May 2024 Technical Information

Future Social Challenges & Disruptive Innovations

Research & Development

#Carbon Neutral #Supply Chain Transformation #Innovation Creation #Co-creation and Open Innovation #Sustainability #Generative AI #IoT/Data Utilization #Research & Development

1. Silicon Qubit Control Method Suited to Large-scale Integration

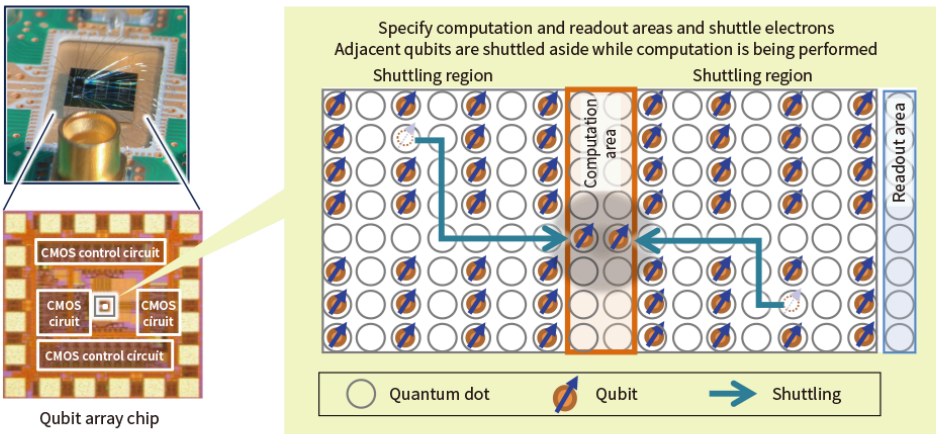
The ability of quantum computers to perform ultra-high-speed computations not possible on conventional computers is why they are seen as potentially useful in a wide range of industries, including materials development, drug discovery, and finance. However, performing the sort of computations used in practical applications requires quantum computers with one million or more qubits.

Hitachi is working on the development of silicon quantum computers that leverage silicon's affinity with circuit integration. Silicon quantum computers work by trapping single electrons in microscopic structures called quantum dots that are formed in the silicon device. By controlling the electron spin, these can be used as qubits to perform computations.

Hitachi has devised and evaluated the efficacy of a shuttling qubit method for the efficient control of large numbers of qubits on a chip. The method works by predefining the region for performing quantum computations. It performs computations and reads their quantum states by "shuttling" electrons, which means moving them freely without disrupting their quantum state. Cross-talk (errors) between adjacent qubits is one of the obstacles to successful large-scale integration. Shuttling qubits minimizes this cross-talk by shifting adjacent qubits aside as the computation is performed. A simulator was built to incorporate this effect. It successfully demonstrated that this new method could maintain high accuracy in large quantum computations compared to the previous method (fixed qubits). Through open innovation, including with the Japan Science and Technology Agency (JST) Moonshot Research & Development Program, this work aims to accelerate research into large-scale integration and hasten the practical application of quantum computers.

The research was supported by Grant Number JPMJMS2065 from the Moonshot Research & Development Program.

［01］**Shuttling qubit method for efficient control of qubits**



CMOS: complementary metal-oxide semiconductor

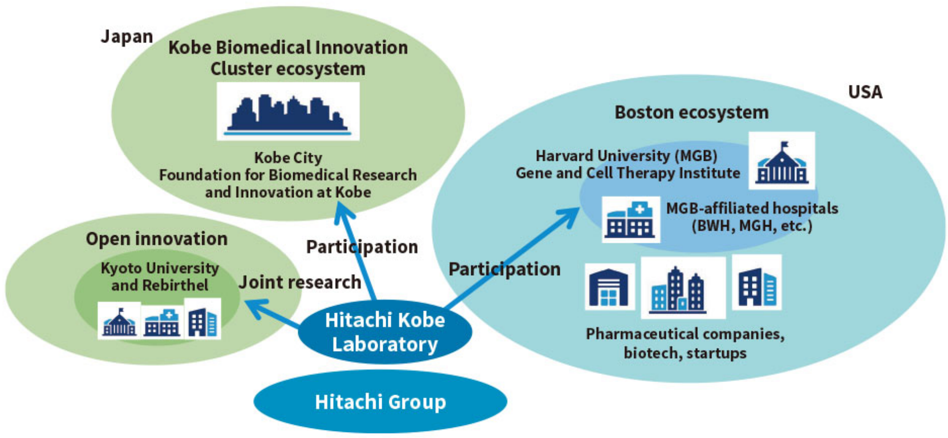
2. Hitachi Kobe Laboratory: Establishment of Ecosystem for Cell-based Drug Development and Manufacturing

High hopes are being placed on new modalities (forms of treatment) such as regenerative medicine or cell and gene therapies for diseases that in the past have been difficult to fully cure. Among these diverse modalities, high efficacy has been demonstrated by ex vivo gene therapies using designed cells that have been genetically modified to give them therapeutic functions.

In its 2050 Project*, Hitachi Kobe Laboratory has been working to establish an ecosystem through co-creation with partners who have synergies with Hitachi businesses. The goal is to overcome challenges such as designed cell development and production cost reduction through seamless improvement in the efficiency of drug discovery and manufacturing processes. Outside Japan, this has involved partnering with the Gene and Cell Therapy Institute established by Havard University in December 2022 to build an ecosystem in North America, including engaging in network building and work with local researchers aimed at resolving challenges that extend from basic research to applications. In Japan, the laboratory has embarked on joint research with Kyoto University and Rebirthel Co., Ltd. and is engaged in open innovation for automating the culturing of T cells derived from induced pluripotent stem (iPS) cells.

* Hitachi research and development strategy for fostering innovation by backcasting from 2050.

[02] Ecosystem in Japan and USA



MGB: Mass General Brigham
BWH: Brigham and Women's Hospital
MGH: Mass General Hospital

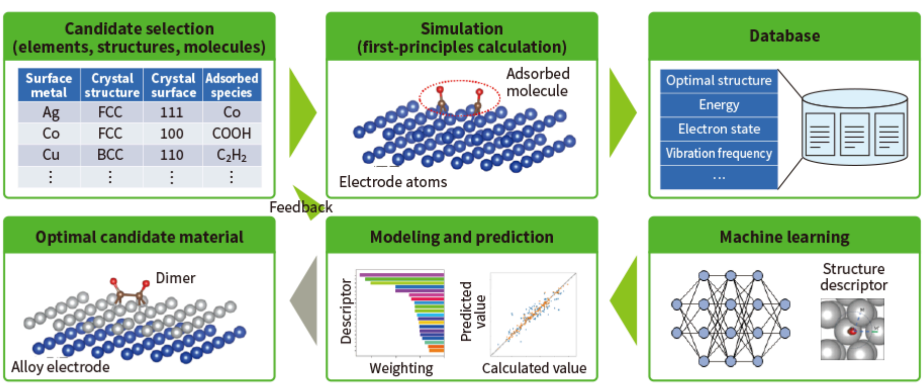
3. Surface Reaction Machine Learning System for Converting CO_2 into Useful Resources

Hitachi has been developing technology for the direct conversion of CO_2, a factor in causing climate change and global warming, into useful substances as a resource. This promising technology uses an electrochemical reaction process to capture CO_2 and convert it into useful substances. The electrochemical CO_2 reduction reaction varies depending on the atomic species and structure of the electrode material and various types of useful substances can be converted from the CO_2. This means that getting the electrode material design right is essential to the selective production of useful substances.

Hitachi has been using a machine learning model to accelerate the development of electrode materials for the selective conversion of CO_2 into useful substances such as ethylene or ethanol. It has now developed a machine learning model that improves the prediction accuracy for surface reactions. This involves running simulations using models of electrode surfaces that have adsorbed a variety of different molecules and using the features of the surface's atomic structure as the descriptors.

In the future, Hitachi aims to resolve societal challenges through technology, not only by reducing CO_2, but also by developing technologies to convert various unused resources into useful chemical substances with zero environmental impact.

[03] Surface reaction database and machine learning system



FCC: face-centered cubic
BCC: body-centered cubic

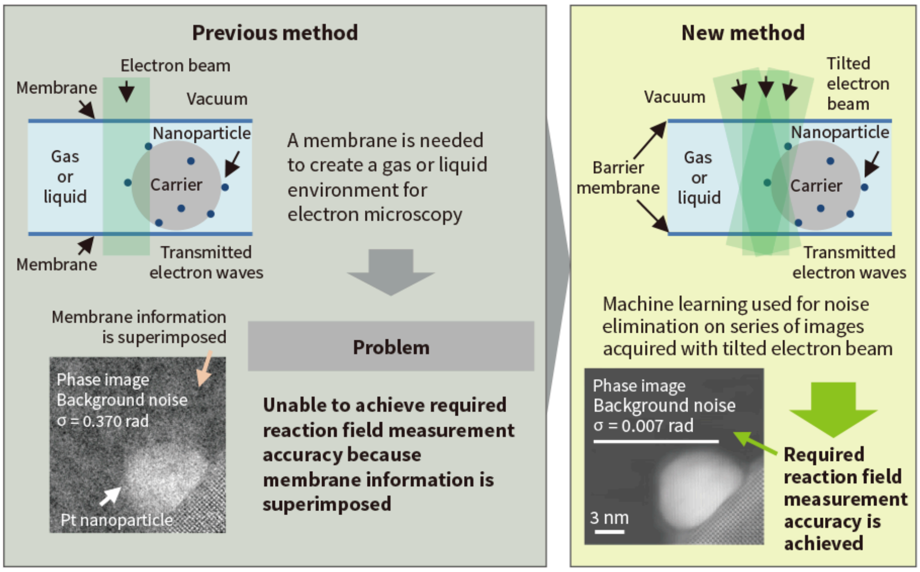
4. Chemical Reaction Field Measurement for Environmental Applications

An environmentally neutral society calls for technologies that can deliver reliable operation and improved efficiency for hydrogen and carbon recycling systems. Unfortunately, a bottleneck to development is that the factors that influence chemical reaction performance or degradation in the catalysts and reaction electrodes have yet to be fully understood. To enable the factors that influence the performance of chemical reactions to be determined and used as feedback to inform catalytic reforming as well as defect analysis and control techniques, Hitachi has developed a technique for chemical reaction field measurement that uses an electron microscope to perform atomic-level visualization of the chemical reaction fields (electric fields) in gases and liquids.

Electron holography can be used to measure electric and magnetic fields, including the measurement in vacuum of the extremely weak electric fields in a catalyst. To establish the gas and liquid conditions for the reaction, however, it is necessary to encase the gases and liquids along with the sample in a membrane. The problem with this has been that it prevents the required reaction field measurement accuracy from being achieved because information from the membrane is superimposed on the acquired transmission microscopy image. To overcome this, Hitachi developed a highly accurate measurement technique that can perform reaction field measurement in the presence of gases or liquids. This was achieved by performing electron holography measurements with a tilted electron beam and eliminating noise by applying machine learning to the series of acquired images*.

* This research was supported by Grant JPJ004596 from the National Security Technology Research Promotion Fund of the Acquisition, Technology & Logistics Agency.

[04] Problems with using a membrane in electron microscopy of gases and liquids and the reaction field measurement technique developed to solve them



5. Hitachi Kyoto University Laboratory: Consensus-Building Support for Resolving Conflicting Opinions

As societal issues are characterized by a deep-rooted mix of conflicting opinions between diverse stakeholders, overcoming such problems requires methodologies for achieving consensus. Accordingly, Hitachi Kyoto University Laboratory has developed a multifaceted process that combines mathematical modeling of group opinions with a means of identifying consensusable proposals. Rather than using methods such as voting that leave minorities dissatisfied, the goal is to reach consensus through discussion (defined here as an acceptable compromise that not everyone rejects).

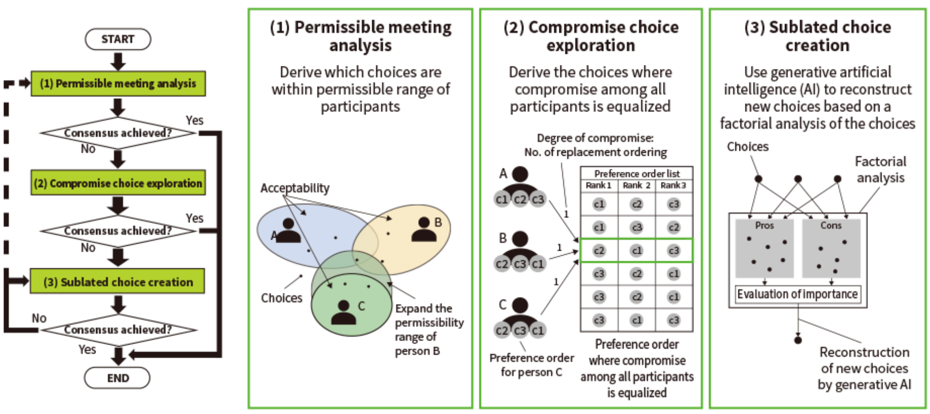
The process utilizes three functions that are based on the participants ranking multiple choices in order of preference: (1) Permissible meeting analysis for deriving which choices are within permissible range of participants, (2) Compromise choice exploration for deriving the choices that compromise among all participants is equalized, and (3) Sublated choice creation in which generative artificial intelligence (AI) is used to reconstruct new choices based on a factorial analysis of the already existing choices. By working through this sequence, the process helps people to reach a consensus[*1, *2].

Joint research with Professor Takehiro Inohara of the Tokyo Institute of Technology, technical collaboration with startups (Liquitous Inc. and AgreeBit Inc.), and field trials (Echizen City in Fukui Prefecture, and a wide-area co-creation network established between Yokose Town in Saitama Prefecture and Bandai Town in Fukushima Prefecture) are being undertaken to put the process into practice.

*1 Y. Asa, T. Kato, R. Mine, “Composite Consensus-Building Process: Permissible Meeting Analysis and Compromise Choice Exploration,” 23rd International Conference on Group Decision and Negotiation, GDN 2023, Proceedings, pp. 97–112 (2023).

*2 Winner of Best Paper Award at Joint Conference of the Japanese Society for Artificial Intelligence and the Institute of Electronics, Information and Communication Engineers

［05］Overview of composite consensus-building process



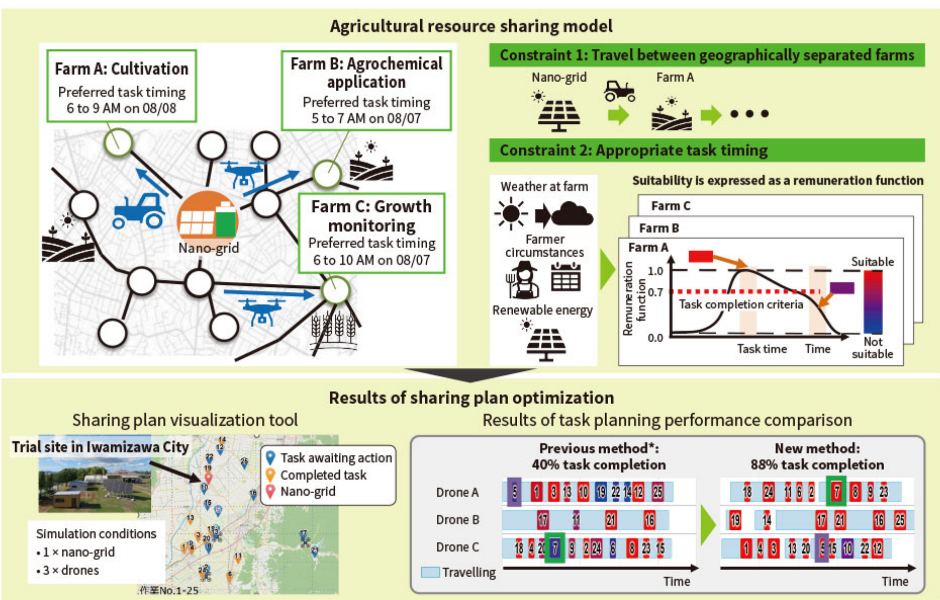
6. Hitachi Hokkaido University Laboratory: Development of Agricultural Machinery Sharing Technique Using Locally Sourced Energy

Hitachi Hokkaido University Laboratory has developed a system for facilitating the sharing of electricity and agricultural equipment that improves efficiency in the agricultural industry while also reducing CO_2 emissions through the use of locally sourced energy. By providing a way to strengthen infrastructure, including power sources, through the interoperation of an independent nano-grid located in Iwamizawa City with drones and other electrically operated agricultural machinery, the system delivers support services that reduce the burden on the agricultural workforce as it faces aging demographics and a trend toward larger scale.

To put the system into practice, the laboratory has developed a plan optimization technique for resource sharing that determines the best time for performing specific tasks while also allowing for travel between farms. It works by formulating a remuneration function for the timeline of factors affecting each task, such as the weather or electricity generation conditions on the nano-grid. In a simulation using geographical information about Iwamizawa City, the new technique delivered an improvement of more than 40% in the task completion rate compared to the previous method.

In the future, Hitachi intends to develop sharing models that will help to maintain and grow regional industries using locally sourced energy.

［06］Diagram of plan optimization technique for agricultural resource sharing and performance evaluation results



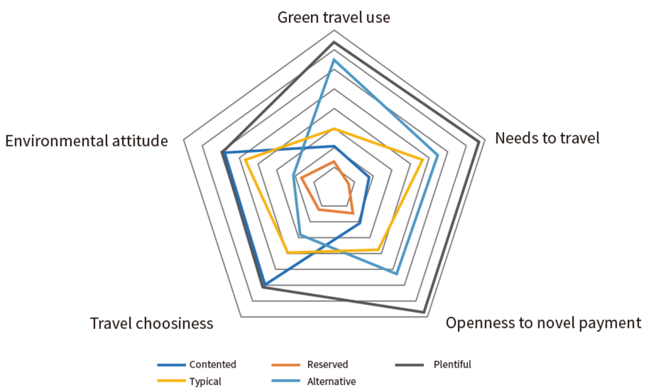
* Using Google OR-Tools. The task completion rate is calculated based on the number of tasks for which the remuneration function is 0.7 or higher.

7. Using Behavioural Science to Support Sustainable Mobility Choices

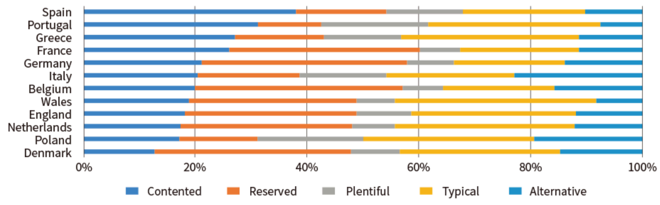
Encouraging citizens to use shared transport instead of combustion engine cars is crucial to meeting global carbon reduction targets and supports Hitachi's business goals. While infrastructure, price and reliability influence citizen's mode choices, behaviours are also driven by habits, attitudes, and social norms. Therefore, transport authorities are increasingly using behavioural science to shift behaviours. Generic, population-wide nudges have a limited effect, since individuals' decision drivers differ, so Hitachi's partnership with Goldsmiths University of London developed a segmentation to target persuasive techniques based on attitudes. A survey of 2,000 Italian adults explored behavioural drivers and factor analysis found five key influences: attitude to green modes, travel need, openness to novel payment, number of travel influences and environmental attitude. Statistical clustering revealed five segments to target services, communications, and behaviour change interventions (see Figure 7-1). Analysis of 46,000 further survey responses showed segment distribution varied between European countries (see Figure 7-2) and cities, emphasizing the need for bespoke approaches. This targeting, which can be replicated in other localities, will encourage long-term adoption of more sustainable mobility choices.

(Hitachi Europe Ltd.)

[07-1] **Segmentation of European adults by factor**



[07-2] **Segment distribution within countries**



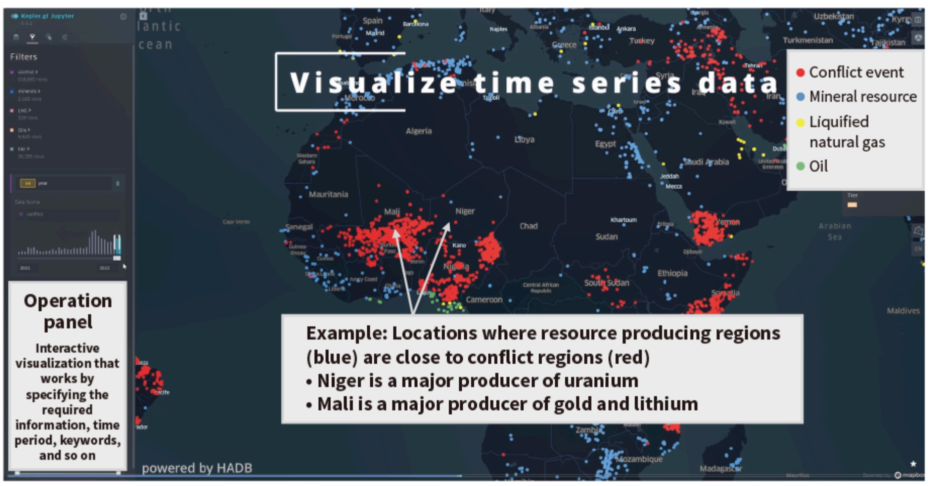
8. Institute for Digital Observatory: A Digital Observatory for Realizing Resilient Societies

Social and economic activity has been confronted with a variety of risks over recent years, including climate change and the geopolitical situation. To achieve a resilient society in 2050, Hitachi has established a research institute in partnership with the University of Tokyo, participating in joint research that involves collecting and using data observations of social and economic activity to understand, pre-emptively identify, and avoid potential risks to society.

Using the supply chains that underpin social and economic activity as subject matter, the institute is working on the interactive visualization of risks facing 15 different sectors that are difficult for individual companies to address on their own. This involves dynamically linking and identifying interrelationships between data based on insights from eight faculties at the University of Tokyo that encompass both the sciences and humanities. The plan for FY2023 is to complete a trial on the topic of conflict minerals that estimates and visualizes the risks from conflict in resource producing regions and supply lines.

Future plans involve building an ecosystem with the University of Tokyo as its hub and utilizing verified insights and data processing techniques to contribute to the supply chain platform business that forms part of Hitachi's TWX-21 service for electronic business transactions.

[08] **Supply chain risk visualization (conflict minerals)**



*Kepler.gl is an open-source web geographical information system (GIS) developed by Uber Technologies, Inc.

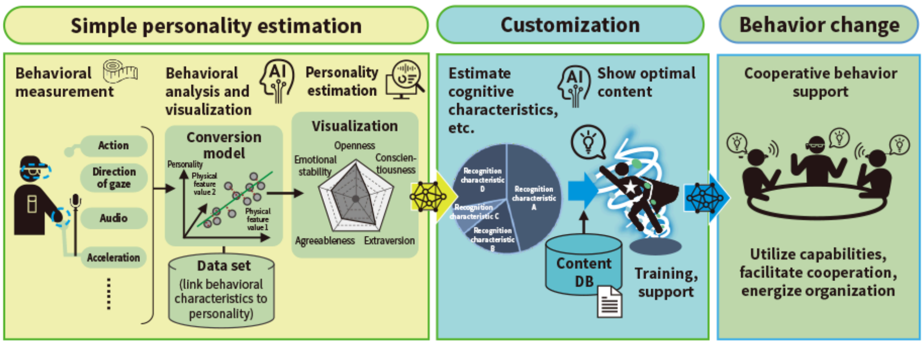
* See the list of "Trademarks."

9. Technique for Rapid Understanding of Individual Characteristics by Estimating Personality Using Behavioral Measurement and Analysis

Hitachi is engaged in research and development work aimed at utilizing an understanding of personality and people's insights as a basis for creating digital solutions that encourage vibrant teams in which everyone participates with enthusiasm. By supporting people's working and private lives, this will enable everyone to utilize their capabilities to their full extent and create energized organizations where cooperation happens more smoothly.

This work includes the study of how to use the measurement and analysis of people's behavior to estimate individual characteristics (personality) from behavioral data, and how to improve estimation accuracy. The goal is to develop quick and easy techniques for understanding people's personality traits that do not impose on the persons concerned or those around them. This is being done by constructing a conversion model that can estimate personality traits based on the behavioral data that can be acquired under the particular use case, without needing specific sensors and taking account of ethical considerations.

［09］Customized work and life support using simple personality estimation



DB: database

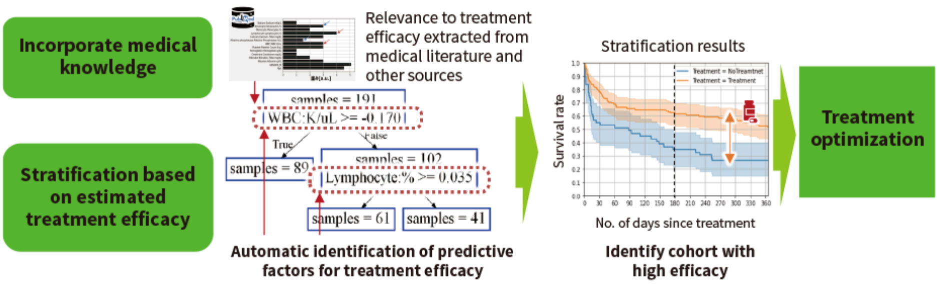
10. Patient Stratification AI for Identifying Predictive Factors of Treatment Success

While advances in medical technology are improving cancer therapy outcomes, the patient-to-patient variability of efficacy remains large. The rising cost of healthcare, meanwhile, is an issue for societies around the world, with considerable price increases in the field of oncology especially. In an effort to address this issue by optimizing treatment based on multi-dimensional real-world data that includes medical history and genomic information, Hitachi has developed an AI technique for patient stratification that can identify predictive factors for determining which patients will respond well to therapy.

The technique combines causal inference and machine learning. To estimate the benefits of treatment based on patient characteristics, it groups patients into different cohorts based on how well they will respond to treatment, directly and on the basis of interpretable conditions. The choice of which patient characteristics to use for this stratification is informed by the extent to which specific characteristics are relevant to treatment efficacy, which is determined in advance from medical literature and other sources. This provides an efficient means of identifying which factors are predictive of treatment efficacy.

Hitachi intends to further develop this technique to help create solutions that will deliver both patient quality-of-life (QoL) and the rationalization of healthcare costs.

［10］Overview of patient categorization AI



11. Design and Adoption of Enablers for Social Implementation of Cyber-systems

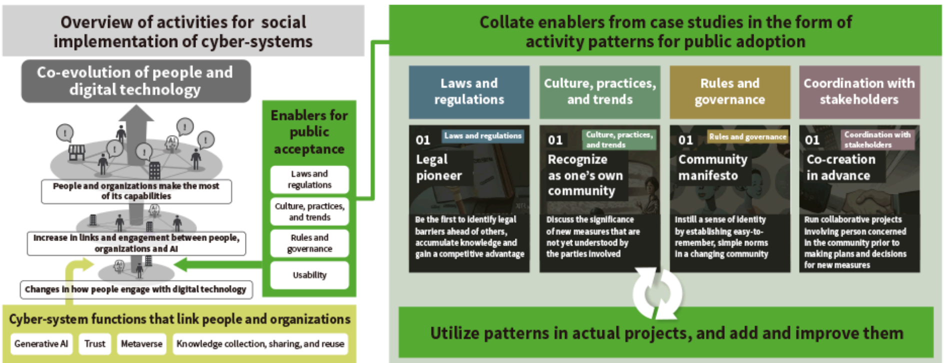
There is a need for societies in which both people and organizations can utilize cyber-systems such as generative AI, Web3, and metaverses to make the most of their capabilities. Unfortunately, among smart city projects in particular, recent years have seen numerous instances of digital solutions that have not gone on to enter practical use, having failed to gain the acceptance or engagement of end users or the authorities.

In response, the Research & Development Group at Hitachi, Ltd. initiated a project in April 2023 for Social Implementation of cyber-systems and commenced studies on how to put “enablers” in place for making cyber-systems an integral part of society. Specifically, this focuses on non-technical aspects (namely the four considerations of laws and regulations; culture, practices, and trends; rules and governance; and coordination with stakeholders), establishing knowledge for encouraging public dialogue and community building so that innovators can utilize it in all aspects of their co-creation activities. The starting point for this is to consolidate knowledge in the form of pattern language*, primarily the expertise acquired from past co-creation work by the Research & Development Group with its customers.

Hitachi intends to utilize this knowledge of how to implement cyber-systems in society for co-creation projects in areas such as transportation, energy, and finance. Further studies will be conducted to assess the efficacy of this approach and to establish knowledge platforms.

* A method for knowledge representation in urban development with resident participation proposed by the architect, Christopher Alexander, in 1977.

［11］Overview of activities for social implementation of cyber-systems and enablers for making them an integral part of society



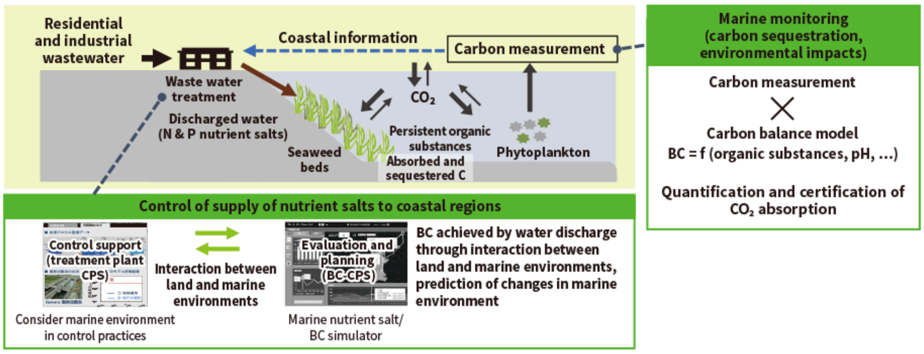
12. Enhanced Bio-DAC Business Development Using Blue Carbon Ecosystems

Taking note of the strong potential that the oceans have for absorbing CO_2, Hitachi has been developing its solutions business featuring enhanced bio-direct air capture (DAC), which utilizes blue carbon ecosystems and the nitrogen- and phosphorous-containing nutrient salts in wastewater to increase the capacity of seaweed beds to absorb carbon. To achieve this, Hitachi is testing and verifying the basic principles behind the measurement of substances in seawater. Along with a technique for controlling the supply of nutrient salts to coastal regions that draws on experience with the control of wastewater quality, this also includes the development of marine monitoring techniques in which the measurement of coastal carbon (including CO_2 and organic compounds) and a carbon balance model are used to quantify CO_2 absorption and to claim credits.

As cooperation with stakeholders is vital to this work, it has been proposed that a joint industry-government-academia project be established by a research group under the Japan Blue Economy Association (JBE), the certification agency for blue carbon credits in Japan (J Blue Credits). A study looking at putting this proposal into practice commenced in March 2023 with participation by 12 corporate, governmental, and academic entities.

Future plans include working in partnership with local government and relevant central government agencies, including the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of the Environment, to trial the technologies that have been developed, and to help with restoring marine environments and biodiversity and with making society carbon-neutral by 2050.

［12］Diagram of enhanced bio-DAC solution



BC: blue carbon
CPS: cyber-physical system

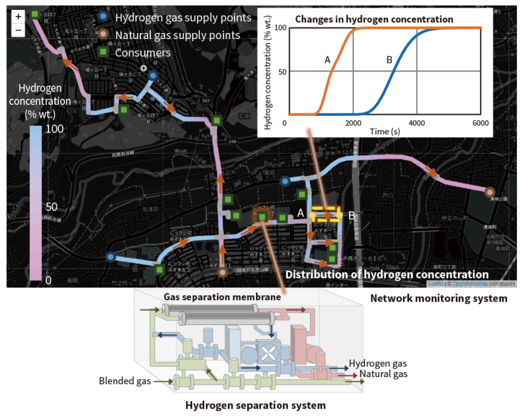
13. Development of Transportation Methods for a Hydrogen Economy

The need to reduce emissions of greenhouse gases globally to address the problem of global warming has led to growing interest in hydrogen. To achieve a hydrogen economy, measures will be needed to resolve physical mismatches in its supply and demand across geographically separated producer and consumer areas. This has included plans in Europe and Australia to blend hydrogen gas with natural gas for transportation through existing distribution networks.

To transport hydrogen at low-cost, Hitachi has developed, (1) a distribution network monitoring system and (2) a hydrogen separation system. Network monitoring determines where and in what quantity to inject hydrogen gas by visualizing the spatial distribution and changes over time in the concentration and flow of gas in the network. This is done by modelling it as a one dimensional compressible flow and using implicit methods for the high-speed calculation of gas flow. The hydrogen separation system, meanwhile, uses a gas separation membrane to separate the blended gas into hydrogen and natural gas, thereby providing customers with their desired gas concentration and flow rate based on the concentration of hydrogen in the incoming blended gas.

Hitachi intends to continue testing these new technologies to help make a smooth transition to a hydrogen economy.

［13］Hydrogen transportation method



* The figure shows hydrogen concentrations for the simulated injection of hydrogen based on publicly available information on gas pipes. There are no plans for the actual injection of hydrogen.

14. Commencement of Phase 3 at Hitachi-UTokyo Laboratory

Hitachi-UTokyo Laboratory commenced Phase 3 of its co-creation with the University of Tokyo in April 2023. The energy project commenced exchanges between the Hitachi-UTokyo Laboratory and the Hitachi-Imperial Centre for Decarbonisation and Natural Climate Solutions on the basis of a May 2023 agreement reached between the University of Tokyo and Imperial College London to strengthen their partnership in clean tech and energy research. In the field of energy systems, the laboratory has been deepening its knowledge of UK initiatives that are at the forefront of rule-making along with more in-depth debate on topics such as challenges and solutions for the greater use of renewable energy. Similarly, the Habitat Innovation Project being undertaken in the field of urban development has been working on realizing 24-hour value maximization for big city residents under the title “Urban Well-being by Digital and Design Together.”

The laboratory intends to continue publicizing its work and proposals, including by hosting forums and exhibiting at smart city expos.

［14］Signing ceremony for strengthening of clean tech partnership between University of Tokyo and Imperial College London

15. Hitachi–AIST Laboratory: Formulation of Grand Design for Achieving Future Circular Economy

Hitachi–AIST Circular Economy Cooperative Research Laboratory was jointly established by the National Institute of Advanced Industrial Science and Technology (AIST) and Hitachi to work on the circular economy. It is engaged in the formulation of a grand design of what such a society should look like and what needs to be put in place to achieve it.

The goals of this work are to devise future scenarios that address the question of how a circular economy will be achieved in Japan and elsewhere, to develop the partnerships that will be essential to the transition to such a society, and ultimately to formulate international standards and present policy proposals to government. The work to date has involved a review of the current situation based on literature surveys, the identification of 12 “hot topics” relating to circular economies, and consideration of the specific matters raised in the future scenarios based on interviews with 11 external experts. Upcoming work includes scenario planning to identify future possibilities and incorporate these into the grand design.

[15] Twelve hot topics relating to circular economies

Future directions and challenges were collated in the form of topics worthy of attention. These were identified by PEST analysis of expert opinions, proposals, and publications as well as government reports from Japan and overseas.

1	Integration and decoupling of economies, resources, and the environment	7	Environmentally aware design, eco-design
2	Common rule-making, systems and standardization, and soft law	8	Changes in international trade and waste exports (rare materials, etc.), border problems
3	Behavior change by consumers, awareness raising, lifestyle change	9	Recycling businesses, human resource development
4	Role of corporates, changes to business models	10	Disclosure of supply chain information and high-level management
5	Circularity indicators (time-based environmental indicators, smoothness of flow)	11	Efficient recycling of waste
6	ESG investment and financial policies	12	Adapting to regional characteristics

PEST: politics, economy, society, and technology
ESG: environment, social, and governance

16. Hitachi-Imperial Centre for Decarbonisation and Natural Climate Solutions: Joint Workshop with Hitachi-UTokyo Laboratory

Hitachi established a joint research Centre with Imperial College London in 2022 to work on the research and development of decarbonization and natural climate solutions (measures that use nature to address climate change). The Centre began work in earnest in 2023. Based on a May 2023 agreement reached between the University of Tokyo and Imperial College London to strengthen their partnership in clean tech and energy research, Hitachi-UTokyo Laboratory and the new joint research Centre partnered to host an international workshop. Set against the backdrop of anticipated growth in the adoption of renewable energy in response to the challenge of decarbonization that is an issue for the entire world, the workshop provided a forum for discussions that included the respective standpoints of Japan and the UK and their technical measures.

In addition to producing reports or whitepapers informed by what came out of the workshop, future plans include contributing to the education of the next generation of scientists and engineers.

[16] Joint workshop with Hitachi-UTokyo Laboratory