Hitachi Review

May 2025 Technical Information

Innovations Addressing Fundamental Issues Facing Society

Research & Development

#Innovation Creation #Co-creation and Open Innovation #Sustainability #Generative AI #IoT/Data Utilization #Digital Solutions #Research & Development

1. Future Cities

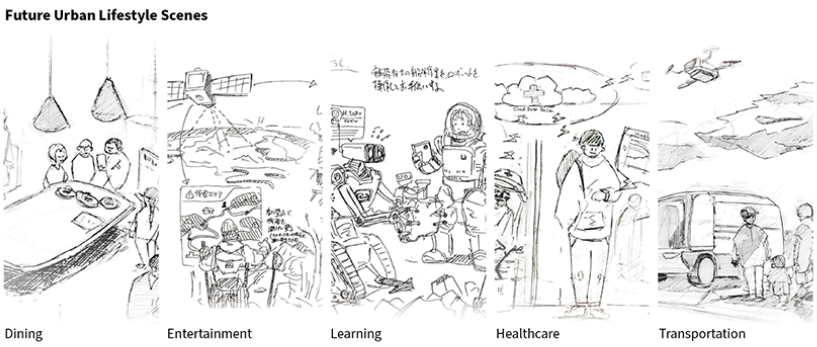
Society 5.0 envisions a participatory society that embraces well-being and the diversity of individual preferences. Partnering with KDDI CORPORATION, Hitachi is supporting the Future Life Expo: Future City project at Expo 2025 Osaka, Kansai, Japan, presenting a vision of the future city as envisioned by Society 5.0.

Looking toward the Expo, Hitachi's Research & Development Group launched the “Future Society Project” in August 2023. Together with KDDI, they have been exploring the realities of daily life in these future cities, supported by cyber-physical systems (CPS). In the Future City project, citizens simulate multiple futures based on data collected and analyzed by CPS across various areas such as food, health, learning, mobility, energy use, and entertainment, then reflect their own choices and preferences in urban development. Bringing this concept of future cities to a reality requires the participation of a diverse range of stakeholders, and Hitachi has been communicating this concept since when momentum was building leading up to the Expo.

In the future, Hitachi will use the Expo as a major opportunity to co-create future urban solutions that span sectors from an integrated perspective, through discussions with citizens, businesses, and public organizations who will visit the Expo.

*See the list of "Trademarks".

[1] Idea for Future Lives in Future Cities Supported by CPS



2. Digital Observatory for Visualizing Risks of Global Manufacturing Sites in the Supply Chain

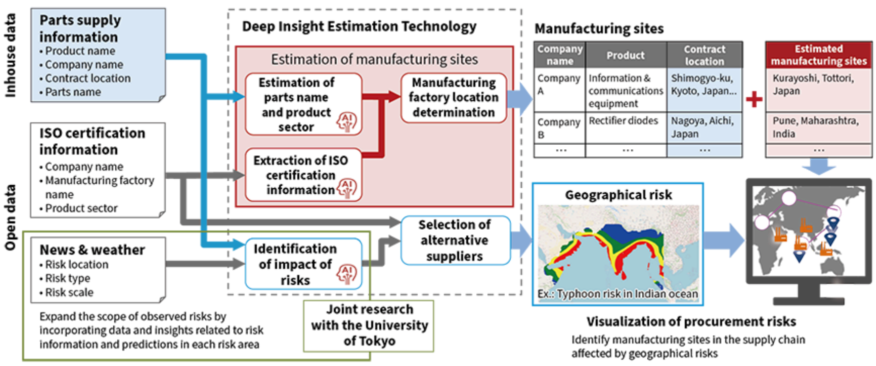
To make a resilient society a reality by 2050, Hitachi is conducting joint research with the University of Tokyo into identifying, forecasting, and avoiding latent risks in supply chains, by monitoring and utilizing data on socio-economic activities.

Hitachi's Research & Development Group is working to analyze the impact risks on sites within each risk domain addressed in this joint research by linking them with procurement information from in-house data. In understanding supply chain risk, information on manufacturing sites of procured parts is critical, however data obtained through contracts or interviews is often limited. Accordingly, Hitachi has developed a deep insight estimation technology that uses open data such as ISO certification information* and company information, along with generative AI, to accurately estimate global manufacturing site locations. This technology enables the identification of manufacturing sites in the supply chain affected by geographical risks, and the quick implementation of pre- and post-risk countermeasures.

Moving forward, Hitachi will promote internal verification of this technology, aimed at contributing to supply chain resilience that supports society and the economy.

* ISO certification data is obtained based on public corporate websites and data services from the Japan Accreditation Board (JAB), and the use of the JAB data is based on the terms of use 1-7 (https://www.jab.or.jp/guide/terms_of_use).

[02] Deep Insight Estimation Technology for Estimating Manufacturing Sites



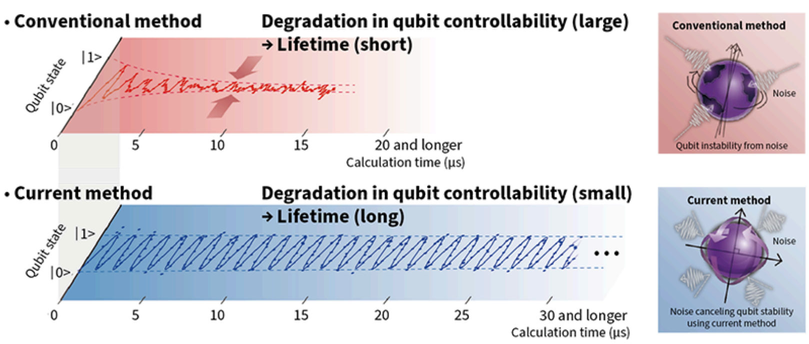
3. Operational Technology to Stabilize and Extend Silicon Qubit Lifetimes Over 100-fold

Practical calculations using quantum computing require systems in excess of one million qubits—this demands large-scale integration of qubits, efficient qubit control, and implementation of error correction. Hitachi has been advancing research on silicon quantum computers, which are considered advantageous for large-scale integration of qubits. However, one challenge is that nuclear spins in semiconductors can cause noise, making qubits unstable and hindering the implementation of quantum algorithms and error correction.

To address this, Hitachi has developed a qubit control technique called concatenated continuous driving(CCD) that stabilizes qubits, with the aim of making silicon quantum computers practically useful. This technology cancels out noise from within the semiconductor by modulating the phase of the microwaves used to operate the qubits. Applying this technology to silicon quantum computers has experimentally confirmed an over 100-fold extension of qubit lifetime. Hitachi will accelerate research not only on large-scale qubit integration, but also on implementing quantum algorithms and error correction, aiming for the early practical application of quantum computers.

* This research was supported by the Japan Science and Technology Agency (JST) “Moonshot Research & Development Program,” “Grant Number JPMJMS2065”

[03] Comparison of Qubit Operation Results: Conventional vs. Current Method

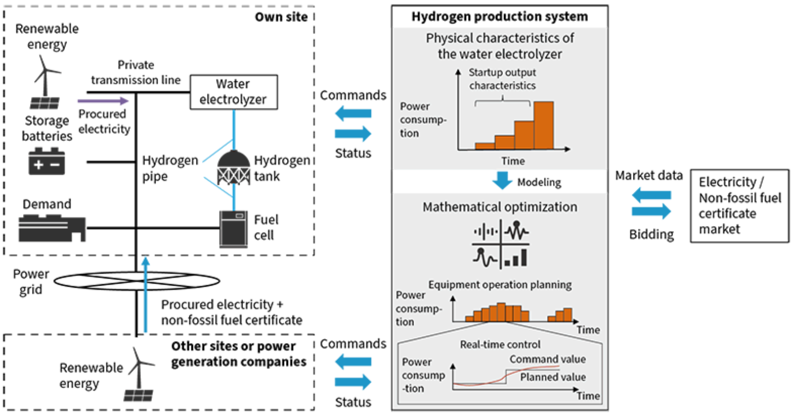


4. Hydrogen Production System Contributing to a Decarbonized Society

There is increased interest in hydrogen fuel as a way to bring about a decarbonized society. While hydrogen production using water electrolysis is gaining attention for its zero CO_2 emissions, this method consumes a large amount of electricity. To reduce the cost of procuring this electricity, it is effective to source inexpensive electricity during periods of surplus renewable energy. At the same time, discrepancies between the power procurement plan and actual power usage—known as imbalances—incur additional adjustment costs, making reduction of this imbalance essential.

Hitachi has developed a hydrogen production system equipped with operational planning and real-time control functions that model the physical characteristics of water electrolysis equipment, and calculate detailed electricity procurement volumes. This enables reduction of both imbalances and hydrogen production costs. Furthermore, the system can also be applied to the integrated planning and control of various facilities, such as storage batteries and fuel cells across multiple sites.

[04] Hydrogen Production Optimization System

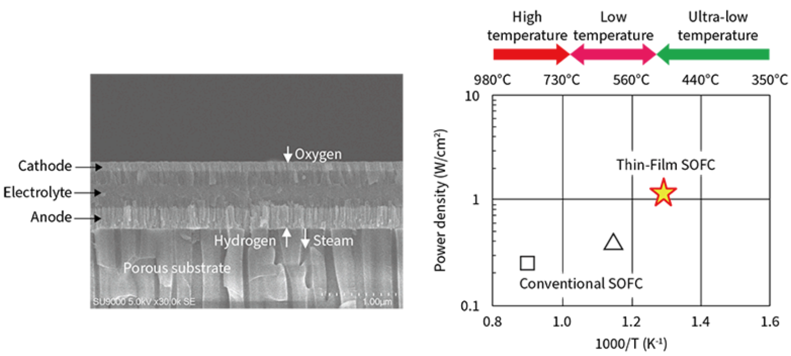


5. Thin-film SOFC System for Greening Local Power Supply

With the increasing focus on renewable energy, fuel cells, especially high-efficiency solid oxide fuel cells (SOFCs), are expected to be the next generation of electricity to achieve carbon neutrality. To expand the use of high-efficiency SOFCs in distributed power systems and promote the greening of local electricity, the key is to improve power density and reduce operating temperature. Thin-film SOFCs based on semiconductor process technology show great promise.

The solid electrolyte layer, which is several micrometers or more thick in conventional SOFCs, has been thinned to less than 1 μm using semiconductor process technology. This reduces the electrical resistance of the solid electrolyte layer. As a result, a power density of 1 W/cm2 is achieved, exceeding that of conventional SOFCs, at an operating temperature of 500°C, which is lower than that of conventional SOFCs. By integrating thin-film SOFCs into a multi-layer stack, it is possible to achieve sufficient power for distributed power generation systems.

[05] Structure and Power Density of Thin-Film SOFC



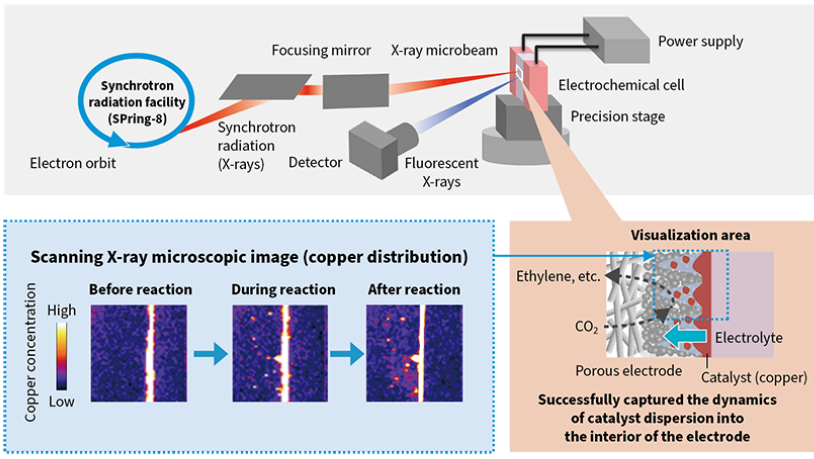
6. Technology to Visualize Catalyst Electrode Structures during Reactions for CO_2 Resource Recovery

CO_2 is a factor in climate change and global warming, and so Hitachi is developing technologies for the direct conversion of this into useful substances. Electrochemical-based reaction processes are a promising technology for capturing CO_2 and converting it into useful chemical raw materials. Catalyst electrodes play a particularly important role in the promotion of efficient electrochemical CO_2 utilization. However, the state of catalyst electrodes during electrochemical reactions could not be analyzed using conventional measurement methods, and so it was difficult to design materials when factoring in structural changes caused by the reactions.

To address this challenge, Hitachi developed a new electrochemical cell for simultaneous conducting of electrochemical reactions and X-ray measurements. Combined with scanning X-ray fluorescence microscopy using X-ray microbeams—an advanced synchrotron radiation measurement technique—this successfully visualized the dispersion of catalyst materials from the upper layer of porous electrodes into the interior of the electrode during the reaction.

Looking to the future, Hitachi will continue improving the reactivity and durability of catalyst electrodes and promote development of technologies to use electrochemical reactions to convert CO_2 into resources, thus contributing to the realization of a sustainable carbon-neutral society.

[06] Observation of Structural Changes in Catalyst Electrodes during Electrochemical Reactions Using Synchrotron Radiation Measurement Technology



7. Synthetic Biology for Carbon Transformation

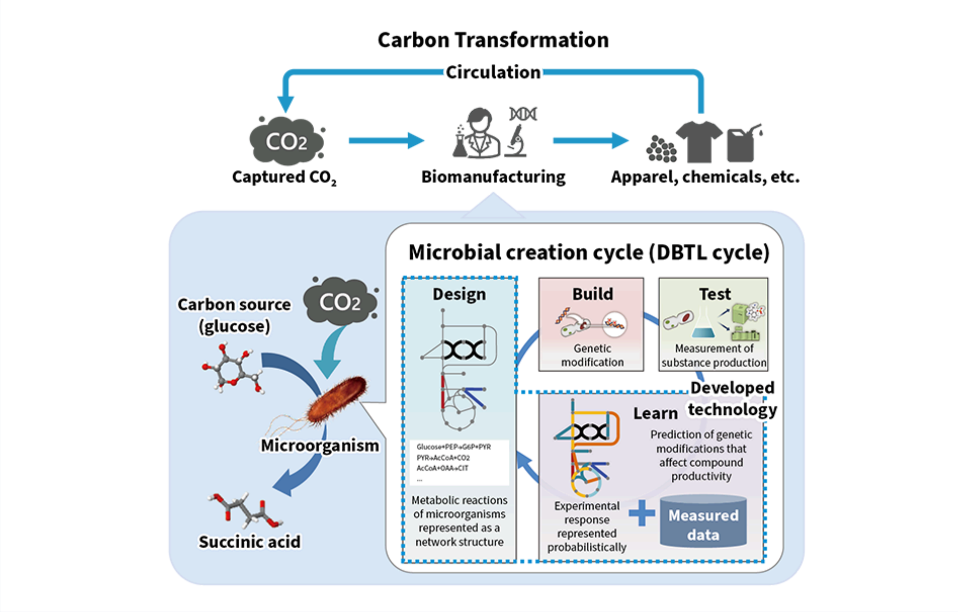
In the chemical industry, there is growing interest in utilizing biomass and CO_2 as carbon-neutral alternatives to conventional fossil resources. Hitachi is working on the development of synthetic biology*1 with the aim of enabling microbial production of valuable chemicals using CO_2 as a raw material.

Synthetic biology involves redesigning the genomes of microbes through genetic engineering and genome editing to enhance the productivity of target compounds. To accelerate the iterative process required to achieve this—referred to as the design, build, test, learn (DBTL) cycle*2—Hitachi has developed a new technology in collaboration with Kyoto University. This technology features the representation of metabolic reactions within microorganisms as network structures, and the responses observed in experiments as probabilistic mathematical models. This enables computational identification of genes that influence the productivity of target compounds. When applied to metabolic design aimed at improving the productivity of succinic acid, the technology successfully predicted genetic modifications that would increase succinic acid production. This result suggests the potential to significantly reduce the trial-and-error typically required in experimental processes to realize microbial manufacturing. Through the further advancement of this technology, Hitachi aims to help contribute to the realization of carbon neutrality.

*1 A field of technology in which biosynthetic pathways (metabolic pathways) and genetic sequences within cells are artificially designed to confer new functions on organisms.

*2 S. Hosoda et al., "BayesianSSA: a Bayesian statistical model based on structural sensitivity analysis for predicting responses to enzyme perturbations in metabolic networks." BMC bioinformatics 25.1, 297. (2024)

［07］Metabolic Design Technology to Accelerate the Microbial Engineering Cycle



8. Success in World-first Observation of Magnetic Fields on Individual Lattice Planes

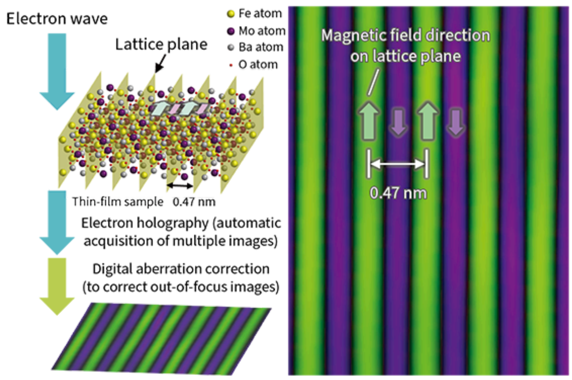
To further advance developments and improvements to high-performance materials and energy-saving devices essential for realizing a carbon-neutral society, there is a growing demand for ultra-high-resolution techniques to observe the electric and magnetic fields at the atomic level that underpin the functions and performance of these materials.

Hitachi has developed a method that combines digital technology with an atomic-resolution holography electron microscope developed in a Cabinet Office project*1. This allows high-resolution observation of magnetic fields in samples with complex structures and compositions, such as magnetic multilayer structures, which had formerly been difficult to analyze, and as a result Hitachi has achieved the world's first successful observation of magnetic fields on individual lattice planes (planes along which atoms are arranged*2. This was made possible by developing automatic electron holography measurement techniques that maintain atomic resolution, along with digital aberration correction technologies for automatically adjusting minute focus errors (aberrations) that occur during data acquisition after imaging. As a result, it is now possible for the first time to observe magnetic fields at the atomic-layer level at local boundaries (interfaces) between materials—areas that significantly influence the physical properties of samples, as well as the performance of electronic devices.

*1 This achievement and a portion of the related research were supported by grants provided through the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST) via the Japan Society for the Promotion of Science, as well as by JST CREST (Grant Number: JPMJCR1664). These results were obtained in collaboration with Kyushu University, the Institute of Physical and Chemical Research (RIKEN), HREM Research Inc., the National Institute of Advanced Industrial Science and Technology (AIST), and the National Institute for Materials Science (NIMS).

*2 T. Tanigaki et al., Nature 631, 521 (2024)

［08］**Schematic Diagram of the Observation Method, and Magnetic Field Distributions of Each Lattice Plane that was Successfully Observed**



9. Battery Sharing to Achieve both Decarbonization and Economic Efficiency in Agriculture

In collaboration with Iwamizawa City and Iseki & Co., Ltd., Hitachi Hokkaido University Laboratory has begun a demonstration trial with the aim of achieving both decarbonization and economic efficiency in regional industries using battery sharing that promotes local production and consumption of renewable energy.

In improving agricultural economic performance, it is effective to increase the utilization rate of expensive batteries by sharing them across multiple applications—in this trial, movable AC/DC multi-function batteries developed by Hitachi were mounted on electric agricultural machinery to utilize renewable energy sourced from stand-alone nanogrids* in a variety of farming tasks.

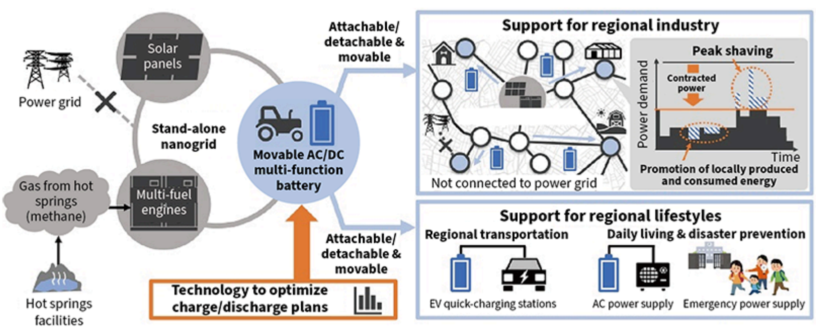
With cooperation from local farmers, a demonstration was conducted using the movable AC/DC battery as the power supply to a water pump used for flower farming during the busy farming season, which faces temporary surges in electricity demand. The results confirmed a 22% reduction in peak power usage.

Going forward, Hitachi plans to apply its technology to optimize charge/discharge plans to improve the efficiency of battery charging, discharging, transport, and operation, while bringing about a regional energy infrastructure that leverages batteries, with the goal of promoting decarbonization of regional industries through the electrification of industrial equipment.

(Hitachi Hokkaido University Laboratory)

* Small-scale power system utilizing solar power and hot-spring-associated gases, etc.

［09］**Expanding Local Utilization of Locally Produced Energy Using a Movable AC/DC Multi-function Battery**



EV: electric vehicle

10. Habitat Innovation

The Habitat Innovation Project at H-UTokyo Lab. is a joint research initiative between Hitachi and the University of Tokyo, established with the mission of “creating a vision for the realization of Society 5.0.” H-UTokyo Lab. positions the smart city as a specific embodiment of Society 5.0, and it is conducting research on its future vision, architecture, key functions (key factors), and implementation methods.

Currently, it is returning to the core definition of Society 5.0 and identifying three visions for the type of society a Society 5.0-style smart city would achieve: (1) a space that actively utilizes urban data and IT technologies, (2) a space that solves residents’ issues and enhances their well-being, and (3) a space that creates innovation in services and daily life while continuing economic growth. To this end, efforts are underway to concretize the mechanisms and methodologies needed to sustainably make these a reality. Additionally, starting in July 2024, the laboratory has been hosting the “Smart City Tokyo Expo” themed around smart city development in Tokyo, sharing its research results both in Japan and overseas.

Going forward, it will advance the implementation of Society 5.0-style smart cities in collaboration with stakeholders such as the Tokyo Metropolitan Government.

(H-UTokyo Lab.)

［10］Key Factors of a Society 5.0-style Smart City

QoL: quality of life
* https://www.ht-lab.ducr.u-tokyo.ac.jp/smartcity_sixkey/

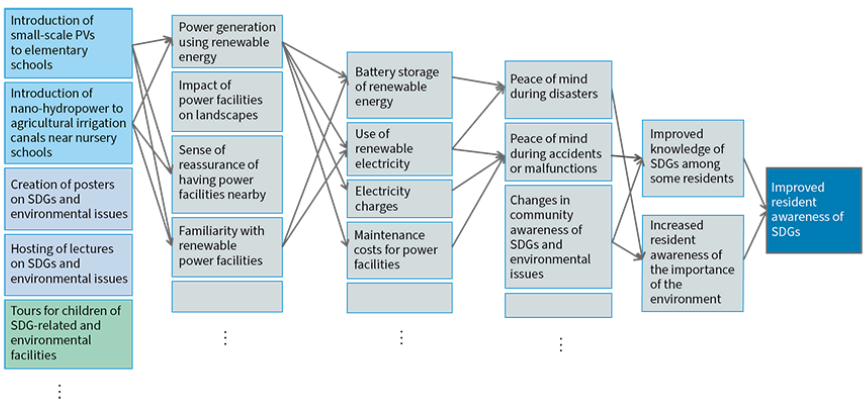
11. Visualizing Multidimensional Value

When expanding social innovation projects at the regional level, it is necessary to take a multidimensional perspective that considers not only traditional economic value, but also environmental and social value. In addition, to promoting better community development and ensuring sustainable, active participation by local residents, there is an increasing focus on evaluating social impact—that is, the long-term social and environmental changes brought about by policies.

To address this need, Hitachi Kyoto University Laboratory has developed technologies to clarify the relationship between policies and their social impact in local communities. This allows the importance of individual initiatives to be quantitatively evaluated. Specifically, the technology incorporates subjective value criteria such as people’s perceptions of “like/dislike” or “good/bad” to determine quantitatively whether policies are likely to be accepted and considered necessary by local residents. By applying this technology, Hitachi aims to support decision-making by local governments and regional businesses, thereby contributing to the sustainable development of communities.

(Hitachi Kyoto University Laboratory)

[11] Example Social Impact Quantification Models



PV: photovoltaics
SDGs: Sustainable Development Goals

12. Development Platform for Cell Design

Chimeric Antigen Receptor (CAR) T-cell therapy is a novel treatment that uses genetically modified cells—designed cells (DesignCell)—that add therapeutic functionality. First CAR-T cell therapy was approved in the United States in 2017 as an epochal treatment for intractable leukemia and lymphoma, which had been difficult to treat using conventional therapies. To date, seven CAR-T cell products have been brought to market. While this treatment holds great promise, challenges remain to be overcome, including high medical cost and limited disease indication.

To accelerate research and development of designed cells, Hitachi Kobe Laboratory has been establishing the development platform for cell design, which integrates an AI for generating gene sequences with a high-throughput cell evaluation system. So far, it has established an in vitro testing system for cellular functions of AI-generated gene sequences, and succeeded in obtaining several new sequences that exhibit higher activity than existing ones. Looking ahead, it plans to improve the platform through in vivo animal experiments to verify these functions, and co-creation with possible customers.

(Hitachi Kobe Laboratory)

* As of December 2024, only for certain types of blood cancers.

[12] CAR-T Mediated Cancer Cell Cytotoxicity, and Hitachi's Proprietary CAR-T Cell Screening