologies, NET) will likely become increasingly essential to limit global warming to below 2°C. Nonetheless, their implementation must be strictly aligned with sustainability principles. Nonetheless, their implementation must be strictly aligned with sustainability principles. Even if some approaches have the potential to sequester significant amounts of carbon in the long term, detailed adaptation to local conditions is essential for their implementation to ensure they function effectively and do not have the opposite effect. Alongside land-based processes such as afforestation and biochar, the emphasis is on various carbon capture and storage/utilisation processes. Most NETs are land-intensive, making scaling difficult, while others demand substantial energy and resources. Additionally, other environmental risks must be considered, such as impacts on biodiversity and the potential reversibility of storage, alongside the interaction between different technologies.

OVERVIEW OF THE TOPIC

Decisive decade for limiting global warming

This decade will largely determine whether global warming can be restricted to 1.5 °C or 2 °C. Immediate and substantial reductions in greenhouse gas emissions are necessary across all sectors to achieve net zero CO_2 emissions. If global warming surpasses a specific threshold, negative emissions—namely, carbon dioxide removal (CDR)—will be essential to reduce the temperature and maintain adherence to the restricted carbon budget over the long term (see also ***geoengineering***). This raises major concerns about feasibility and sustainability (IPCC, 2023). In particular, non-CO_2 emissions from agriculture (methane, nitrogen dioxide, fluorinated gases), emissions from specific industrial processes, and residual emissions from the energy sector are classified as difficult to avoid; removal processes should offer a solution in this context (IPCC, 2022; Ragwitz M., 2023).

NET only affects the climate, if CO_2 is stored in the soil or products in the long term

Natural and technical processes for removing greenhouse gases from the atmosphere include biological, physical and chemical processes. These only affect the climate if the removed gases are not released back into the atmosphere over the long term. Land-based processes store CO_2 in vegetation or the soil; these include afforestation, climate farming (carbon farming), or biochar production (also referred to as biochar). Other processes focus on the chemical and physical capture of CO_2: waste gases, such as after biomass combustion for energy production (bioenergy, BE) or directly from the air (direct air, DA). The captured CO_2 is either stored in geological formations (CCS, Carbon Capture and Storage) or used industrially (CCU, Carbon Capture and Utilization). Many of the NETs under discussion are land-intensive, competing with food and animal feed production or adversely affecting nature conservation, such as biodiversity loss. Although extraction directly from the air requires less land, it is highly energy- and resource-intensive. Other NETs, such as ocean fertilisation and ocean alkalisation, are highly controversial due to their significant environmental risks and are also of limited relevance to Austria.

CCUS - Capture and utilisation of CO_2: new technologies, old hopes

The market for *carbon capture, utilisation, and storage* (CCUS) technologies has demonstrated significant growth in recent years (Itul, 2023). CO_2 can be utilised in various processes in the chemical and petroleum industries (urea production, fuels), the food industry (refrigeration, processing), mineralisation (baking powder, CO_2 concrete curing), energy production (heat pumps), energy crop production (algae cultivation), pharmaceuticals (chemical synthesis), the pulp and paper industry (injection into metal casting) and other areas (e.g., water treatment) (Peres et al., 2022). Given the industry's high demand for CO2-neutral carbon, competition between CCU and CCS processes is anticipated to rise (Ragwitz M., 2023). Currently, most CO2 capture processes rely on absorption, adsorption, membranes, and chemical recycling. These processes are utilised in agriculture and the conversion of CO2 into fuels (catalytic processes), chemicals (photocatalytic processes), polymers, and building materials (Peres et al., 2022). New processes for capturing and processing CO_2 have been tested in the chemical industry to produce valuable products such as ethanol, polyurethane, urea or pharmaceuticals; the technical development of the processes has been partially completed. However, the commercialisation of these processes is still in its early stages (see also ***CO_2 as a resource***).

Currently, marginal contribution to climate protection

Many products arising from these processes still cannot compete economically with conventional products or meet the necessary product standards. Additionally, a standardised method is absent to ensure that the technologies consistently reduce CO_2 emissions overall (GAO, 2022). A genuine contribution to negative emissions does not seem tangible at present. A study examining 74 CCU processes concluded that only four possess the capacity to significantly contribute to achieving the Paris climate targets, including cement-free building blocks made from steel slag (de Kleijne et al., 2022). Another study examining various products derived from CO_2 also indicates that their contribution to CO_2 removal is minimal. For instance, in synthesising urea, crucial for the energy-intensive fertiliser industry, only 0.3% of the annual CO_2 emissions worldwide can be utilised for a global production volume of approximately 150 million tonnes (Richers & Schütz, 2022).

BECCUS - Bioenergy with carbon capture and storage/utilization

In processes for *bioenergy production with carbon capture and storage and/or utilisation* (BECCS, BECCU), CO_2 is fixed by plants via photosynthesis. The biomass produced in this way is burned to generate energy, and the resulting CO_2 is captured and stored in the soil. The primary limiting factors are land consumption for biomass production and competition with other types of biomass usage. The type of biomass processed is also crucial for a negative emissions balance (see biochar). Potential environmental impacts include deforestation, forest degradation, and challenges for preserving biodiversity, depending on the type of vegetation used (Ragwitz M., 2023).

Direct Air CCUS - technical progress, old risks

Direct air capture is a process that chemically captures CO_2 from ambient air (DACCS, DACCU) and then stores it geologically or uses it for industrial purposes. Land consumption is considerably lower than that of the other NETs. However, given that the CO2 content of the atmosphere is 100 to 300 times lower than that of point sources, a substantial amount of energy is required, leading to very high costs of $600 to $1,000 per ton of CO_2.[1] This energy must be generated climate-neutral, as this is the only way to achieve negative emissions. In addition, considerable resources are required to produce this (large-scale) technology. There is also the risk of technological lock-in, that is, dependence on a large-scale technology in case of shutdown or failure, resulting in serious climate consequences due to insufficient implementation of alternative emission reduction methods. In general, most of the DACCS/BECCS processes have not yet been tested on an industrial scale and, therefore, entail high economic efficiency and sustainability risks.

Accelerated weathering - few possibilities in Austria

Similar to DACCS, enhanced rock weathering relies on chemical CO_2 binding. Crushed silicate and/or carbonate minerals are added to the soil, where they bind CO_2 through the natural weathering process due to the significant surface area of the rock flour. This process is particularly pertinent for warm and humid agricultural systems, which is why the potential for Austria is estimated to be quite low; the EU represents only 3.6% of the global potential. In addition, energy costs and the associated greenhouse gas emissions from extraction, grinding, transportation and soil application are often not considered when estimating the reduction potential of accelerated weathering (Kraxner, 2024).

Reforestation: Forest as a carbon sink

During *reforestation*, the growing trees remove CO_2 from the atmosphere for longer periods. The effect is heightened if the wood is subsequently used as a

[1] *weforum.org/publications/carbon-dioxide-removal-best-practice-guidelines/*.

building material, thereby storing the carbon it contains in buildings for longer. However, fire and pests pose significant risks to the storage period of carbon in forests; an increase in such disruptive events is anticipated in the future (see Forest fire: *combating and restoring*). The land requirement is also substantial, and competition exists with other uses, such as agriculture. However, afforestation is likely to enhance soil quality and water retention capacity. There may be advantages and disadvantages regarding biodiversity, contingent on the tree species planted and the previous vegetation. The albedo effect should not be overlooked, namely the extent to which forest areas reflect sunlight. They are darker than other types of land use or snow and ice surfaces and consequently reflect less sunlight, which can contribute to warming (Ragwitz M., 2023). It is generally assumed that afforestation in Austria, in the medium term, will aid in achieving the established climate targets by 2050 and provide an opportunity to develop other technologies to reduce emissions (Kraxner, 2024).

Biochar, biochar, biochar: pyrolytic carbon capture and storage

Under specific conditions, the production of biochar and its incorporation into soils can sequester substantial amounts of carbon and retain it over the long term, as biochar can remain stable in the soil for centuries. Biochar can serve as a carbon sink with the appropriate starting materials (residues at the end of the utilisation chain) and pyrolysis technology. The technology is mature (TRL, technology readiness level 8-9) and is regarded as a promising solution by the Intergovernmental Panel on Climate Change (Soja, 2022). Residual materials such as green waste, pomace, or grain husks— typically diverted for composting or fermentation— are suitable (up to 60% of the carbon content escapes into the atmosphere as CO2 or methane). Worldwide, biochar can potentially eliminate up to 3 gigatons of CO2 equivalents from the atmosphere each year (Lehmann et al., 2021), corresponding to almost 10 % of global emissions. There are also other positive effects: Soil quality improves in terms of structure, drainage capacity, and organic matter content; in agriculture, yield increases are feasible due to the enhanced availability of nutrients and water; furthermore, soil remediation occurs as biochar absorbs pollutants and reduces phosphorus leaching nitrate. The enrichment of agricultural soils with biochar is a very old technique that has been used for thousands of years in many regions of the world (Amazon basin, but also in Europe). The production of biochar by pyrolytic carbonisation in the absence of air at 400-1,000 °C also produces toxic and flue gases, which, however, are captured in modern plants, burned and used for heat or electricity production. The European Biochar Directive (EBC) (or ÖNORM S 221) regulates pyrolysis technology, which biomass may be used for production, and which properties biochar must have (e.g., PAH (polyaromatic carbons) and heavy metal content[2]). EBC-certified biochar has been permitted in Austria by decree[3] for some time, but has only been allowed in the EU as an additive in fertilisers and compost since 2022. Ten EBC-certified farms have been developed throughout Austria , but widespread use in suitable soils (such as the Weinviertel and Waldviertel regions) has not been implemented. Biochar is also used as an additive in building materials such as concrete to make it CO_2-neutral or negative.[4]

2 *european-biochar.org/en/*.
3 *bio-austria.at/a/bauern/pflanzenkohle/*.
4 *burgenland.orf.at/stories/3180987/*.

Carbon sequestration in the soil

Carbon can also be stored in the soil through land management practices, such as agroforestry systems. While these practices are also land-dependent, food and animal feed production remain feasible. In addition to carbon storage, there are other positive effects on soil, air, and water quality; however, uncertainties exist, such as a potential increase in NO_2 emissions.

Peatlands - little potential for negative emissions, but important for avoiding greenhouse gases

Drained peatlands release a lot of greenhouse gases (up to 5 % of human greenhouse gases) as they rot, so the rewetting of peatlands is often discussed in connection with CO_2 storage. However, this is merely a CO_2 avoidance strategy—albeit an important one—not negative emissions in the narrower sense. As the peat body grows too slowly for this, the CO_2 removal potential is estimated to be low (Ragwitz M., 2023).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Controversial: techno-economic performance and impact on reduction strategies

Technological progress and the widespread failure to reduce greenhouse gas emissions are reviving the debate on negative emission technologies. The capture of CO_2 from the atmosphere or directly from industrial point sources, such as cement plants, and its recycling into industrial processes is becoming increasingly appealing to companies. Regardless of this, the question arises regarding the actual potential of NET against the backdrop of sustainability goals, the potential side effects of NET usage on public discourse concerning emission reductions, and how these can be managed intelligently. The Austrian carbon management strategy, scheduled for presentation in mid-2024, aims to provide greater clarity in addressing natural and technical greenhouse gas sinks alongside difficult-to-avoid residual emissions CCUS. [5]

PROPOSAL FOR FURTHER ACTION

Despite new technologies: No simple solutions on the horizon

The potential of various NETs should be examined specifically for the Austrian context regarding predicted costs, potential, duration of carbon sequestration, possible environmental impacts, technological maturity, and social acceptance. A forward-looking impact analysis of the interactions between the respective processes, the energy system, agriculture, and forestry should be conducted. Furthermore, analysing the hope-driven discourse concerning new CCUS technologies is essential to distinguish between myths and facts regarding these technologies.

[5] *bmf.gv.at/themen/klimapolitik/carbon_management.html*.

REFERENCES

de Kleijne, K., et al. (2022). Limits to Paris compatibility of CO_2 capture and utilisation. *One Earth*, *5*(2), 168-185.

GAO (2022). *Decarbonisation: Status, Challenges, and Policy Options for Carbon Capture, Utilization, and Storage*, **gao.gov/products/gao-22-105274**.

IPCC (2022). Summary for Policymakers. In J. S. P.R. Shukla, et al. (eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY, USA.

IPCC (2023). Climate Change 2023: Synthesis Report. Summary for Policymakers, **de-ipcc.de/358.php**.

Itul, A., et al. (2023). *Clean Energy Technology Observatory: Carbon capture storage and utilization in the European Union - 2023 Status Report on Technology Development, Trends, Value Chains and Markets.*

Kraxner, F., et al. (2024). Chapter 5: Mitigation of climate change. In R. Jandl, et al. (Eds.), *APCC Special Report: Land Use and Climate Change in* (S. 275). Springer Spektrum: Berlin/Heidelberg. S. 275-338.

Lehmann, J., et al. (2021). Biochar in climate change mitigation. *Nature Geoscience*, *14*(12), 883-892, **doi.org/10.1038/s41561-021-00852-8.**

Peres, C. B., et al. (2022). Advances in Carbon Capture and Use (CCU) Technologies: A Comprehensive Review and CO_2 Mitigation Potential Analysis. *Clean Technologies*, *4*(4), 1193-1207. doi:10.3390/cleantechnol4040073.

Ragwitz M., et al. (2023). *Scenarios for a climate-neutral Germany. Technology transformation, consumption reduction and carbon management (analysis). Publication series "Energy Systems of the Future" (ESYS)*, **doi.org/10.48669/esys_2023-3.**

Richers, U., & Schütz, R. (2022). *Possibilities and climate-relevant effects of the material use of carbon dioxide*. Karlsruhe: KIT Scientific Publishing, **ksp.kit.edu/site/books/m/10.5445/KSP/1000143474/**.

Soja, G. (2022). *Biochar for CO_2 removal from the atmosphere. CCCA Fact-Sheet #38*, **ccca.ac.at/fileadmin/00_DokumenteHauptmenue/02_Klimawissen/FactSheets/38_pflanzenkohle_202209.pdf.**

A NON-ENGLISH AI LARGE LANGUAGE MODEL

© CC0 (Volodymyr Hryshchenko/unsplash)

SUMMARY

The launch of ChatGPT and other language models (Large Language Models - LLMs) generated excitement and high expectations for positive disruptions in business and society. These models are mainly based on training data in US English. This has technical implications for the quality in other languages and cultural influences, as the language structures in English and German, for instance, differ. Additionally, the application has legal issues (e.g., data protection compliance). Economic concerns also arise regarding the confidentiality of business secrets. The political aspect involves an even greater dependence on global corporations and further eroding digital sovereignty. Therefore, the objective could be to develop an open language model based on the German language, with participation from Austria and Switzerland to harness its potential fully.

USA and China dominate the market

Where is Europe?

OVERVIEW OF THE TOPIC

LLM with disruptive potential

Since the release of ChatGPT in autumn 2022, there is no doubt that large language models (LLMs) represent a significant leap forward in the development of artificial intelligence systems. It remains to be seen to what extent the hype surrounding large language models (such as ChatGPT, Microsoft Bing, Google Bard, BLOOM, and others) is justified and whether they will genuinely be disruptive, leading to corresponding upheavals in the economy and society.

The primary use of US English training data for the existing models leads to technical limitations regarding the quality of use and output in other languages. Moreover, cultural influences are present through forms of expression, linguistic logic, and legal and economic policy aspects. Two distinct development strategies are now foreseeable: one aims to create the largest and most effective model, while the other focuses on being specifically tailored to the demands of economic reality (e.g., customer processes) (Bomke 2024). From a European perspective, the second strategy could also address other problematic peculiarities of existing models, such as data protection issues and copyright infringements.
All major language models currently under discussion are predominantly based on US English training data. This structure within the training data has technical implications for the quality of results in other languages (Nicholas/ Bhatia, 2023). Texts must be broken down into machine-processable units known as tokens to create the models. A token can be regarded as a text that processes a model simultaneously. In German, a token could be a word, a punctuation mark, a part of a word, or even a letter. A token can have different lengths in different languages, e.g., in English, it can often be a word, while in languages such as Chinese, it is often a character.[1] This work is done by software programs known as "tokenisers". If these are trained in English, they utilise the structural features of the English language. As other languages possess different structural features, words are split and distributed across several tokens. A proven rule of thumb for the ratio is, for example, in English: 1 word ≈ 1.3 tokens; in German: 1 word ≈ 1.8 tokens; in Spanish: 1 word ≈ two tokens; and in French: 1 word ≈ two tokens.[2] Since all LLMs have a (technical) token limit[3] (and the providers' services are usually billed by token), the application of tokenisers trained in English to training data in other languages means that fewer texts (per prompt) can be produced and, above all, linguistic units of meaning are not well represented. Additionally, Ali et al. (2023) demonstrate that multilingual tokenisers trained in the five most common European languages (German, English, Spanish, French, and Italian) need a threefold increase in vocabulary compared to English. When English-language tokenisers are used to train multilingual LLMs, it has been shown that this leads to a sharp deterioration in performance and additional training costs of up to 68%. A research paper by Meta (Touvron et al. 2023) also found that a "training corpus with a majority in English means that the model may not be suitable for use in other

US English dominates the training data - with implications for the model's effectiveness.

---

1 *online-marketing-leipzig.de/das-tokenlimit-ein-einstieg-fuer-anfaenger-mit-tipps-zum-prompting/*.
2 *deinkikompass.de/blog/openai-gpt-token-guide*.
3 E.g., GPT 32,765, Llama2 2,048, Claude_2 100,000 and PaLM 8,000 see *empolis.com/blog/entfesselte-llms-trotz-token-beschraenkung/*.

languages." And "(m)ost data is in English, meaning that Llama 2 will perform best for English-language use cases." Almost 90% of the pre-training data is in English. Other languages such as German, French, Chinese, Spanish, Dutch, Italian, Japanese, Polish, Portuguese and other known languages make up less than 2%.[4]

Cultural, ethical and legal problems

Alongside the technical effects, cultural characteristics are primarily mirrored in the training data and, consequently, in the models' responses (see Ramesh et al. 2024). With the predominance of US English training phrases, US formulations, ways of thinking, ethical guidelines, and so forth are also conveyed, which may create a tendency to standardise forms of communication globally. Besides the potential cultural effects, legal issues in the application have become particularly evident. The training data is often not disclosed. Many models were trained using data from the internet, sometimes from social media platforms. For numerous current models, it remains unclear where the data originates, whether personal data has been processed, and whether the data subjects involved have been asked for their consent, that is, whether it can be used in accordance with the GDPR and, consequently, essential European fundamental values. Furthermore, it is also uncertain whether copyright infringements have occurred for many data.

Economic considerations

There are also economic considerations, as it is not always clear whether, for instance, trade secrets could be disclosed through the use of large language models. Nevertheless, the economic potential of large AI language models is regarded by many as promising. Their adaptability to a wide range of industry- and company-specific requirements and their high reusability opens up countless use cases. A publication from the German Academy of Science and Engineering (acatech) employs practical examples to demonstrate the opportunities and challenges posed by language models. The authors advocate for establishing an open, commercially viable data set in German that aligns with European values and regulations, thereby supporting the development of language models in Germany (Löser 2023).

Geopolitics and digital sovereignty

In addition to the technical, legal, cultural and economic issues mentioned above, there is also the political dimension. Using models produced primarily in the USA and China leads to even greater dependency on the large American and Chinese technology companies, which seems counterproductive regarding the digital sovereignty we strive for.

Goal: an open language model based on the German language

The aim is, therefore, to develop an open language model based on European, non-English language[5] and thus ensure that linguistic as well as cultural and legal characteristics of the German and European language area are considered. It also seems important that in addition to Germany, both Austria and Switzerland participate in the development (and Liechtenstein and Luxembourg if interested) to reflect all varieties of the German language and to be able to cover national differences (e.g. in legal requirements).

[4] *slator.com/meta-warns-large-language-model-may-not-be-suitable-non-english-use/*.

[5] This means using training data from the five largest European languages or specifically from the German language area and developing and using suitable tokenizers for the European languages or the German language.

Developing a German language model should be integrated into a European strategy, as a robust European AI industry is crucial not only for purely economic reasons. Hirschbrich (2024) emphasises that strong AI competition on equal terms among a diverse array of providers from numerous democratic nations should also be pursued for geopolitical reasons. A European AI would embody European values and our legal and ethical standards.

First initiatives

Projects are underway to build general German language models (Aleph Alpha, Fraunhofer with OpenGPT-X, etc.)[6] and specific models for the clinical sector (Idrissi-Yaghir et al. 2024). These are also considered the most common European languages, vital for the aforementioned European positioning in the global market. Another initiative is Laion,[7] which has adopted the free Llama model for German, which is primarily intended to break the English-language dominance (Grüner 2023). The advantages of a German-language model could be that the models can be more efficient. This also positively impacts the reduced hardware requirements (e.g., the fast graphics cards necessary for AI models) and the increased operating speed. Targeted, pre-selected data can enhance quality, allow a focus on specific subject areas, and provide optimal user guidance with awareness of the results. Furthermore, it would lead to lower operational costs (see Meffert 2023).

RELEVANCE OF THE TOPIC FOR THE PARLIAMENT AND FOR AUSTRIA

Promotion of the Austrian AI landscape, as well as linguistic and economic independence

Developing a language model based on non-English training data can confer technical, cultural, and economic advantages. To maintain the distinctions between the languages, including between the German and Austrian varieties within the model, and to incorporate Austria as a location in this development, it seems necessary to consider potential collaborations to ensure that genuinely Austrian content can also be integrated into the training data. The Austrian AI landscape[8] can certainly make important contributions to this. Last but not least, references should be made to establish the new Cluster of Excellence on Bilateral AI.[9]

PROPOSAL FOR FURTHER ACTION

As shown, the language used for training large language models makes a difference. The model also learns cultural and value biases through the language.

TA study on the language and cultural bias of LLM

Parliament could commission a TA study to determine, based on existing findings regarding the influence of different languages on the performance of language models, the extent to which it would be appropriate for the Austrian economy, consumers, and citizens to develop their model. Following the results, a cost-

6 *youtube.com/watch?v=IoBSYIOarwM*, *.aleph-alpha.com/de/*.
7 *laion.ai/blog/leo-lm/*.
8 *aiaustria.com*, *ai-landscape.at*, *asai.ac.at*, *brutkasten.com/artikel/nxai-ai-experte-sepp-hochreiter-gruendet-neues-ki-startup*.
9 *fwf.ac.at/aktuelles/detail/oesterreichs-naechste-exzellenzcluster-starten*.

benefit analysis should be conducted to ascertain the advantages of Austria's participation in relevant European activities, particularly in Germany.

REFERENCES

Ali, M., Fromm, M., Thellmann, K. and 18 Co-Authors, 2023, *Tokenizer Choice For LLM Training: Negligible or Crucial?*, ***arxiv.org/pdf/2310.08754.pdf.***

Bomke, L., 2024, Intel, Allianz and Unilever rely on Silo AI, *Handelsblatt, weekend April 5/6/7, 2024,.*

Grüner, S., 2023, ***Riesigesgolem.de/news/laion-riesiges-sprachmodell-fuer-deutsch-trainiert-2309-178081.html*** Sprachmodell für Deutsch trainiert, *golem.de*.

Hirschbrich, M., 2024, Es braucht einen KI-Wettbewerb auf Augenhöhe, *Der Standard*, 26.3.24, ***derstandard.at/story/3000000212698/warum-es-einen-ki-wettbewerb-auf-augenhoehe-braucht***.

Idrissi-Yaghir, A., et al, 2024, *Comprehensive Study on German Language Models for Clinical and Biomedical Text Understanding*; ***arxiv.org/pdf/2404.05694.pdf.***

Löser, A., Tresp, V. et al, 2023, *Developing and applying large language models - approaches for a sovereign approach*, Munich.̈: Whitepaper from the Learning Systems Platform, acatech, ***doi.org/10.48669/pls_2023-6.***

Meffert, K., 2023, Artificial intelligence: German texts in AI language models *Dr. DSGVO Blog*, ***dr-dsgvo.de/kuenstliche-intelligenz-deutsche-texte-in-ki-sprachmodellen.***

Nicholas, G. and Bhatia, A., 2023, *Lost in Translation: Large Language Models in Non-English Content Analysis*, commissioned by: Center for Democracy & Technology: cdt Research, ***cdt.org/insights/lost-in-translation-large-language-models-in-non-english-content-analysis/***;
also published as: ***arxiv.org/abs/2306.07377.***

Ramesh, K., Sitaram, S. and Choudhury, M., 2024, *Fairness in Language Models Beyond English: Gaps and Challenges*; 2024], ***arxiv.org/pdf/2302.12578.pdf.***

Touvron, H., Martin, L. and Kevin Stone et al, 2023, Llama 2: Open Foundation and Fine-Tuned Chat Models, *Meta*, ***ai.meta.com/research/publications/llama-2-open-foundation-and-fine-tuned-chat-models/.***

3 CURRENT EPTA STUDIES

The European Parliamentary Technology Assessment (EPTA)[1] is a network of institutions producing technology assessment studies for their respective parliaments. The network currently comprises 25 members globally, including numerous European countries and members from the USA, Latin America, and Asia. The EPTA database[2] was assessed for this monitoring report to identify studies relevant to the Austrian parliament. The search for project reports and policy briefs from May 2023 to May 2025 yielded 273 entries. These documents were then evaluated based on the relevance criteria outlined in section 1.2, where the specific relevance to Austria was considered.

Evaluation of the EPTA database revealed a total of 227 studies for the reporting period

The following topics have recently been discussed internationally[3]:

Recent topics at a glance

- *Information technologies*: 6G mobile communications; Wearables and disease prevention; Dynamic digital twins; Quantum computers; Long-term archiving of data (see also AI); Biometric data; Digital exclusion; Digital textile labelling; Digital Legacy; Metaverse; Big Data, AI and Football; Digitalization and Culture; Immersive Technologies; Critical Municipal Infrastructures; Digital Twins; Post-Quantum World; Social Implementation of IT; Cybersecurity; Online Advertising; Digital Age Discrimination; Data Mining; Digital Games in Education; Languages and Streaming Platforms; Workforce data analytics; Zero trust architectures, Alternative data storage, Blockchains, Augmented reality, Quantum computing (and data security), Data centres, Data mining, Digital twins, Metaverse; Chat GPT, AI and health, AI and governance, Fair use of data, AI and agriculture/food production
- *Artificial intelligence*: Energy security and AI; AI and mental health; AI and society; After ChatGPT; Large Action Models; AI hardware in Europe; Creative industries; Resources and climate change; Deepfakes; Generative AI/Norway; Social consequences; Women and AI; Rare cancers; Forensics; Generative AI; Responsible use of AI; AI modelling of natural disasters; AI awareness; Policy options; AI and genetic analysis
- *Biosciences:* Gene drives; Synthetic biology; Neurotechnology
- *Democracy/domestic affairs:* Civil defence; Social media, Freedom of expression and national security; Cyber security and elections; Regulation of opinion polls; Censorship of Russian media in the EU; Trust in the media; Participation in elections in the media; Participation in elections; E-voting; Hate online; Surveillance technologies, algorithms and opinion-forming; Automated speech/face/voice recognition.
- *Energy*: Final disposal of nuclear waste; Fusion reactors; Energy security and AI; Electrification of the economy; Large-scale energy storage; Nuclear energy; Energy independence; Strategic autonomy in nuclear energy; Fusion energy; Demand side response; Equity in the energy transition; Energy storage; Economical energy consumption; Energy production in space; Fusion energy; Zero energy districts; Heat pumps; Advanced batteries, Green hydrogen, Energy

[1] *eptanetwork.org*.
[2] ***eptanetwork.org/database/policy-briefs-reports.***
[3] Partly multiple assignments.

consumption of ICT infrastructure, Intermediate energy storage, Fusion energy

- *Health/Medicine:* Health in schools; Psychedelic-assisted therapy for mental health; Water fluoridation and dental health; Rehabilitation after sick leave due to stress-related disorders; Plastics and health; Wearables and disease prevention, AI and mental health; Bioprinting in medicine; Speed limits and health; Rare diseases; Industrial air pollution; AI and Cancer; Covid-19/Luxembourg; Covid-19 Vaccine consequences; Autism and Learning Disabilities; Psychiatric Drugs; Heat and Public Health; Mental privacy in neuroscience; Systemic causes of health; Prenatal supplementation; Access to healthcare; Origins of pandemics; AI and genetic analysis; Embryo models from human stem cells; New tobacco and nicotine products; Cost of smoking; Rare diseases and biosensors; Childhood food insecurity; Indoor air quality; Health and climate change; Use of AI, Brain-computer interfaces, Technologies for the disabled, Ageing research, Artificial cells, Electromagnetic fields, Causes of pandemics
- *Nutrition:* Artificial meat; Innovations in food technology; Cybersecurity in the food industry; Meat and dairy substitutes; Highly processed foods
- *Economy*: Hybrid working; AI hardware in Europe; Bioprinting in medicine; Clean technologies for critical raw materials; Supply of semiconductor chips; Data gaps in the textile industry; Textile industry; Critical raw materials; Copper shortage; Alternative protein sources; Material sciences; Online advertising; Future of horticulture; Collaborative industrial robots; Online advertising; Innovation in the construction industry, Abolition cash, Innovation-critical metals and minerals, Urban timber construction
- *Military:* hypersonic weapons; innovative military planning; anti-drone technologies
- *Transport:* Speed limits and health; Air taxis; Self-driving cars; Transportation
- *Environment/climate*: Urban heating and cooling; Natural forest conversion in times of climate change; Ocean policy; Strategies for achieving net-zero CO_2 emissions; Space debris and satellites; Reducing emissions in the primary industry; Decarbonisation of the aviation sector; Biodiversity governance; Water/Blue Economy; Rock weathering for CO_2 removal; innovative fishing methods; food waste; Green Deal and Horizon Europe; plastic waste; recycling; CO_2 tax; space weather; micro-water pollution; ocean warming; water scarcity; options for Net Zero; CO_2 offsets; Climate education; Fertilizers of the future; Freshwater habitat restoration; Future of horticulture; Wildfires; Transport resource planning; Plastic recycling; Plastic pollution; Decarbonization of fisheries; Climate labelling; Sustainable cooling; New solutions to tackle the climate crisis; Impact of climate change on economy and society; Future of cycling; Food production and environment; Health and climate change; Plant biosecurity; Satellites, Persistent chemicals, Wastewater monitoring, Water management, Energy efficiency for old buildings, Green Deal, Plant breeding, Energy consumption of ICT infrastructure
- *Other:* Monitor scientific freedom (EU); Monitor practice-orientated research (Netherlands); Crisis radar; Housing market/England, Foresight/critical infrastructures Infrastructure; Spaceport in Germany; Defense Policy/ Luxembourg; Protection of Academic Freedom; Academic Freedom; Complex Systems; Generational Change; Space Policy; Food, Energy and Technological Security; Open, Strategic Autonomy for Crisis Management; Effects of Generational Change; Non-medical Bioelectronics

The following international studies are proposed for closer examination by the Austrian Parliament due to their relevance for Austria, their topicality and because there are no specific studies for Austria yet:[4]

Topic	Title of the study	Country; Institution	Year
Bioprinting in medicine	Bioprinting for medical applications	GER, TAB	03/2025
Heating and cooling generation	Integrated municipal heating and cooling generation	GER, TAB	03/2025
Space debris	What if orbital debris destroyed satellites?	EU, STOA	03/2025
Critical raw materials	What if we use clean tech to source critical raw materials within the EU? What if we use clean tech to source critical raw materials within the EU?	EU, STOA	03/2025
Speed limits 20 mph	Speed limits and zones: public health impacts UK,	UK, POST	03/2025
Air taxis	Air taxis - manned, all-electric vertical take-off and landing vehicles Germany	GER, TAB	03/2025
Mental Health and AI	AI and Mental Healthcare - (I) ethical and regulatory considerations; (II) opportunities and delivery considerations	UK, POST	01/2025
Energy security	Energy security and AI	UK, POST	12/2024
Telecommunications	6G mobile technology	UK, POST	12/2024
Social Media	Social Media, Freedom of Expression, and National Security	NOR, NBT	11/2024
Protein sources	Alternative protein sources for food and feed	EU; STOA	04/2024
AI modelling of extreme weather events	Artificial Intelligence in Natural Hazard Modeling: Severe Storms, Hurricanes, Floods, and Wildfires	USA, STAA	12/2023
Digital age discrimination	Digital inequality and older adults: an age-wise digital divide	ES, CAPCIT	2023
Forensic technology	Forensic Technology: Algorithms Offer Benefits for Criminal Investigations, but a Range of Factors Can Affect Outcomes	USA, STAA	01/2024
Horticulture	Future of Horticulture	UK, POST	10/2023
Generative AI	Generative AI brings new data privacy challenges	NOR, NBT	02/2024
Immersive technologies	Immersive Technologies	N, Rathenau	11/2023
Materials science	Materials Science: The State of the Art and Future Options	JP, RLRB	03/2024
Space weather	Space Weather	F, OPECST	11/2023
Recycling	Strategies and instruments for improving the use of recyclates. With case studies on plastic packaging, electrical appliances and building materials	GER, TAB	03/2024
Fertiliser use	The future of fertiliser use	UK, POST	01/2024
AI in education	Use of artificial intelligence in education delivery and assessment	UK, POST	01/2024

[4] There is a possibility that the Austrian Parliament will commission (if necessary, the translation and) an abridged version and transfer to Austrian conditions of the above-mentioned studies by EPTA institutions.

Topic	Title of the study	Country; Institution	Year
Traffic resource planning	What if the problem with cars was not their method of propulsion?	EU, STOA	10/2023
Emission reduction/ raw materials industry	Alternative technology paths for reducing emissions in the primary industry	GER, TAB	2024/05
Artificial intelligence and climate change	Artificial intelligence, scarce resources and climate change	N, NBT	2024/05
Cybersecurity of elections	Cyber security of elections	UK, POST	2024/05
Climate-friendly air travel	Innovative drives and fuels for more climate-friendly air traffic	GER, TAB	2024/05
	La décarbonation du secteur de l'aéronautique [Decarbonization of the aviation sector]	F, OPECST	2024/05
Media restrictions and freedom of expression	Les restrictions à la diffusion de certains médias russes dans l'Union européenne et le respect de la liberté d'expression au Luxembourg [Restrictions on the broadcasting of certain Russian media in the EU and respect for freedom of expression in Luxembourg].	LUX, CellSciLux	2024/05
Deepfakes	Deepfakes and manipulated realities – technology impact assessment and recommendations for action for Switzerland	CH, TA-Swiss	2024/06
Food waste	Food Waste	UK, POST	2024/07
Digital estate	Death in the digital age	CH, TA-Swiss	2024/07
Plastic waste	Reducing plastic waste	UK, POST	2024/07
Metaverse	What is the metaverse, and what impacts will it have on society?	UK, POST	2024/07
Digitisation and culture	Streamed, liked, ephemeral - brave new cultural world? Digitalisation and culture in the light of technology assessment	CH, TA-Swiss	2024/08
Biometrics	Biometric data: Misuse, use, and collation	UK, POST	2024/09
Meat and milk substitutes	Meat and dairy substitutes - better for health and the environment? Effects on nutrition and sustainability, the consumer's perspective and ethical and legal considerations	CH, TA-Swiss	2024/09
Food supply	Cybersecurity in the food supply sector	GER; TAB	2024/10
Employee data	People analytics – technologies for analyzing of employee data	GER, TAB	09/2023
Digital games	Digital games in education	GER, TAB	09/2023
Electricity market	Electricity market reform	UK, POST	05/2023
E-voting	E-voting – alternative forms of voting and how to safeguard them	GER, TAB	09/2023
Bicycle traffic	Bicycle turnaround	GER, TAB	09/2023
Indoor air quality	Indoor Air Quality	UK, POST	09/2023
Climate label	Establishing a horizontal European climate label for products	EU, STOA	09/2023
Sustainable cooling	Sustainable Cooling - sustainable cooling strategies	GER, TAB	05/2023

Topic	Title of the study	Country; Institution	Year
Nicotine products	Nouveaux produits du tabac ou à base de nicotine: lever l'écran de fumée [New tobacco and nicotine products: lift the smoking ban]	F, OPECST	09/2023
Zero energy districts	Local area energy planning: achieving net zero locally	UK, POST	07/2023
Online advertising	Online Advertising Technology and Competition	UK, POST	10/2023
Plant biosecurity	Plant biosecurity in Great Britain	UK, POST	07/2023
Plastic recycling	Le recyclage des plastiques [Plastic recycling]	F, OPECST	06/2023
ChatGPT	ChatGPT and other computer models for language processing: basics, potential applications, and possible effects	GER, TAB	2023
AI and food production	Artificial intelligence in the agri-food sector: Applications, risks and impacts	EU, STOA	2023
Quantum computer	Securing Data for a Post-Quantum World	USA, GAO-STAA	2023
	Quantum Information Technologies	JP, RLRB	2022
Automated biometrics	Automated recognition of voice, speech and face: technical, legal and social challenges	CH, TA-Swiss	2022
Face recognition	Facial Recognition Technology: Federal Agencies' Use and Related Privacy Protections	USA, GAO-STAA	2022
ITC and energy	Energy consumption of the ICT infrastructure	GER, TAB	2022
Rare earths	Research review on innovation-critical metals and minerals	SWE, ERS	2022
Data centers	Making better decisions about data centres: The need for a broad perspective on digital infrastructure	N, Rathenau	2022
Genome editing	Genome Editing Technologies: Issues arising on the frontline and future prospects	JP, RLRB	2022
AI in the healthcare sector	Artificial Intelligence in Health Care: Benefits and Challenges of Machine Learning Technologies for Medical Diagnostics	USA, GAO-STAA	2022
	AI and health: potential and challenges	ES, Oficina-C	2022

WWW.OEAW.AC.AT