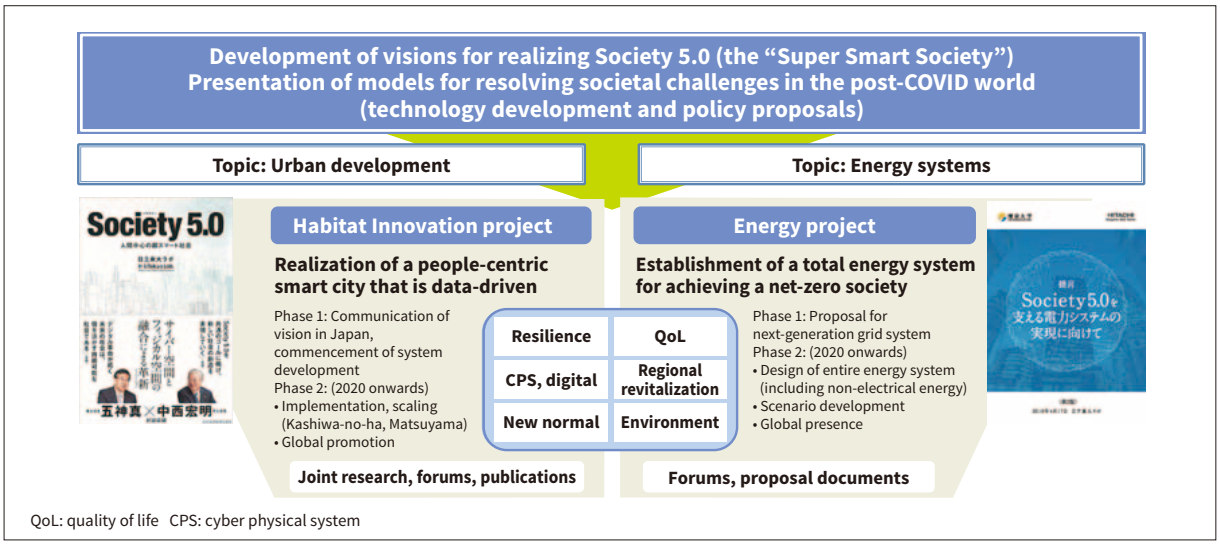
Exploratory Research



1 Work by Hitachi-UTokyo Laboratory

1 Hitachi-UTokyo Laboratory: Phase Two of Energy Project

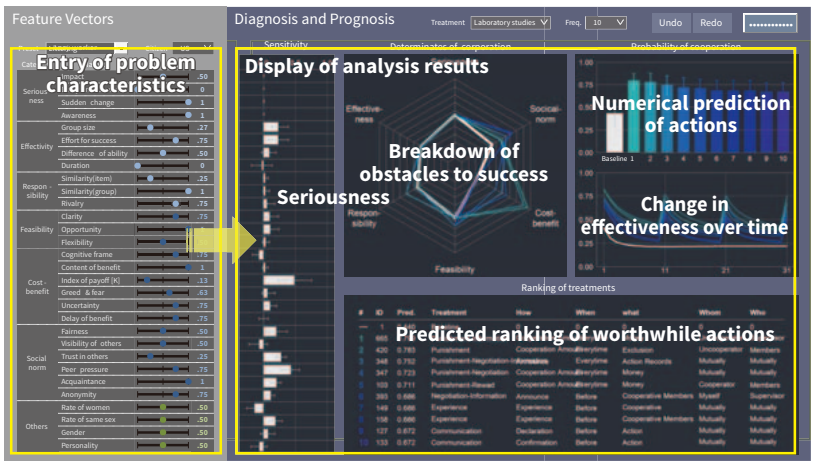
In April 2020, the Hitachi-UTokyo Laboratory commenced phase two of a collaborative creation (co-creation) partnership with the University of Tokyo. One aspect of this partnership is the energy project, which since 2016 has been developing a vision for the future energy systems that will underpin Society 5.0. Activities to date including holding public forums and making proposal documents widely available. Phase two will involve developing scenarios for what society should be in 2050, including action on climate change, and forging a vision for the energy systems needed to reach this goal.

One event undertaken as part of this project was a June 2020 round table with the President of the University of Tokyo, Makoto Gonokami. The event shed light on potential scenarios for the technologies that will underpin society, with a wide-ranging discussion covering aspects that have not been explored in any great depth by past energy strategies, and how these relate to energy, including the social context of energy and its close relationship with how people live and the information society. Along with holding public forums, the Hitachi-UTokyo Laboratory also plans to expand activities associated with communicating its ideas globally.

2 Hitachi Kyoto University Laboratory: AI Trained on Psychology

It has been common in the past to advocate mechanistic or policy-based approaches to the sort of societal challenges that arise out of human behavior. The spread of environmental "eco" products are an example of the former and environmental taxes of the latter. Unfortunately, such measures can only go so far in addressing the many challenges facing society. This has led to greater interest over recent years in psychological approaches that encourage cooperative action. Giving people an emotional motivation to save electricity is one example. The difficulty with this approach has been that a professional analysis and design needs to be undertaken for each problem if the measures are to be effective, something that takes a lot of work to accomplish.

To address this problem, the laboratory has developed an artificial intelligence (AI) that learns from psychology, being trained on large amounts of data from psychological experiments, and can undertake such analyses in place of an expert. As the AI can conduct extensive simulations encompassing a wide variety of human motivations, it is also a useful means of screening solutions for ethical problems. The widespread application of this technique to the solution of societal challenges will help bring about a society where cooperation happens spontaneously.



2 Prototype analysis software screen

come to an agreement with Morinaga Milk Industry Co., Ltd. and Hokkaido University to develop intellectual property for expanding programs of health checks for mothers and children, making this publicly available to help create a sustainable society in which mothers and children can enjoy healthy lives.

In the future, Hitachi Hokkaido University Laboratory intends to work towards regional economic development and the creation of a society in which everyone can be healthy and secure through its involvement in urban developments that integrate health, nutrition, agriculture, and energy, including the development of small distributed direct-current grids that alleviate regional disparities and expansion of the health data analysis platform to encompass remote medicine.

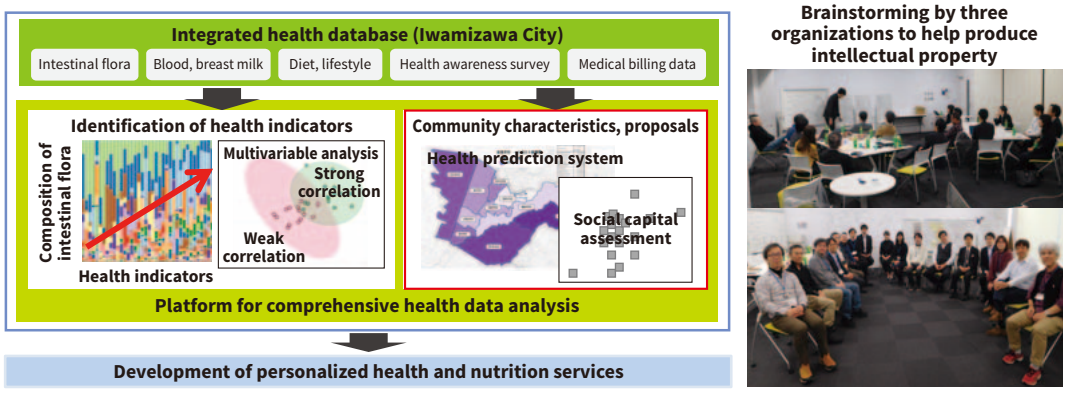
3 Hitachi Hokkaido University Laboratory: Community Development Platform for Regions at Forefront of Future Challenges

Hitachi Hokkaido University Laboratory has been working with Hokkaido University and other stakeholders on the co-creation of a community development platform for facilitating regional economic development and greater convenience to help address societal challenges in Hokkaido, including depopulation, aging, and the low birth rate.

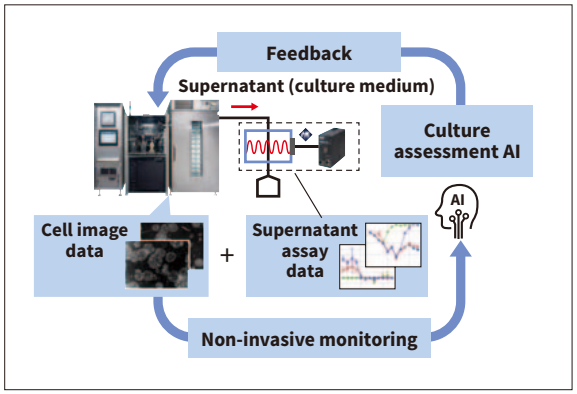
The laboratory has developed a platform for comprehensive health data analysis that can be used in partnership with local government to establish health policies. This takes consideration of community characteristics highlighted by the analysis of medical bills and social capital, and also the factors that influence child growth and development identified from the health and living practice data collected by a study of mother and child health conducted in Iwamizawa City. The laboratory has also

4 Hitachi Kobe Laboratory: Regenerative Medicine

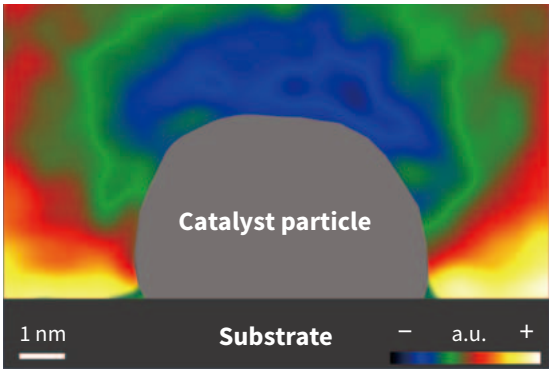
Regenerative medicine is seen as an innovative new approach that, through the use of cells and tissue, can lead the way to cures for diseases that in the past have lacked effective treatments. While past practice for the manufacture of cells for regenerative medicine has involved manual culturing by expert technicians, this is costly and poses reliability and safety issues in relation to quality. To overcome these problems, Hitachi has developed



3 Platform for comprehensive health data analysis established in Iwamizawa City



4 Schematic diagram of intelligent automated cell culturing



5 Electric field in catalyst particle observed using atomic-resolution holography electron microscope

techniques for completely closed automated cell culturing and has made it available in the form of automated cell mass culture systems for commercial production.

Work is now underway on the next generation of technology for intelligent automated cell culturing. Past culture systems have worked by programming the device to follow culturing processes that have been formulated on the assumption of manual preparatory work by a technician. In contrast, intelligent automated cell culturing achieves the reliable and efficient production of high-quality cells by using systems equipped with AI to assess the condition of the cells for themselves, also utilizing automatic feedback control to maintain optimal culturing conditions.

Such systems need to be able to assess cell condition in a non-invasive way and to perform measurements in real time. In 2019, Hitachi Kobe Laboratory was commissioned by the Japan Agency for Medical Research and Development (AMED) to identify and assess the suitability of indicators that can be used to assess cell condition directly, using cell images acquired during culturing together with a comprehensive assay of the culture supernatant.

Part of the work described in this article was conducted as a Basic Technology Research Promotion Project of the New Energy and Industrial Technology Development Organization (NEDO) and AMED project JP20be0404010.

5 Observation of Electric Fields in Catalysts Made Possible by More Sensitive Electron Holography

The elucidation of physical principles is essential to improving the functionality of the products that underpin society. Electron holography is a useful imaging technique for this purpose, being able to make direct observations of the microscopic electromagnetic fields present in materials that are a determining factor in their properties. Very high sensitivity is needed to observe these weak electromagnetic fields in nano-scale regions, including how they vary with time. Hitachi has worked with Kyushu University and Osaka University to develop a technique capable of observing electromagnetic fields with sensitivity at the level of individual electrons[*1].

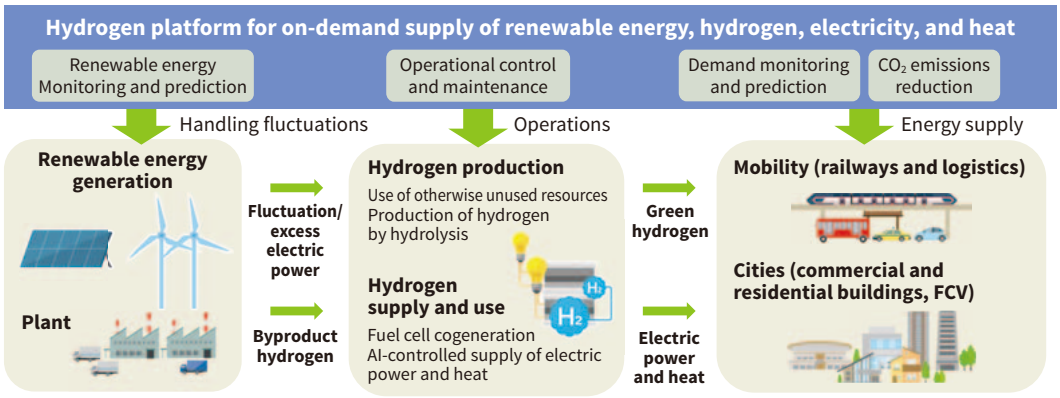
The new technique combines electron holography with analytical methods that were developed or incorporated from information science. These include: (1) Use of a wavelet hidden Markov model (WHMM) for noise elimination, and (2) Automatic collection of large amounts of data with image analysis by AI and machine learning (an enhanced form of cumulative averaging).

The technique was used with Hitachi's atomic-resolution holography electron microscope[*2] to observe electric fields in catalyst particles. Catalytic reactions play an important role in overcoming societal challenges in the environmental and energy fields, with uses in hydrogen applications and the transformation of carbon dioxide (CO_2) into fuel. It is anticipated that the new technique will contribute to the development of innovative catalysts that can reduce costs and improve the efficiency of catalytic reactions by enabling the study of localized electric fields in catalytic materials, thereby helping to elucidate how they work.

*1 Developed with assistance from the Core Research for Evolutional Science and Technology (CREST).
*2 Developed with assistance from the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST).

6 Hydrogen Platform for Zero-emission Energy Systems

To facilitate the creation of a zero-emission society through the wider adoption of renewable sources of energy such as wind and photovoltaic power generation, work is ongoing on the development of green energy



FCV: fuel cell vehicle

6 Hydrogen platform encompassing electricity, heat, and fuel

systems that make use of hydrogen, an element recognized for its a potential as a store of renewable energy.

In particular, this has involved the development of control techniques for the highly efficient production of hydrogen from fluctuations in renewable energy or other forms of excess electric power, and of techniques for using fuel cells for the efficient delivery of electric power or heat from hydrogen. Furthermore, Hitachi is establishing hydrogen energy platforms that balance energy supply and demand through interoperation with other sectors like mobility (including vehicles and railways) as well as district electricity and heat supply and the maintenance of grid stability in the presence of a large installed capacity of renewable energy to optimize hydrogen derived from renewable energy.

Through activities that include demonstration projects for trialing these hydrogen-using green energy systems and hydrogen platforms in partnership with industry, academia, and government, Hitachi intends supply such systems both in Japan and overseas.

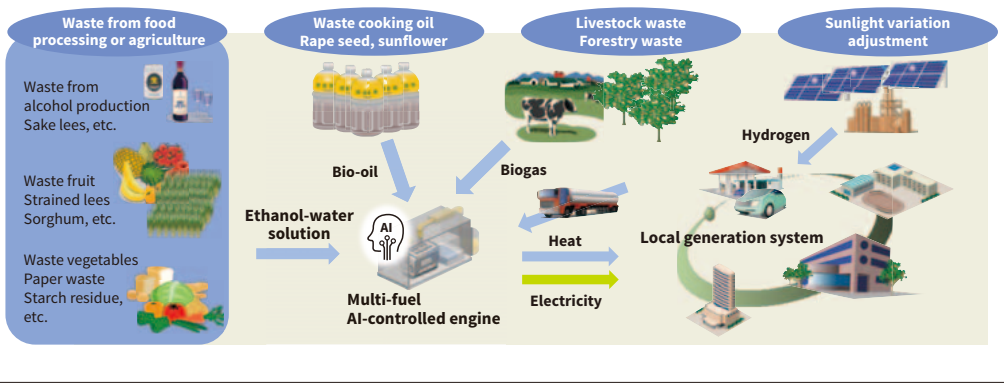
7 Establishment of Happiness Planet, Ltd. to Develop New Industry Based on Happiness Measurement

Advances in digital technology and globalization over recent years have been accompanied by rapid change in the business environment. In particular, along with rising concerns about happiness and health around the world as the spread of COVID-19 has prompted a shift toward work-from-home and other remote working practices, how to further enhance the sense of wellbeing that serves to underpin internal communications, productivity, and creativity has also become an important challenge for companies.

To help resolve this societal issue, the Center for Exploratory Research has undertaken research into the quantitative measurement of happiness based on data from accelerometers worn by staff and has developed an app called Happiness Planet that encourages them to adopt a positive attitude. The effectiveness of the app has been tested in a trial involving about 4,300 participants across 83 different companies. The service was launched in July 2020 with the establishment of a new company, Happiness Planet, Ltd.

In the future, Hitachi plans to pioneer a new happiness and wellbeing industry by putting this measurement technique to use in a wide range of applications, not only to support corporate management but also in areas like urban development, nursing and healthcare, and house-hunting.

7 Happiness Planet app



8 Zero-emission energy system able to use hydrogen or biofuel

8 Engine System Able to Run on Hydrogen and Biofuel to Help Achieve Zero Emissions

To help achieve zero emissions, Hitachi is developing a hydrogen mixed-fuel engine system able to make highly efficient use of both hydrogen and biofuel.

This new clean engine system is able to run on a range of fuels, including biofuels like bioethanol and biogas as well as hydrogen. The system is also capable of running on ethanol that contains a high proportion of water (an ethanol concentration of only around 7 to 12%), a fuel that can be produced by fermentation alone from waste material such as sake lees or discarded fruit.

The ability to generate electric power with high efficiency from such a wide range of fuels is achieved by the use of AI in engine control and the use of engine heat to modify the fuel prior to combustion. This makes it viable to use not only hydrogen or conventional fuels for this purpose, but also whatever biofuels are available in the local area. Efficiency can be further improved through the utilization of waste heat recovered from the engine.

By having these technologies play a core role in making efficient use of a mix of different fuels, including hydrogen derived from renewable energy and biofuels produced from waste materials, Hitachi is seeking to combine zero emissions with lower energy cost.

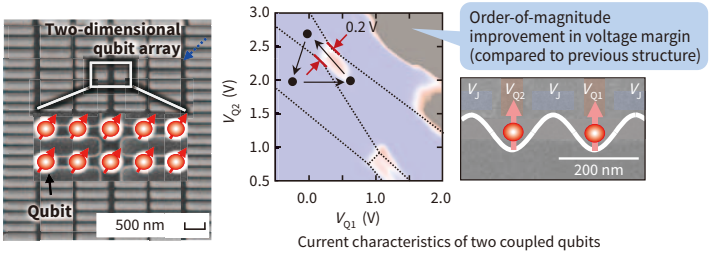
9 Large-scale Integrated Quantum Computing

Quantum computers are recognized as a new approach to computing that can solve problems that are intractable using a conventional computer. The challenge, however, is to achieve the high level of integration (in the order of millions of qubits or more) needed for the practical computational tasks demanded by customers.

Hitachi Cambridge Laboratory has recently played a central role in the development of core array technology that combines fundamental quantum physics with a control technique for large semiconductor memories to control a large two-dimensional grid of silicon qubits on a semiconductor chip. A prototype of the proposed array structure was produced and its operation tested to demonstrate that it is possible to fabricate a correctly positioned two-dimensional array of quantum dots, which are able to serve as traps for single electrons. The utility of the new structure concept was also demonstrated by an order-of-magnitude improvement in the operating voltage margin compared to the previous structure. This voltage margin plays an important part in ensuring the reliable operation of large quantum dots.

In the future, Hitachi intends to continue working toward the early practical realization of quantum computing through developments that combine hardware and software, utilizing open innovation practices that include participation in large national projects ("moonshot" research and development initiatives).

Part of the research described in this article drew on the results and outcomes of joint research with the Tokyo Institute of Technology.



9 Core technology for silicon qubit arrays