

Exploratory Research

1 Hitachi-UTokyo Laboratory: Habitat Innovation Project

Through the Habitat Innovation Project, the Hitachi-UTokyo Laboratory is engaging in collaborative creation with The University of Tokyo on spreading their vision of what cities will look like in Society 5.0, identifying the challenges that will need to be overcome to achieve this, and developing the policies and technologies for doing so.

The cities of the future envisaged by the project will be able to solve the challenges they face while also improving quality of life (QoL) for individuals, with the city's data providing a basis for this activity. As achieving this will require the design of systems for handling data, the development of ways of using it, and the building up of knowledge about the public acceptance of technology, these are the main focus of the project. In parallel with this, work is also proceeding on the practical implementation of policies and technologies for resolving issues in actual cities.

In Matsuyama City in Ehime Prefecture, the site of one such demonstration project, Hitachi is working with Urban Design Center Matsuyama (UDCM) on participatory urban development through Cyber-PoC for Cities, an application of NEXPERIENCE to urban management. A visualization tool was installed at the

center in March 2019 and a workshop was held with local businesses.

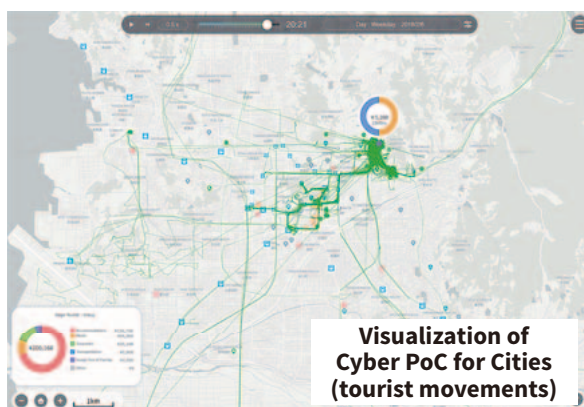
In the future, Hitachi plans to draw on the knowledge gained from further workshops to develop practices for participatory urban development and to identify the requirements for data platforms for data-driven urban development.

2 Hitachi Kyoto University Laboratory: Imagination 5.0

Hitachi Kyoto University Laboratory is engaging in collaborative creation with Kyoto University on research that seeks to identify the social issues that Japan will face in the future and consider scenarios for how to overcome them.

Based on discussions held in 2018 with Kyoto University researchers and students from a variety of specializations, this work hypothesized that social issues arise from the fears people experience when things like human life, property, human rights, or identity come under threat, devising the concept of "Crisis 5.0," a situation in which people suffer a three-fold loss, with "nothing to believe in," "nothing to rely upon," and "nothing to do."

Following studies involving activities such as workshops on ways of avoiding Crisis 5.0 with students



PoC: proof of concept



Workshop in progress

1 Hosting of urban development workshop



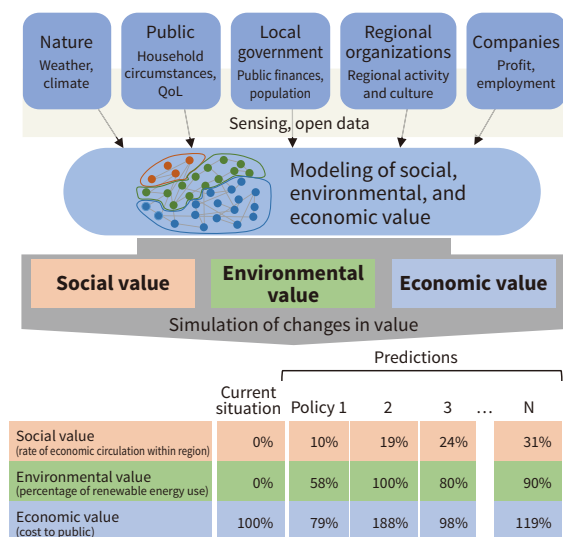
2 Workshop on identifying ways of avoiding Crisis 5.0

who will still be around to deal with these issues in 2050, a conclusion was reached that people taking the initiative to come up with ways of dealing with these issues was vital and that a readiness to use one's imagination was the key to this happening. This was dubbed "Imagination 5.0."

The plan for the future is to publish suggestions for what companies and universities can do to foster a readiness to use one's imagination.

3 Hitachi Kyoto University Laboratory: Systems in Harmony with Society Based on Social, Environmental, and Economic Value

Hitachi Kyoto University Laboratory is working with Kyoto University on a joint research project covering both the sciences and humanities entitled, "Exploration of Basics and Theory Based on an Understanding of Humans and Culture."



3 Trial quantification of three forms of value using actual data

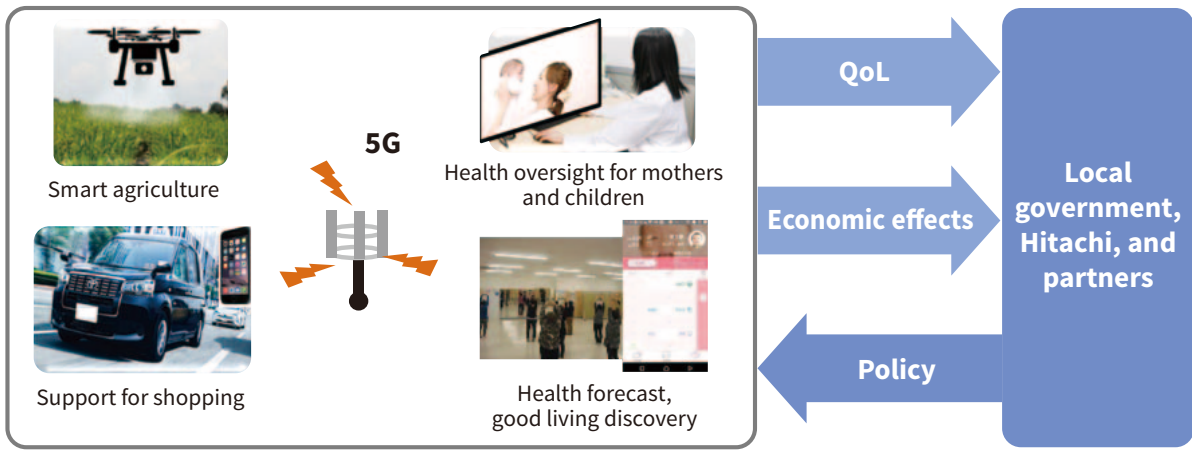
While Hitachi has committed itself to managing in a way that focuses on social, environmental, and economic value, improving all three of these at once is a major challenge. An emphasis on economic value (efficiency), for example, tends to take the focus away from social value (fairness). Hitachi Kyoto University Laboratory is engaged in initiatives for improving the well-being of society as a whole by incorporating social norms and an ethical approach into the actions of individuals and companies in advance with the aim of achieving a suitable balance between society (fair distribution), the environment (sustainability), and economics (production efficiency). One example is a study into the potential for using renewable energy to boost local economic activity and bring greater vitality to Takaharu, a town in a mountainous part of Miyazaki Prefecture. Social norms and ethics arise out of mutual expectations and consent rather than imposing rules on IT systems, for which interactions between people and consensus building are key. Accordingly, the project is trialing a system for establishing a consensus on the measures associated with installing renewable energy generation.

As cutting back on urbanization is one of the keys to establishing a sustainable way of life, Hitachi intends to help enable a regionally distributed society through support for regional revitalization.

4 Hitachi Hokkaido University Laboratory: New Public Services for Regions at the Forefront of New Challenges

Hitachi Hokkaido University Laboratory has been working on solutions for regions at the forefront of new challenges by undertaking demonstration projects and research activities in partnership with local governments to overcome societal challenges in Hokkaido such as depopulation, low birth rate, aging, and regional development.

In the past this has involved working with the Center of Innovation (COI) at Hokkaido University to investigate the intestinal environments of mothers and children in the town of Iwamizawa, collecting and analyzing health data over an unprecedentedly long period of time, in order to identify factors that influence the growth and development of children and the causes of various illnesses. This research represents one



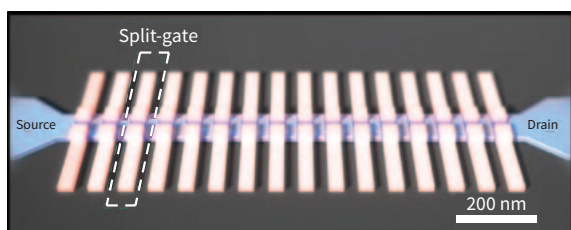
4 Smart project for making Iwamizawa City a better place to live

example of a technique for the analysis and prediction of human data that can be used to uncover relationships between QoL and the problem of population decline.

In the future, Hitachi will participate in a smart project that promotes better living in Iwamizawa. The project was launched to overcome various challenges faced by the community in order to make it a better place to live. The aim is to implement measures for boosting the local economy that support the living and healthcare infrastructure for residents so that they can live healthy and secure lives by developing public services through the collaboration of the private sector and local government, rather than relying on public services or funding.

5 Si-Quantum Computing for Information and Communication Technology Innovation

The miniaturization process of microprocessor technology is reaching its fundamental limits, posing a challenge for further increases in computational performance. A shift of focus away from reduced transistor size and toward new forms of computing is hence



5 Patented 16-qubit module based on silicon nanowire split-gate technology

paramount to solve this crisis. The Hitachi Cambridge Laboratory (HCL) explores quantum computing, a computing paradigm that will outperform conventional computers in tasks such as database searches, material simulation, and general optimization.

The HCL designs and validates hardware for a scalable quantum computer based on electron spins in silicon, a technology that will reduce the cost of development and facilitate large-scale manufacturing. Hitachi's patented technology is based on split-gate field-effect transistors that can be used to trap individual spins (qubits) and operate on them. Recently, the HCL has demonstrated the fastest qubit readout method and showed hybrid integration of these quantum devices with conventional transistor circuitry all operating at the low temperatures required to perform calculations.

The HCL's main target now is to scale this successful technology to build a sufficiently large quantum processor that will help solve societal challenges. The HCL is building a large ecosystem of researchers across the world to accelerate the rate of development.

6 Research into Regenerative Medicine at Hitachi Kobe Laboratory

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. In particular, induced pluripotent stem (iPS) cells, which were developed by Professor Shinya Yamanaka of Kyoto University and can be harvested with comparative ease from skin or



6 Automated cell sheet culture equipment

blood, have the characteristic of pluripotency, which means they are able to differentiate into a large number of different cell types. This has led to their being used in new clinical research and testing that has got underway in recent years to address a wide variety of conditions.

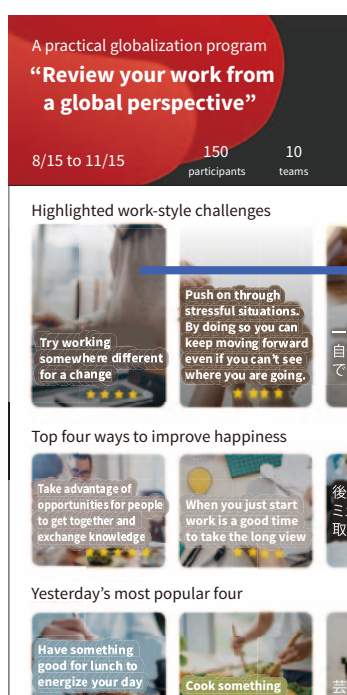
In March 2019, Hitachi in collaboration with Dr. Masayo Takahashi and her team at the Institute of Physical and Chemical Research (RIKEN) was the first in the world to successfully automate the culturing of sheets of retinal pigment epithelium (RPE) cells derived from human iPS cells, which was done using

Hitachi's original, completely closed automated culture equipment for cell sheets. In doing so, the culturing system solved the problems of cost and unstable quality that were issues with the conventional method, manual culturing. It is hoped that this will find applications in the transplantation of RPE cell sheets as a means of treating age-related macular degeneration, an eye disease that is difficult to treat, and also that it will contribute more widely to the spread and progress of regenerative medicine. The work was published in PLOS ONE, a scientific journal, on March 14, 2019.

Note that 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), the Advanced Interdisciplinary Center for the Establishment of Regenerative Medicine, part of the Creation of Innovation Centers for Advanced Interdisciplinary Research Areas Program of the Ministry of Education, Culture, Sports, Science and Technology.

7 Happiness Planet

It is known that happier workplaces are more productive. Happiness Planet is a service that helps build organizations that act on management policy in a positive



Topic and duration set by employer

Employees state their personal objectives for each day



The employer sets the topic and duration while employees select and enter daily work objectives in accordance with the topic. As whatever they enter is shared with other staff, employees get a sense of moving forward together.

7 Use of smartphone app

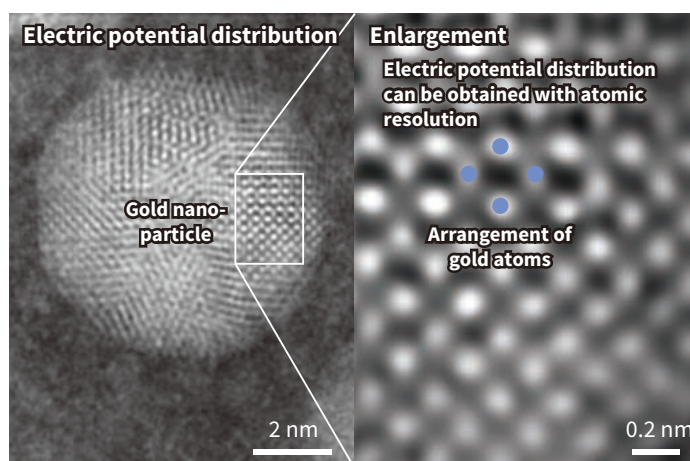
and self-directed way. While it is the case that new management policies can bring about uncertainty and confusion among employees, having each employee use an app to perform a small action each day can bridge the gap of understanding between management and the workforce and foster an environment where employees have the confidence to take action on management policy at their own initiative.

The app works by having employees choose a daily objective (work-style challenge) and making this known to the rest of the team, and by making objective measurements of the state of the organization based on “happiness” (in the form of bodily rhythms). These functions allow staff to seek out the working practices that work best for them, getting feedback on the changes as they go in a way that makes it feel like a game. To date, more than 3,000 people from a wide range of companies have participated in trials of the service. Of these, more than 90% reported that they undertook their goals on their own.

Hitachi plans to conduct proof of value (PoV) trials for corporate customers who will pay to use the service.

8 Upgrade of Atomic-resolution Holography Electron Microscope for Use in Materials Innovation

Innovation in materials will be needed to help reduce CO₂ emissions to prevent global warming. An important requirement for achieving this is the ability to make high-sensitivity observations with atomic resolution of the electromagnetic fields inside and around materials that confer their functionality.



8 Atomic-resolution holography electron microscope (left) and image of electric potential distribution on gold nano-particle (right)

Hitachi in partnership with Kyushu University and Osaka University is developing ways to achieve a ten-fold improvement in electromagnetic field measurement sensitivity with the aim of being able to measure the electric potential in a catalyst reaction field with single-electron sensitivity^{*1}. The aim is to achieve this by combining the collection of large amounts of data using a technique for automatically acquiring electron holograms with the use of deep learning for image classification and integration. Using the ultra-high-voltage holography electron microscope with atomic-resolution^{*2}, images of electric potential distribution have been successfully obtained by automatically collecting 10,000 separate electron holograms with atomic resolution (up to 0.2 nm).

The image classification and integration technique is being developed in parallel with this work and is on track to achieve the targeted improvement in electromagnetic field measurement sensitivity. The intention is to contribute to innovation in materials to support sustainable societies by elucidating the mechanisms by which functional materials such as catalysts and batteries exhibit their properties.

^{*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).

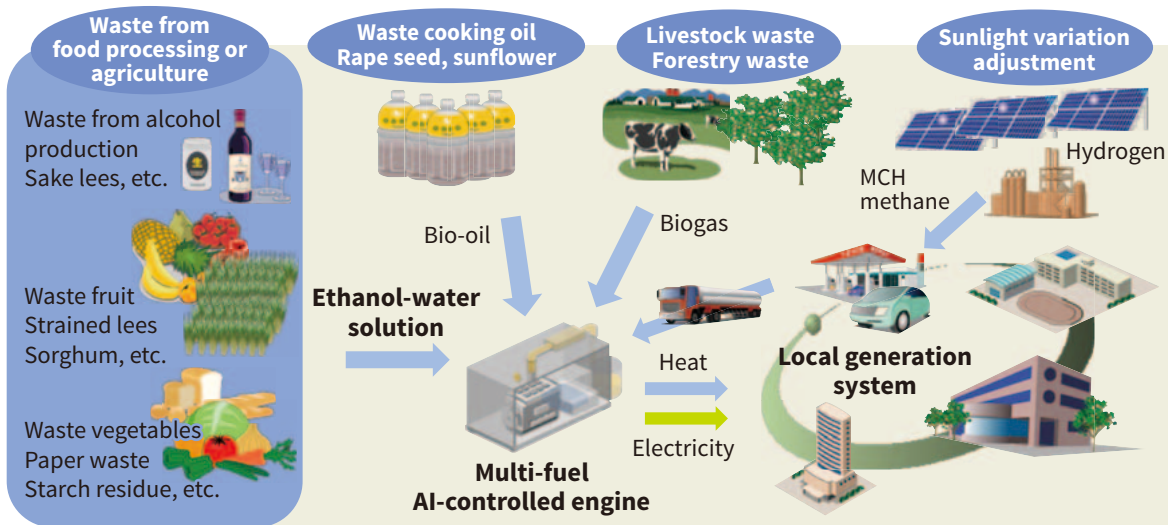
9 Local Power Generation from Waste Biomass and Hydrogen

Hitachi is developing multi-fuel engine systems able to make efficient use of biofuels and hydrogen to enable society to take advantage of the energy cycle. These

engine systems are able to burn a number of different fuels in addition to conventional petroleum products, including bioethanol, biogas, and hydrogen. It is also possible to fuel the engines with ethanol-water solutions with a high water content (ethanol concentrations of only about 7 to 12%) that can be produced from waste products such as sake lees or leftover fruit using only fermentation. Moreover, the use of artificial intelligence (AI) for engine control and the use of engine exhaust heat for fuel reforming make it possible to

generate electric power from these diverse fuels with high efficiency, allowing biofuels to be chosen based on what is locally available.

By having these technologies play a core role in combining a wide variety of biofuels manufactured from waste and by using them efficiently, Hitachi aims to contribute to simultaneously recycling resources and cutting energy costs while also helping society more quickly establish an energy cycle.



MCH: methylcyclohexane

9 Outline of how waste biomass can be put to good use