satw technology for society

Technology Outlook

Looking ahead.
Preparing.
Moving forward.

2025

Turning waste into gold
A research team at ETH Zurich is using whey to extract gold from electronic waste. The result: high-purity gold nuggets.

Pioneering technologies

Technologies drive innovation and shape global competition. Technology Outlook 2025, published by the Swiss Academy of Engineering Sciences SATW, analyses and evaluates 31 technology fields that will become relevant for the Swiss economy and society over the next three to five years.

The study pays increasing attention to technologies that contribute to a sustainable (circular) economy, including recycling technologies that return valuable materials from waste into manufacturing processes, or technologies that harness CO_2, a greenhouse gas, as a resource. Experts' assessments show that environmental issues will have a decisive impact on companies' future viability.

Compared to the 2023 study, the number of technologies from Manufacturing Processes and Materials has increased, particularly those enabling energy-saving and resource-conserving processes. In contrast, the number of digitalisation technologies has decreased, because some of these technologies – such as artificial intelligence applications – are now market-ready and are unleashing their disruptive potential through innovative products and services across industries.

Technology Outlook: a national study

Technology Outlook is the only national foresight study that assesses the potential of promising technologies specifically for Switzerland. The foresight committees and the foresight team at SATW select the technologies to cover, based on their technological maturity. The analysis is based on standardised interviews with experts from all over Switzerland. These discussions also gathered quantitative data on research capabilities and economic potential in Switzerland.

SATW conducts technology foresight on behalf of the Swiss federal government. Published every two years since 2015, Technology Outlook targets representatives from the worlds of business, academia, politics and administration, not to mention technology enthusiasts.

Explore the study at: www.technology-outlook.ch

Transformation drivers

Not every innovative technology receives the attention it deserves. Technology Outlook 2025 describes four such examples and demonstrates how they could bring about significant progress for the economy, society and the environment.

Underappreciated cross-cutting technologies
Cross-cutting technologies – also called enablers – offer tremendous disruptive potential for many applications. Catalysts, for example, speed up or enable chemical reactions. Using new, highly selective catalysts, sustainable resources like biomass, pyrolysis oil and CO_2 can be converted into synthetic fuels and non-fossil platform chemicals. Switzerland is in an excellent position: a highly competitive research environment, innovative start-ups and targeted research funding are all driving development forward. If the breakthrough is successful, **catalysis** could speed up the energy and raw materials transition.

Adhesives and sealants are another enabler. They are indispensable in vehicle construction, the building trade and many other industries. New formulations enable material savings, in the likes of lightweight vehicle bodies or wind turbine rotors. Full-surface bonding replaces traditional joining methods and improves the thermal insulation properties of components. If innovative adhesives and sealants are made from renewable resources, they make end products even more sustainable and can bring about a sustainable transition in joining technologies.

Deep tech: a beacon of hope
Deep-tech technologies are also gaining in importance alongside enablers. They solve fundamental problems in new ways. Well-known examples include mRNA vaccines and quantum computers. These technologies are highly complex and require long-term investment horizons. They offer tremendous potential due to their high level of importance for both society and the economy.

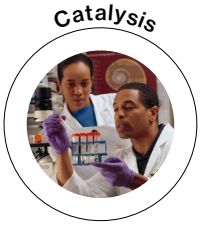
A lesser-known deep-tech technology is photonic integrated circuits on semiconductor chips (known as **PICs** for short). PICs transmit data via light signals rather than electrons, making them faster and more energy-efficient than conventional chips, with the potential to help reduce the power consumption of AI applications. However, the technology is not yet market-ready. New semiconductor materials that enable even more efficient and faster PICs, not to mention clean rooms for manufacturing, are required.

In medicine, **bacteriophage** treatments offer huge potential. These naturally occurring viruses that specifically attack bacteria are considered a promising alternative to antibiotics. Modern approaches harness genetically modified phages to further increase their efficacy and safety. Phages also offer potential in agriculture and the food industry.

Four unknown game changers

Versatile and highly innovative

Catalysis

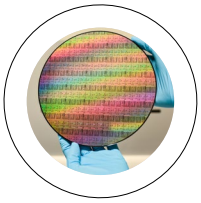


New catalysts enable targeted and resource-conserving synthesis of many platform chemicals. Researchers are seeking more selective catalysts to produce climate-friendly artificial fuels from CO_2, water and solar energy.

Sustainable adhesives and sealants

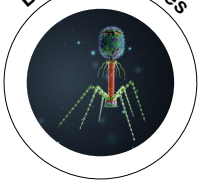
New materials enable energy-efficient manufacturing, lighter-weight end product design and improved insulation between components. Promising formulations include ones that are easily recyclable or that can be reused without any problems.

PICs



They transmit digital signals using light, enabling more energy-efficient operation of high-performance computers. They also enable new applications in photonics, quantum research and sensor technology.

Bacteriophages



The use of these naturally occurring antibacterial viruses offers new hope in overcoming the antibiotics crisis in medicine. Applications in the food industry and agriculture supplement the portfolio.

Waste – the resource of the future

Rethinking waste uncovers potential for sustainability, innovation and futureproof business models. The brochure presents technologies and case studies that support a circular economy.

The huge amount of electronic waste produced represents the dark side of the computer age. However, researchers at ETH Zurich are quite literally turning this waste into gold. Using whey, a by-product from milk processing, they dissolve the precious metal from discarded computer circuit boards and obtain pure gold nuggets.

Beneficial sustainability profile

This case study shows that products that are reused following consumption not only fit into a circular system, but also have economic potential. Technology Outlook 2025 focuses on six technologies that turn this vision into a reality: bioplastics from waste, CO_2-based plastics, artificial photosynthesis, plastics recycling, phosphorus recycling and synfuels. The sustainability profile of these technologies shows that they offer many advantages in terms of environmentally relevant criteria (see the graphic on the right).

Plastics recycling is tremendously significant, as Switzerland generates 830,000 tonnes of plastic waste annually. New processes can return the recyclable materials it contains back into the production chain. One example is the method developed by DePoly, a company based in Valais. The ETH Lausanne spin-off breaks down mixed plastic waste, something which was previously only incinerated, into its basic components.

Even carbon dioxide (CO_2) is no longer just a harmful greenhouse gas. It replaces fossil raw materials for CO_2-based plastics and serves as the starting material for sustainable fuels in technologies such as synfuels and artificial photosynthesis.

The sticking point: CO_2 pricing

Switzerland is a perfect target for the transition into a low-emission, resource-conserving circular economy. The highly competitive research landscape and innovative start-ups are driving development forward. According to industry figures, the number of start-ups in the waste and resource efficiency segment alone more than doubled between 2017 and 2024.

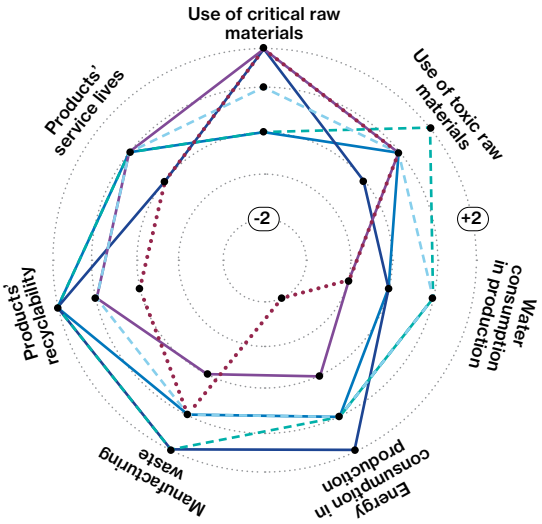
Whether the investments will pay off in economic terms remains to be seen. Some technologies are not yet market-ready. Political and regulatory framework conditions, such as CO_2 pricing, are important. If emissions are priced in higher, opportunities emerge for scaling the technologies.

Switzerland would benefit in several ways. It could meet the Sustainable Development Goals, reduce its dependence on imported raw materials and provide a platform for new business models. The example of phosphorus recycling is particularly impressive – by recovering phosphorus from sewage sludge, meat and bone meal waste and even human excrement, the country could largely meet its own needs.

Sustainability profile

Products' environmental impacts

Assessment of the change compared to the status quo



- Bioplastics from waste
- CO_2-based plastics
- Artificial photosynthesis
- Plastics recycling
- Phosphorus recycling
- Synfuels

+2: strong improvement
+1: slight improvement
0: consistent
-1: slight deterioration
-2: strong deterioration

Key findings

The circular economy is picking up speed

Facts: Switzerland consumes 140 million tonnes of new materials annually. That's just under 16 tonnes per person, per year.

Tip: Companies that pursue the vision of a resource-conserving circular economy early on can expect to enhance their reputation.

Relevance: Switzerland benefits in two ways – consistent recycling helps achieve climate targets and reduces dependence on raw material imports.

Trends: The number of start-ups in the waste and resource efficiency segment doubled between 2017 and 2024 to 58 companies.

Future: When greenhouse gas emissions are priced in higher, opportunities emerge for developing and scaling new technologies.

Showcases

The showcases are examples of applications and pioneering projects from Swiss industry and research. They are realistic and inspiring and are an impressive demonstration of how technological innovation leads to groundbreaking products.

ETH Zurich

Going for gold with whey

Gold, the symbol of wealth and power, is now also found in our electronic devices – but mining it harms the environment. Although electronic waste contains significantly more gold percentage-wise than mines, it is barely recycled. Professor Raffaele Mezzenga's team at ETH Zurich uses sponges made from whey, a by-product of the dairy industry, to bind gold from electronic waste. Burning the sponges turns two waste products into a valuable product: high-purity gold nuggets.

BloqSens AG

A passport for batteries

Batteries are integral parts of many electronic applications. However, the lack of clarity concerning their origin and use makes second-life use and recycling more difficult. That is why the EU is introducing the Digital Battery Passport (DBP) from 2027 to ensure transparency. BloqSens AG, a Swiss start-up, is using blockchain technology to create such digital passports. The aim of the DBP is to promote recycling, reuse and trust, and it also forms part of an EU digital product passports initiative.

Modual AG

Used – but not obsolete

Electromobility is key to reducing greenhouse gas emissions in the mobility sector, but it also brings with it challenges like battery recycling. An innovative solution from Switzerland could solve these problems: Modual AG is using retired batteries from electric vehicles like cars and buses to build stationary energy storage systems for use in private homes and industry. This contributes to the sustainable use of resources.

Empa

Old smartphones in the service of energy efficiency

Buildings account for around 40 percent of Switzerland's energy consumption. Smart control systems can help us to use energy more efficiently – but require resource-intensive hardware. Hanmin Cai, a researcher at Empa, demonstrates how used smartphones can take over building control. Their computing power is sufficient for such applications, and they are affordable and environmentally friendly. Initial tests in laboratory settings were successful, and now the next step is scaling and developing suitable interfaces.

How relevant are the technologies?

The diagram classifies selected technologies according to their relevance for Switzerland. The horizontal axis indicates the economic importance, which takes into account future market potential, and the vertical axis shows Swiss research capabilities. The technologies deep geothermal energy and quantum computing are not included in the graphic due to missing data points.

Research category

- Digital World
- Energy and Environment
- Life Sciences
- Manufacturing Processes and Materials
- Space Sciences

1 Niches

Artificial photosynthesis

Negative emissions technologies

Hydrocarbons are produced from solar energy, water and CO_2. This enables the production of climate-friendly fuels and the storage of renewable energies in the form of hydrogen. As an innovation hub, Switzerland can contribute to fundamental research and materials development.

Earth observation

0 — Economic importance

2 Hopefuls

Bioplastics from waste

Plastic is an all-purpose material. While traditional production is mainly based on fossil raw materials, new approaches use waste streams as resources for manufacturing. Challenges certainly exist, but this technology is indispensable for achieving global climate targets.

Perovskite

Hydrocarbon

Plasma technologies

Phosphorus recycling

Phosphorus is an essential nutrient for plants and human nutrition. Recovery from sewage sludge, meat and bone meal ash and urine could reduce domestic dependency on imports and increase local value creation. Implementation has been delayed for political and economic reasons.

Plastics are affordable and versatile, but most plastic waste – 80 percent in Switzerland – is burned in a way that is harmful to the environment. Expanded recycling with an optimised value chain – from production to reuse – could reduce the carbon footprint.

Plastics recycling

TIMs

PICs

mRNA

Diamond-based photonics

2D materials

Bacteriophages

Flexible batteries

1 Niches
They have high research capabilities but low economic significance and limited revenues. Does investment actually boost revenues? Or can industry leverage these technologies in niche applications to demonstrate their strengths?

3 Stars
They are well established. Economic significance is high, research is strong and the opportunity for positive development is good. The key to success: companies harnessing the knowledge gained and consistently tapping into new business areas.

2 Hopefuls
Little research has been conducted and economic significance is low. Are they rising stars or dead ends? Their development should be monitored, market potential determined and challenges identified.

4 Sure-fire successes
They are unexpectedly significant from an economic point of view, despite relatively little research being conducted, and grow rather slowly. The strategy for success: targeted investment in education and training, not to mention applied research.

10

IoT

Industry 5.0

URLLC

Bioinspiration and biointegration

Personalised nutrition

Synfuels

They reduce dependence on fossil fuels. New catalysts convert sustainable resources such as CO_2, biomass and sunlight into fuels. AI-supported experiments and automation speed up development, but require major investment.

Stars 3

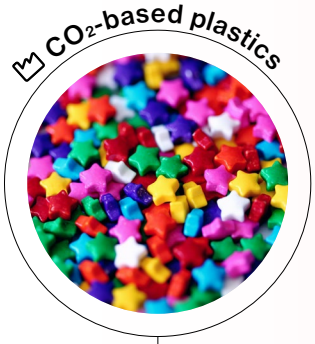
10

Sure-fire successes 4

Synthetic biology

Human augmentation

CO_2-based plastics



New technologies use the unwanted CO_2 from industrial exhaust gases as a source of carbon for plastics production. This is a decisive step towards achieving the net-zero target and towards a carbon circular economy.

Low-carbon concrete

Fibre-optic sensors

Biocatalysis

Sustainable adhesives and sealants

Research capabilities

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The Swiss Academy of Engineering Sciences SATW is Switzerland's most important network of experts in engineering sciences and maintains contact with Switzerland's highest committees for science, politics and industry. The network consists of elected individual members, member societies and experts.

SATW identifies industrially relevant technological developments on behalf of the Swiss federal government and informs politicians and society alike about their significance and consequences. As a unique professional organisation that has a high level of credibility, it provides independent, objective and holistic information about technology – as a foundation for well-founded opinion-forming. SATW also promotes interest in and understanding of technology amongst the general public, particularly young people. It is politically independent and non-commercial.

Technology Outlook

Vision for increased innovation

From Earth observation to bioinspiration – Technology Outlook sheds light on technologies that offer particular potential for Switzerland's future. It is therefore a guide for strategic work in industry and administration, and a guide for all of our futures.

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How companies successfully deploy new technologies.

satw

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