Hitachi Review

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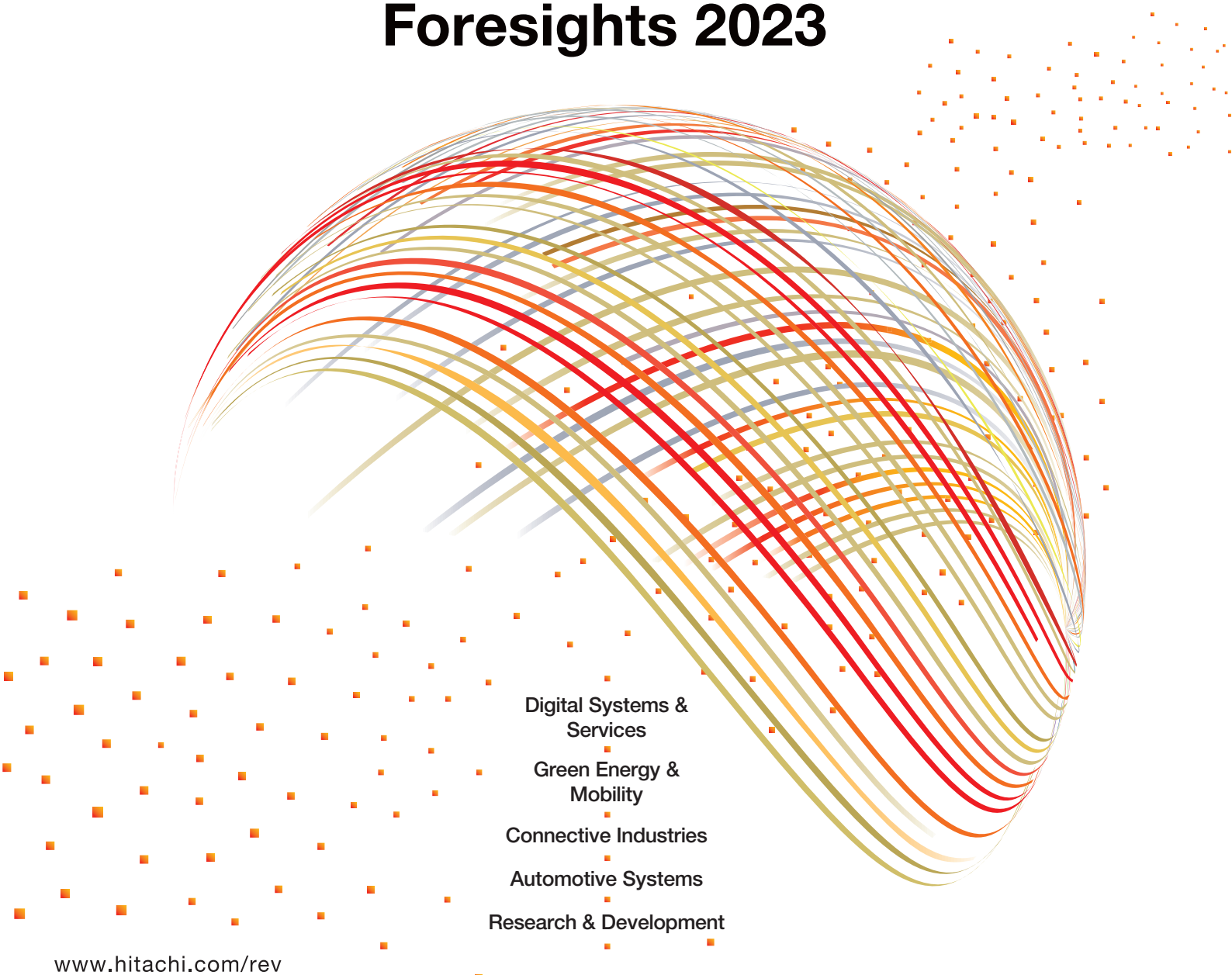
Technology & Innovation Foresights 2023



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Realizing a Sustainable Society with Data and Technology

I would like to thank you for your ongoing support of Hitachi Group activities.

While abnormal weather events and other natural disasters continue to occur around the world, the COVID-19 pandemic, rising prices, and heightened geopolitical risks are creating a state of uncertainty both in people's lives and in corporate activities. In terms of the economic outlook, many countries are facing a downturn with rapid inflation and difficult conditions which appear likely to continue for some time yet. On the other hand, once we make it through these challenging times, we can look forward to a new era of growth. For this to happen, however, it is essential that we acquire an accurate understanding of how society and the world around us are changing, and that we share a clear view of how we can reach the future to which we aspire.

In 2022, Hitachi published its Mid-term Management Plan 2024, which positions the following three years as a "mode change for growth." Along with pursuing growth through innovation with a view to society of the future, creating value through "digital and green," our goal also involves supporting people's quality of life with data and technology that fosters a sustainable society. In other words, to realize both the sustenance of society within planetary boundaries and the wellbeing of every individual living in that society.

Hitachi's operations are divided into three sectors: the Digital Systems & Services Sector, which is working to resolve the challenges faces by our customers using digital technologies; the Green Energy & Mobility Sector, which is pursuing a transformation in the area of railway systems, and energy including power grids; and the Connective Industries Sector, which provides industry and other markets with solutions that combine products with digital technology. None of these businesses, however, can achieve sustainable growth on their own. For example, achieving carbon neutrality in manufacturing plants requires that they come together to combine their skills in energy, digital, and industry. Along with supporting our customers to realize their own digital transformation (DX) and green transformation (GX), Hitachi will continue with its group-wide efforts to realize a sustainable society.

In the area of research and development, Hitachi is looking past our immediate challenges to consider what lies beyond. To resolve the increasingly complex societal challenges, it is important that our actions are guided by a backcasting approach based on an innovation strategy that looks ahead to 2050, and that we ask what we need to do now if we are to realize this vision. 2022 is said to be the first year of Web 3.0, the third evolutionary form of the Internet, and with further development of next-generation digital technologies such as the metaverse and generative artificial intelligence (AI), it is anticipated that new market needs will arise. To drive disruptive innovation, Hitachi will be strengthening investment in growth areas such as hydrogen, cell, and quantum technologies as well as in these digital technologies, to focus our efforts on developing new technologies and solutions that will contribute to resolving societal challenges.

Since its foundation, Hitachi has overcome adversity through a commitment to harmony and sincerity, adopting a pioneering spirit in its efforts to resolve the societal challenges of each era. Given the difficult times we are currently experiencing, it is essential that we combine our strengths to address the challenges we face. In this issue of *Hitachi Review*, we present examples of collaborative creation with a diverse range of stakeholders including customers and corporate partners, and new technologies and solutions from a wide range of fields. We ask for your continued patronage as the Hitachi Group undertakes the challenge to realize a sustainable society through its Social Innovation Business.

President & CEO
Hitachi, Ltd.

Toshiaki Kojima

Voices and Visions

Creating the Future through Dialogue

How to Achieve Society 5.0 and Deliver Wellbeing without Exceeding Planetary Boundaries

Teruo Fujii
President, The University of Tokyo

Discussion

Toshiaki Higashihara
Director, Executive Chairman, Hitachi, Ltd.

Smart city initiatives are underway in various of locations in Japan, serving as preliminary explorations of Society 5.0, a people-centric super-smart society envisioned in the government's 5th Science and Technology Basic Plan of 2016. Alongside this, the University of Tokyo and Hitachi have been engaging in joint research on two topics in particular that are aimed at achieving Society 5.0: the creation of sustainable and people-centric smart cities and the formulation of a vision for the energy systems of the future. This scheme for collaboration between industry and academia being undertaken at the Hitachi-UTokyo Laboratory has been recognized as a model for the harmonious collaborative creation (co-creation) that is essential to overcoming societal challenge. Globally, the situation is becoming increasingly complex, with worsening climate change and a changing international order. Japan, meanwhile, is facing the new reality of depopulation. Combining people's wellbeing with a society that can stay within planetary boundaries will be crucial to overcoming these challenges. In this article, Teruo Fujii, President of the University of Tokyo, and Toshiaki Higashihara, Director and Executive Chairman of Hitachi, Ltd., engage in a discussion that sheds light on how the University of Tokyo and Hitachi are addressing this task.

Changing Environment for both University and Company

Higashihara: I am delighted to have this opportunity to discuss Society 5.0 with you today, as it is one of the research topics being addressed by the Hitachi-UTokyo Laboratory.

Following your appointment as President of the University of Tokyo in April 2021, you published new guiding principles of the university called UTokyo Compass that came out in September of that year. Can you please tell us what you were seeking to achieve by this?

Fujii: UTokyo Compass was titled "Into a Sea of Diversity: Creating the Future through Dialogue" and highlighted three core values: "creation through dialogue," "diversity and inclusion," and "a university for everyone in the world." Along with a global agenda that includes climate change and the pandemic, humanity is also faced with the threat to multilateralism posed by Russia's invasion of Ukraine. In such a world, universities have an even greater role to play as places where people from many different walks of life can engage in dialogue.

Dialogue is the act of trying to learn something unknown. To discover and understand something unknown, we need to pose questions. By sharing and thinking about common questions through dialogue, we can build mutual understanding and trustful relationships among people. Universities can serve as a place for creating knowledge and building the future, discovering solutions to a variety of different challenges through dialogue, not only within academia, but also with people from outside or overseas who come from different backgrounds. When we fulfill this mission, I believe that universities are contributing to international society. I am conscious of how co-creation between industry and academia, as exemplified by the Hitachi-UTokyo Laboratory, provides a framework for creating the knowledge to take on difficult challenges through dialogue.

Higashihara: Dialogue is also a key concept in today's corporate activities. This year is the 113th since Hitachi was founded, and over the 100 years or so of our business, we have largely pursued a "product out" approach in which factories have played a central role. In recent years, however, that approach has undergone considerable change as co-creation with customers has come to play an ever more important part. Co-creation means sharing a vision and goals with the customer, identifying the challenges that need to be overcome to achieve those goals, and making use of digital technologies to find

Teruo Fujii

President, The University of Tokyo

Received his Ph.D. in engineering from the University of Tokyo in 1993. Following work at the University of Tokyo Institute of Industrial Science (IIS) and the Institute of Physical and Chemical Research (RIKEN), he served as Director General of the IIS, Executive Director and Vice President of the University of Tokyo, and Executive Vice President (in charge of finance and external relations) of the University of Tokyo. He was appointed the 31st President of the University of Tokyo in April 2021. In September 2021, he published "UTokyo Compass – Into a Sea of Diversity: Creating the Future through Dialogue," a statement of the guiding principles of the university. Since March 2021, he has served as an Executive Member (part-time) of the Council for Science, Technology and Innovation. His specialties are applied microfluidics systems and underwater technology.

solutions. To borrow your own words, it is about dialogue as a business model.

While products remain important, these increasingly large and complex challenges cannot be resolved by the conventional approach to manufacturing. Along with the immediate challenges facing them and their customers, the companies of today also need to take a broader and more long-term perspective that incorporates the resolution of societal challenges into their businesses. Doing so calls not only for co-creation with individual customers, but also for working through consortiums of companies; collaboration across industry, academia, and government; and dialogue with non-profit organizations (NPOs) and communities.

In the "product-out" era, value was delivered through productivity-boosting efficiency gains and profit-enhancing cost savings. Nowadays, in contrast, what customers are seeking is changing toward forms of value that encompass societal challenges. For example, rather than just price and quality, when choosing products and services, customers are starting to prioritize things like the use of recycled materials and whether materials procurement and production respect human rights and are not damaging to the environment. With planetary boundaries (global-scale environmental issues) and wellbeing (individual happiness based on leading a life that is both mentally and physically healthy) becoming key considerations for business, I have come to recognize the importance of how co-creation between industry and academia brings a transformation in our thinking and an appreciation of new ways of looking at things that incorporate these ideas.

Acceleration of Green Transformation

Fujii: While I believe that climate change represents the greatest societal challenge that we currently face, what we have now is better described as a "climate crisis" whereby continuing along our current path will result in action being too little, too late. In recognition of the need for a fundamental reorganization of social and economic systems as well as the structure of industry, we highlighted

green transformation (GX) as one of the key pillars of the UTokyo Compass action plan, with a three-tiered approach that addresses the issue at the global, national, and university levels.

At the global level, the Center for Global Commons at the University of Tokyo[*1] has played a central role in developing and publishing the "Global Commons Stewardship Index"[*2]. The objective is to stimulate international policy debate on how to safeguard the global commons and to encourage behavioral change at various levels of society in individual nations.

At the national level in Japan, we established the Energy Transition Initiative – Center for Global Commons (ETI-CGC) as a platform for investigating how Japan can make the energy transition to carbon neutrality by 2050, with participation by senior managers from 13 Japanese companies, including yourself. The intent is to develop Japan's pathways for achieving both carbon neutrality and wellbeing, including the formulation of policy proposals.

At the university level, we are playing our part in pursuing the goal of net-zero by 2050, participating as an academic partner in "Race to Zero," an international campaign launched by the United Nations Framework Convention on Climate Change (UNFCCC). We formulated and published our action plan for achieving this in October 2022, entitled "UTokyo Climate Action". Based on this plan, students, faculty, and staff members will work together to strengthen sustainability at the university.

Higashihara: Government action on GX has included the July 2022 inaugural meeting of the GX Implementation Council chaired by the prime minister. Against a backdrop of ongoing energy supply concerns, this included work on what needs to be done to achieve carbon neutrality by 2050 and the creation of a roadmap for the JPY150 trillion of combined public and private investment planned over the next 10 years[*3].

As for industry, the Japan Business Federation (Keidanren) is seeking to achieve "Society 5.0 with Carbon Neutral," its term for a new economy and society that features fundamental change in how energy is sourced, innovation in the processes of production, wider adoption of innovative products for decarbonization of the transportation and consumer sectors, public behavior change, and a transformation in living practices.

Taking an All-encompassing View of Environmental Problems

Higashihara: When considering fundamental changes in the sources of energy, it is vital to differentiate between the short- and medium-to-long-term future. While an expansion of renewable energy is essential in the long term, Japan will face electricity shortages in 2030 unless it makes progress on restarting its nuclear power plants. To ensure security of supply, we need to structure our electric power supply system in a way that treats nuclear power generation as a significant source of baseload power. In terms of thermal power generation, we need to establish a clear pathway toward reducing it, while also reducing carbon dioxide (CO_2) emissions by making greater use of alternatives such as hydrogen or ammonia, which can be mixed in with existing fuels. At the same time, there is also a need for longer-term action in the form of fundamental research into carbon capture and storage (CCS) and carbon capture utilization and storage (CCUS) so that it will be ready for practical implementation in the decade starting around 2040.

On the demand side, wider adoption of distributed power sources with the use of batteries or artificial intelligence (AI) for energy management will likely play a key role, facilitating the use of renewable sources of energy by

*1 An organization launched in 2020 with the goal of serving as a facilitator, guiding the reform of societal and economic systems through co-creation with leaders from a wide range of fields in order to secure the earth as a global commons, humanity's common property. With the aim of building a sustainable future for both people and the planet, the center is working on a common international intellectual framework for managing the global commons (global commons stewardship). Based on this framework, the center is also working with a diverse range of stakeholders to encourage the transformation of societal and economic systems.

*2 An overall indicator that is used to score nations for their impact on climate change and biodiversity and to encourage action by serving as a basis for comparison. Jointly developed by the Sustainable Development Solutions Network (SDSN) of the United Nations, Yale University, and the Center for Global Commons at the University of Tokyo, indicators have been published for more than 100 nations to date.

*3 A draft of the "Basic Policy for the Realization of GX" with 10-year roadmap was presented at the Fifth GX Implementation Council held on December 22, 2022.

communities, factories, offices, and families together with energy efficiency measures for saving electricity.

Carbon neutrality is far from the only challenge, however, and it is also important that we think about how to sustain global systems and the ecosystem. We live in a time when we need to be thinking about the impacts we have on the environment in comprehensive and global terms, encompassing every stage from materials and other resources to the factory and office, transportation, use of products and services, and their ultimate disposal and recycling. We need to be deploying technologies that can reduce the load on the environment, not only in Japan, but also elsewhere such as in Asia and the Global South.

Fujii: As you say, it is vital to adopt an all-encompassing view and address the issues in a scientific manner. The information disclosure framework for organizations involved in sustainability has been expanded from the Taskforce on Climate-related Financial Disclosure (TCFD) to the Taskforce on Nature-related Financial Disclosures (TNFD), calling for reporting, not just on CO_2 emissions in the supply chain, but also on assessments of the risks and opportunities posed to the natural environment and biodiversity across all steps in the value chain. Considering issues such as those associated with food or human rights in procurement and production, there is a need for further research into how we can monitor the activities of companies and other organizations in all their different facets together with the collection of this data and the calculation of indicators.

Higashihara: Transparency and analysis are essential if effective action is to be taken. This in turn calls for data collection and analysis platforms. With the European Union (EU) already working on its Gaia-X project to establish integrated infrastructure for the coordination of data across different companies, I feel that Japan, too, should be talking about open platforms for the integrated collection and coordination of data between companies in Japan and Asia that will facilitate the provision of services.

Need to Adopt a User Perspective

Higashihara: Alongside planetary boundaries, Hitachi also sees "wellbeing" as an important consideration, one that is highlighted as a key concept in the people-centric super-smart society of Society 5.0. Smart cities are seen as providing a preview of Society 5.0. At Smart City Institute Japan*4, meanwhile, in which Hitachi is participating alongside academics from the University of Tokyo and where wellbeing is defined as living a fulfilling life, support is being given to work on smart cities that seeks to improve on this measure. The institute has also developed the Liveable & Well-Being City Indicators for use in activities taking place around the country. Intended specifically for Japan, these indicators can be applied to urban developments that enhance the wellbeing of community residents.

While people tend to think of smart cities as greenfield developments that start from a blank slate, brownfield projects in which digital technology and data are put to work to transform existing cities are likely a more realistic solution. One notable example comes from Kakogawa City in Hyogo Prefecture where an investigation into the potential for installing surveillance cameras to reduce the crime rate was prompted by community feedback to also incorporate a monitoring service for children and the elderly that works by using beacon tags*5, thereby improving the town's livability. The requirements for establishing a smart city are: (1) leadership, (2) clearly defined objectives and key performance indicators (KPIs) for the planned activities, and (3) community involvement. In the case of Kakogawa City, however, three key elements that came together to make their project a success were, I believe: (1) the mayor, (2) the installation of a crime prevention and monitoring service, and (3) the adoption of a feedback scheme that can collect a wide range of community views by means of a website.

An advantage of brownfield projects is that they are able to make use of community feedback while changes are being put in place. In recent years, a growing number

*4 A not-for-profit organization established to promote the expansion and enhancement of smart cities in Japan.

*5 A public-private project being jointly undertaken by Kakogawa City and a number of private-sector businesses. The project has installed surveillance cameras equipped with beacon tag detectors in the area around an elementary school and along the paths taken by children going to and from school. The system is used to monitor the children and others, including elderly people suffering from dementia. It works by updating a smartphone app belonging to the person's caregiver or family with details of their movements whenever they pass near one of these detectors while wearing the tag.

of people have come to treat societal challenges as matters of personal concern to the extent that they are prepared to involve themselves in urban development. I am hopeful that brownfield smart city projects will prove to be the catalysts that initiate the transition to Society 5.0. In the private sector, likewise, we want to play our part in this movement through means such as digital technology.

Fujii: As a university, being a place where different types of people can come together is one of our defining characteristics and, as such, I hope that we can serve as a place for community participation and for connecting stakeholders together.

For Society 5.0, it is important to clarify who we are talking about when we refer to it as "people-centric." As you mentioned earlier, whereas the evolution of 20th-century industry was more about the things that mattered to producers, the progress of digitalization since we entered the 21st century has placed greater weight on the perspectives and values of the people who use products and services.

This change now informs the debate about smart cities, where a switch in focus toward user considerations is called for in fields like social infrastructure and in public services such as healthcare and education. Those in healthcare are asking themselves what constitutes value for patients, while for us in the education sector, we need to be rethinking what is needed if students are to study the things they really want to study. This is a time for the providers and consumers of services to be getting together to engage in genuine dialogue and to think about issues of concern and what constitutes value in those services.

Treating Issues as Matters of Personal Concern

Fujii: For myself, I have spent a lot of time studying the ocean and have been engaged in the Ocean Monitoring Network Initiative (OMNI). I have launched this project to perform large-scale oceanographic surveys using low-cost sensor systems. To achieve this, the project has drawn on design capabilities to develop sensors and data platforms for collecting a variety of oceanographic data such as water temperature and salinity, with involvement by

Toshiaki Higashihara

Director, Executive Chairman, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1977 after graduating with a degree in electrical engineering from the Faculty of Engineering at Tokushima University. He obtained a Master of Science in Computer Science at Boston University in 1990. His past roles have included COO of the Information & Telecommunication Systems Group, President of Hitachi Power Europe GmbH, President and Representative Director of Hitachi Plant Technologies, Ltd., Vice President and Executive Officer of Hitachi, Ltd., President & CEO of Hitachi, and Executive Chairman & CEO of Hitachi. He took up his current position in April 2022.

the general public as well as researchers. Participation in the project fosters a sense of personal connection with the ocean environment, with activities including workshops for elementary, junior high, and high school students and helping them come up with ideas for sensing devices. Having more people collecting observations increases the volume and resolution of the oceanographic data while also providing an opportunity for personal behavioral change as people gain a shared awareness of the problems. I hope that this project will serve as a model for using dialogue with the community as a means of overcoming challenges.

Rather than being conferred by other people, I believe that wellbeing is something we acquire when we voluntarily engage with each other to make society better.

Higashihara: That is right. Because wellbeing means different things to different people, if everyone pursues happiness in their own way, they may end up just getting in each other's way, like trying to inflate a lot of balloons in the same small space. What is called for, rather, is empathy and to consider the viewpoints of others. The same applies to planetary boundaries, a problem where it is important that we think in terms of win-win rather than zero-sum outcomes.

The best overall outcomes can be achieved by local government, companies, universities, and residents adopting this approach to working with one another to address local issues, with these communities working together seamlessly based on Japan's Vision for a Digital Garden City Nation. It is when this happens that I believe wellbeing will be improved.

Fujii: Working with the local community is also important for us. In November 2022, we entered into a comprehensive partnership agreement with Wakayama Prefecture. The aim of the agreement is to help resolve local issues and create a distinctive regional society through academic research and the exchange and training of personnel.

While this is the third such agreement, we have reached at the local government level, the earlier ones being with Mie and Fukushima prefectures, a number of our faculties were already doing work in Wakayama. The Institute of Industrial Science to which I belonged has set up a laboratory at Kada in Wakayama City to conduct studies aimed at regional revitalization, while the Research Center for Advanced Science and Technology partnered with Kongobu-ji, the Main Temple of the Koyasan Shingon Sect, as well as with Koyasan University and Koya Town to hold the Koyasan Conference. Similarly, our Graduate School of Humanities and Sociology has entered into an agreement with Shingu City involving the establishment of a satellite facility and the hosting of the UT Jimbun-Kumano Forum. The graduate school has also entered into an agreement with Kitami City in Hokkaido to engage in joint work in which Shingu City will also participate, with plans to go deeper into areas such as multi-regional cross-cultural studies.

We have also embarked on a "field study-based partnership project between local governments and UTokyo." This involves students spending time at local government agencies to conduct on-site studies of local issues and come up with ways of resolving them with assistance from faculty and staff members. During the 2022 academic year, we worked with 19 such local governments and communities at locations across Japan.

Improving Diversity, Equity, and Inclusion through Mutual Understanding

Higashihara: Diversity and inclusion are both key considerations when seeking to create a people-centric society, and together with equity, these concepts have been a focus of much attention over recent times, collectively known by the abbreviation "DEI." For Japan to retain its vitality as it confronts the reality of depopulation, it is essential that both the private and public sectors promote globalization and diversity more than ever before. To this end, Hitachi has declared a goal of increasing the percentage of female and non-Japanese executive and corporate officers to 30% by 2030.

Equity, being about the rectification of imbalances with respect for difference, is not the same as equality. Rather than something that can be expressed in simple rules, it is about formulating rules that are consistent with an understanding of people's individuality and of local culture and history, or of providing support and creating a level playing field that leads to a society that leaves no one

behind. In other words, it is about mutual understanding. It means first understanding and accepting the values of other people, and then having them understand your values. While it may seem trivial, I believe that order is crucially important.

Fujii: I agree. Building relationships of trust through dialogue demands both understanding and respect for others as you mentioned. As I spoke about earlier, the University of Tokyo is seeking to become "a university where anyone in the world would want to come and join." Being accepting of people from a range of different backgrounds is important in academia just as it is in business. In order to raise the level of our research, debate needs to encompass diverse viewpoints. DEI is implicit in the topics like Society 5.0 and wellbeing that we are addressing in our discussion and I believe that they constitute genuine value.

One of the ways in which universities need to respond to depopulation is by fostering and utilizing a diverse range of people so as to maintain national vitality. As part of such efforts, we aim to recruit 300 female teaching staff by the 2027 academic year. By raising the percentage of female faculty and supporting their activities, our hope is that this will also increase the number of female students. Likewise, increasing the number of international students should foster deeper understanding and allow them to develop closer ties to Japan while also helping to improve diversity domestically.

Disability inclusion is also essential. We have students who get around the university in wheelchairs and the Research Center for Advanced Science and Technology is engaged in an assessment and rehabilitation project whereby people with disabilities or illness study their own concerns, such as the difficulties they experience and the ways in which their illness manifests in their daily lives. Providing an inclusive environment for education and research not only promotes innovation, but also serves as a model for other organizations.

Responsibilities of Science and Technology

Higashihara: Along with changes in attitude, the way in which DEI is achieved at a technical level also raises issues. For example, as long as they are able to operate the relevant devices, new digital realms such as the metaverse allow people to communicate, work, and study wherever they live and without the constraints of time, regardless of their age, gender, or physical condition. If not only sight and sound, but also other senses such as touch, smell, and taste can be provided as virtual experiences, then the possibilities could extend to the immersive study of history or the interactive acquisition of skills and expertise.

On the other hand, these new technologies have both advantages and disadvantages and come with ethical issues. Given that virtual reality is artificial, how far can we allow it to go? While Hitachi provides training to our researchers and engineers about the ethics of emerging technologies like gene recombination, genome editing, and regenerative medicine, there is also an urgent need to establish effective rules through a process that includes public debate and assessment.

Fujii: The ethical, legal, and social issues (ELSI) raised by science and technology have themselves become a topic of academic study. Moreover, the EU has, in recent years, been addressing the concept of responsible research and innovation (RRI).

As exemplified by the issue of genetically engineered foods, new technologies can foster uncertainty and distrust in science when they first enter the public realm. To avoid this, rather than a closed debate among the ranks of scientists, it is important to engage in dialogue with the public from the early stages of research and development. While responsibility as a concept also embodies ethics, I see it as having two aspects when it comes to research, namely the responsibility to "create" scientific knowledge and the responsibility to "utilize" scientific knowledge. Scientists and other researchers are called upon to fulfill both of those responsibilities, which is why we include "Promote Responsible Research" as one of the 20 goals in the UTokyo Compass.

Mutual Engagement for Development of Human Resources and Resolution of Challenges

Fujii: Given a global agenda including the ethical questions of new technology as well as climate change and the new international order characterized by the COVID-19 pandemic and the invasion of Ukraine, a mountain of issues call for our action. Today's discussion has reinforced for me how our ability to overcome these challenges is enhanced by companies like Hitachi and universities like ours working together to take them on.

As a university, providing students with on-the-ground experience is a particular emphasis of ours when it comes to addressing ever more complex challenges. We promote internships both in Japan and overseas in the hope that knowledge of the practical world will encourage students to make a personal commitment to action on these challenges. I also see an important place for startups when it comes to initiatives for addressing challenges. As many students want to be involved with startups in the social as well as the technology sphere, such as businesses that can make a social contribution on the ground in the Global South, for example, the university is looking for ways in which we can support them.

Higashihara: While we spoke earlier about the university's role in developing talent, companies also have an important role to play in fostering people who can take on a global agenda. This is about having a personal commitment to addressing societal challenges from a global perspective and resolving those challenges in a way that brings people onboard based on mutual understanding. What I would like to see is for us to build a relationship in which, through mutual engagement, we can resolve societal challenges together. More than just internships, this could involve things like our people going to the university to learn or having university researchers come to us.

Fujii: I very much hope we can do that. When it comes to the fostering of talent at universities, I am conscious of the need for us to build up our capabilities for acquiring understanding of other subjects as well as our own, or for engaging in team-based research with specialists from other fields. It is by acquiring such capabilities that our engagement with companies will deliver benefits.

Higashihara: With a philosophy like that, the Hitachi-UTokyo Laboratory will have a more important role to play than ever. The pursuit of interdisciplinary research is an area worthy of particular attention along with incorporating public feedback into efforts to create Society 5.0, and we need to make further progress toward it serving as a forum for dialogue that encourages active debate and the exchange of views between companies and universities along with numerous other stakeholders. I look forward to its coming up with many good ideas that will help Hitachi toward our goal of using the resolution of societal challenges as a means of creating a society that delivers wellbeing to everyone without overstepping planetary boundaries. Thank you for your time today.

Interview with CEO Taniguchi of Hitachi Digital "Digital is an Important Driver of Growth"

CEO Jun Taniguchi Talking about Digitalization Strategies

In April 2022, Hitachi, Ltd. announced its new Mid-Term Management Plan in which the company indicated a growth strategy centered on digitalization as one of its future policies. So what are Hitachi's digitalization strategies? Jun Taniguchi, CEO of Hitachi Digital LLC, talked about that.

Interview and text by Kai O'Connor

The Fields of Digitalization that Will Be Focused On in the Future

—Firstly, please talk about your current position and career at Hitachi.

I am the CEO of Hitachi Digital LLC, which was founded in April 2022 and am currently located in Silicon Valley, USA. We are responsible for developing digitalization strategies for the entire Hitachi Group and for driving the expansion of the Lumada business (a generic name for solutions and services that leverage Hitachi's cutting-edge digital technologies).

I started my career as a front-end engineer and later assumed the role of overseeing control system engineers. In 2019, I took control of the product management of the home appliances and air conditioning business at Hitachi Global Life Solutions, Inc., a company that manufactures and sells home appliances and other products, and in 2022, I became CEO of Hitachi Digital LLC, the position that I am currently in. I want to take advantage of my experience so as to expand the digitalization business across Hitachi.

—In recent years, Hitachi and many other companies have been focusing on businesses related to digitalization. What are your thoughts on these trends?

In the past, many business models were simply based on selling products, but nowadays, a vast number of products are connected digitally, and technologies are evolving on a daily basis. I believe that digitalization connects products and makes the user experience more convenient and comfortable.

Moreover, I also see the areas of Web 3.0, the metaverse, and non-fungible tokens (NFTs), which are hot topics recently, as very significant opportunities. Although these areas are still in their infancy, Hitachi is currently exploring what we can do in these areas, and I have no doubt that these will be areas that we will focus on in the future.

—In this context, what are your thoughts on the positioning of digitalization in its new Mid-term Management Plan?

Hitachi has set a goal of becoming a global leader in the Social Innovation Business. We also believe that Hitachi's role in providing railroads, energy, and other social infrastructure is to enrich people's lives while also being environmentally friendly. To achieve these goals and fulfill our role, we believe that digitalization is an important growth driver for Hitachi.

The Four Digitalization Strategies

—Please explain in detail about the business strategies for digitalization, which is a growth driver.

We have devised four strategies to further strengthen and expand Hitachi's digitalization business. The first is a digitalization strategy to provide value to customers through "cyclical solutions" centered on Lumada, which Hitachi calls the "Lumada Business Growth Cycle" and describes it in four steps.

In the first step, issues are identified through design thinking (a method of thinking to find valuable solutions from the user's or customer's point of view). The second step is to build a system in the cloud to solve the issues. The third step is to expand and enhance the functionality of the system by, for example, connecting the built system to the product so that the operational status can be visualized. In the fourth step, we upgrade the operation of the system so that the client can focus on their own business, and at the same time, we analyze the collected operational data to identify new issues. Through this growth cycle, we will continue to develop the Lumada business.

—What are some of the other digitalization strategies?

The second strategy is to reuse Lumada customer case. By making the customer cases more generic, they will be easier for other customers to reuse. We believe that this will benefit both Hitachi and our customers in various ways, including by enabling us to provide our digitalization solutions to customers faster.

The third strategy is related to the fact that we must compete in markets where we can take advantage of Hitachi's traits. Hitachi has been providing social infrastructure of high quality and reliability for many years, and we will continue to focus on the social infrastructure field as a priority market and enhance the user experience with the power of digitalization.

—What is the final digitalization strategy?

Last but certainly not least is the developing and expanding of digital human capital. Hitachi intends to increase the amount of digital human capital to approximately 100,000 workers by the end of FY2024 in order to focus on our digitalization strategy. GlobalLogic, which has joined the Hitachi Group, has a very good system for developing human capital, including building relationships with universities and providing training opportunities. We will continue to develop and expand our digital human capital while incorporating this type of system into Hitachi.

We also believe that in order to secure talented digital human capital, it is important to convey to people outside the company in an easy-to-understand manner about what Hitachi can contribute to society and the value that we can provide. By doing so, we believe that understanding and sympathy with Hitachi will deepen, making it easier to attract digital human capital.

Challenges to Implementing the Digitalization Strategies

—What are the challenges that you are facing in implementing such digitalization strategies and how are you working to solve them?

To my mind, there are three challenges. First, there does not always appear to be sufficient understanding within the company of what can be done digitally. To solve this problem, we held the Hitachi Digital Summit in the USA in October 2022 that was attended by Hitachi Group leaders.

Hitachi Group customers who have succeeded in digital transformation (DX) were invited to this event to share their experiences of how they achieved DX for their businesses and increased profits through the customer journey (the process of how customers decide to purchase a product or service), which created an opportunity for participants to learn. We believe that this has deepened their understanding of what can be done by leveraging digitalization and has helped speed up the growth of their digitalization businesses.

—What are the other challenges?

The second challenge is that, in order to circulate the Lumada Business Growth Cycle, it is difficult to effectively collaborate to achieve the goal because of the wide variety of divisions and group companies involved. To solve this problem, I believe that Hitachi Digital must first lead

the divisions and group companies while jointly creating a business plan and making the respective roles clear.

Another issue is to make it easier to reuse customer cases. Although there have been efforts to promote reuse previously, it has mostly been from the perspective of the solution creator, while the perspective of the users has been lacking. If solutions are not created with the involvement of the users, the reuse of customer cases will not move forward. Therefore, we are currently working on a rule book for solution development.

These challenges will be the hurdles to growing our digitalization business that we are working to solve.

Hitachi's Vision for a Digitalized Society

—Could you expand on the future world that Hitachi hopes to realize through digitalization?

The idea of making life convenient and comfortable by destroying the global environment is no longer acceptable to society. I believe that Hitachi's role should be to make people's lives more comfortable, safe, and secure while conserving the global environment through digitalization.

The world that Hitachi hopes to realize in the future is a sustainable society with well-being, and we will contribute to the realization of such a society by utilizing digitalization and co-creating with our customers.

Digital Systems & Services

Services & Platforms

Financial Systems

Social and Public Sector Systems

IT Services

Services & Platforms

1 Hitachi Cloud & DX Solutions Accelerating Customer DX

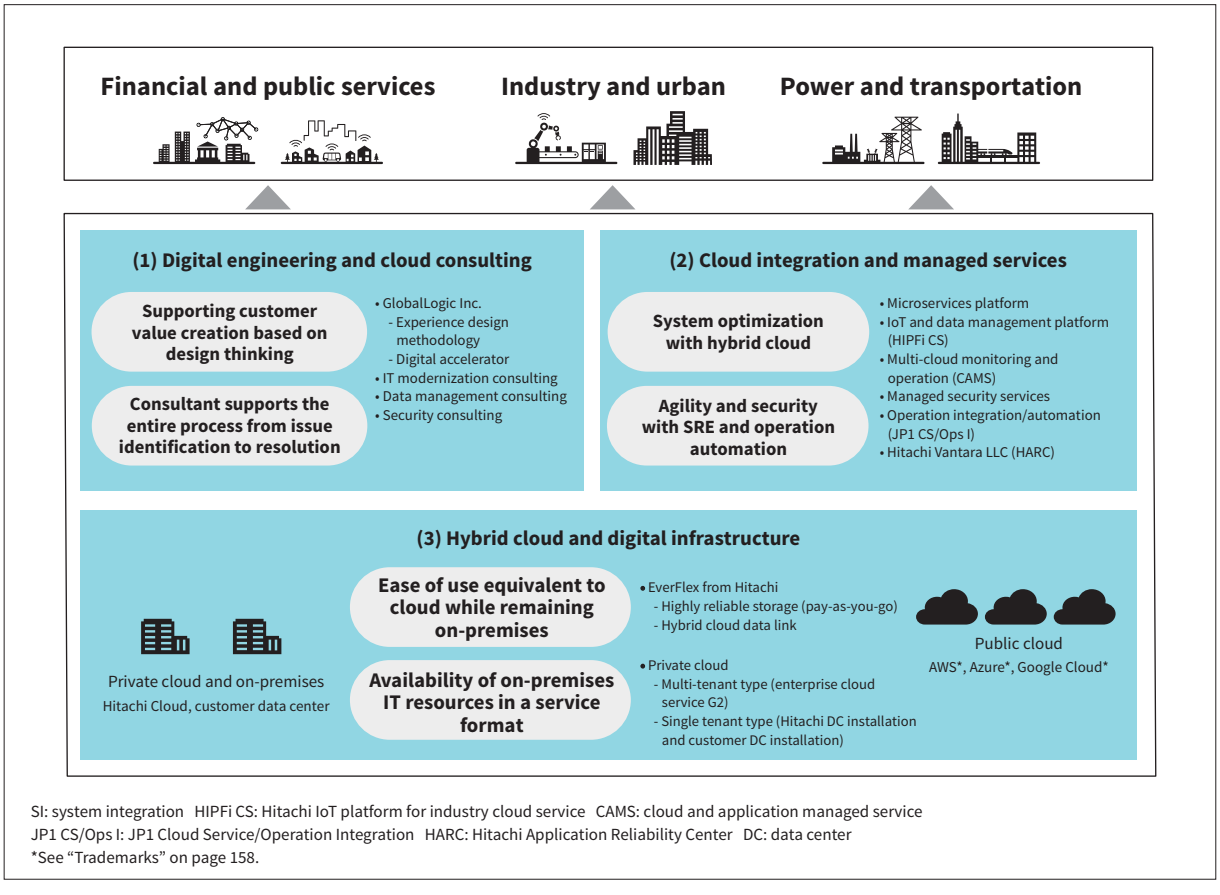
Many companies are engaged in digital transformation (DX) initiatives to cope with advances in digital technologies, the spread of COVID-19, and ever-increasing uncertainty. With a certain level of success in improving productivity by streamlining work, future challenges in this regard include an urgent call for the creation of new products and services to swiftly adapt to business environments, and for results from the fundamental transformation of business models.

To help accelerate customer DX efforts, Hitachi offers a full range of upstream and downstream services such as consulting to solve customer management issues, digitally driven business value creation, multi-cloud platform driven system integration, and operation, maintenance, and security tasks for constructed systems.

Hitachi solutions that support customer DX efforts are shown in the figure below. Services that support customer problem solving are provided from viewpoints (1) to (3), and continued support for customer DX promotion is provided through a combination of these services.

(1) Digital engineering and cloud consulting

GlobalLogic's proven design methodology facilitates business value creation using customer digital methods based on "design thinking." Designers that are masters in experience design methodology work with customers through the entire process from identifying issues to proposing solutions, while architects simultaneously formulate feasible development plans, providing end-to-end support in their realization. Additionally, a variety of consulting services are available to support modernization of existing systems for improving business agility, utilization of existing data buried in-house, and security measures for migration to the cloud.



SI: system integration HIPFi CS: Hitachi IoT platform for industry cloud service CAMS: cloud and application managed service
JP1 CS/Ops I: JP1 Cloud Service/Operation Integration HARC: Hitachi Application Reliability Center DC: data center
*See "Trademarks" on page 158.

1 Hitachi solutions supporting customer DX efforts

Hitachi provides a full range of support solutions from the formulation of grand designs for maximizing customers' business value with hybrid cloud services, to the proposal of action plans, and system construction and operation. This is offered through a collaborative effort between engineers with experience in building and operating social infrastructure systems and cloud vendor certified engineers, by utilizing on-premises and cloud solutions according to customers' specific requirements, designing system allocation plans, cloud migration methods, and cloud native development support.

(2) Cloud integration and managed services

Developing new services from scratch for each project results in long turnaround times when building cloud-driven systems. Hitachi has turned the knowhow it has gained from collaborative creation (co-creation) efforts with customers, cloud vendors, and partner companies into an asset that functions as a framework used to build highly reliable, highly secure cloud platforms in a short period of time, and to speed up customer IT modernization.

Additionally, cloud service operation and maintenance can result in a variety of issues such as unexpected high costs, unstable service, and the manifestation of security risks due to complex hybrid and multi-cloud platform operation. Hitachi solves such problems by offering operational services that are tailored to private cloud (on-premises) and public cloud platforms, eliminating silos through standardized operations, automated operation tailored to both IT operations and security operations, and advanced DevOps support through site reliability engineering (SRE).

(3) Digital infrastructure and hybrid cloud

Requirements of foundational services that support hybrid cloud platforms include ease of use equivalent to the cloud while remaining on-premises, and availability in a service format (pay-as-you-go) for on-premises storage, servers, and networks. EverFlex from Hitachi, seamlessly links on-premises Hitachi storage data and public cloud data for operation of applications without any awareness of where the data is stored. Because Hitachi's highly reliable IT resources such as storage, servers, and networks are available in a service format similar to a public cloud platform, customers can use these without any significant investment, on a pay-as-you-go basis.

Hitachi provides continuous support for customer DX efforts by first understanding the issues, studying solutions, then initiating a cycle that entails designing, implementing, operating, and maintaining cloud systems. Hitachi provides optimal support for customers through a collaboration between GlobalLogic and Hitachi Vantara for expanded assistance on a global scale, and by working with various partner companies.

The Services and Platforms category introduces some of the features and use cases of services and initiatives that support customer DX efforts.

2 Nojima's DX Acceleration Empowered by GlobalLogic's Digital Engineering

Nojima Corporation announced a partnership with GlobalLogic Japan, Ltd. in June 2022. The collaboration intends to accelerate the development and implementation of Nojima's DX strategy.

The co-creation program focuses on the deployment of brand-new customer experiences that integrate GlobalLogic's digital engineering with Nojima's digitalization initiatives. The program targets accelerating the transformation of Nojima's brick-and-mortar stores, as well as its unique "consulting-based sales" approach for home appliance sales in Japan.

Currently, Nojima, GlobalLogic Japan, and Hitachi are promoting discussions to evolve the program to provide new customer experiences with better visibility throughout the partnership.

The program will support the consolidation of Nojima's DX initiatives to reinforce its "inspiring services." Program objectives may include developing initiatives to improve customer satisfaction; constructing a platform using digital engineering technology; and developing applications that strengthen the connection to end users.

2 Interview during store visit

3 GlobalLogic to Expand the Digital Engineering Footprint

GlobalLogic is strongly expanding its digital engineering footprint through the opening of new offices and acquisitions across the globe. In addition to the inauguration of new engineering centers in Mexico in 2022, GlobalLogic announced plans to open new engineering centers across Spain in 2023, and this announcement was made at a meeting between the Spanish Prime Minister Pedro Sánchez and GlobalLogic President and CEO Nitesh Banga. GlobalLogic also signed an agreement to acquire Fortech, a leading Romanian engineering company, in November 2022 and Hexacta, a Latin American company headquartered in Uruguay, in January 2023.

With 28,000 employees at locations in 16 countries as of the end of December 2022, GlobalLogic is a leading digital engineering company that supports digitalization efforts at over 500 companies. The expansion of GlobalLogic's footprint in Latin America and Europe is part of the company's strategy to meet the growing global demand for DX, which is expected to increase further in the future. For Hitachi, which aims to achieve the top global position in the DX market in its 2024 Mid-Term Management Plan, the expansion of GlobalLogic is positioned as a growth investment to strengthen its business by leveraging IT, operational technology (OT), and products, and to make a leap forward in Lumada business.

GlobalLogic will continue to provide better services to its customers by accelerating to expand its access to the strong digital talent base spread around the world.

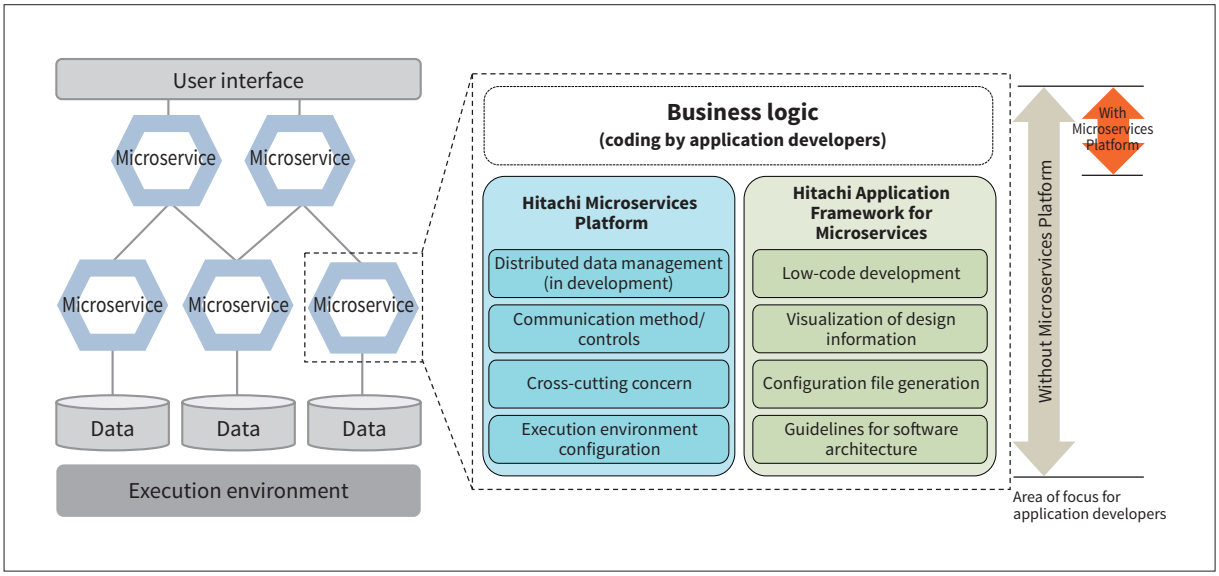
4 Microservices Platform Fusing GlobalLogic and Hitachi Know-how

Microservices architecture is one approach to quickly realizing DX-led business transformation. This architecture divides the overall system into multiple, loosely coupled services and connects each one through communication to enable speedy system improvements and easy scale-out according to the processing volume.

Hitachi now offers the Hitachi Microservices Platform for use in Japan, an enhanced version of the Microservices Accelerator from GlobalLogic, the experts in cloud-driven development, and the Hitachi Application Framework for Microservices, a development tool that supports microservices applications in large-scale projects. This platform combines various common components developed based on GlobalLogic's development know-how and Hitachi's distributed data management technologies, design, and development know-how cultivated in Japan.

Utilizing this platform vastly simplifies the development of common functionalities in microservices, which are difficult to implement, allowing engineers to focus on business logic, which is the true value of the system, resulting in speedy, high-quality development. With this platform at the core, Hitachi supports system modernization at corporations engaging in enterprise-level agility improvement.

3 A meeting between GlobalLogic President and CEO Nitesh Banga (left) and the Spanish prime minister (The plan to open engineering centers in Spain was officially announced there.)



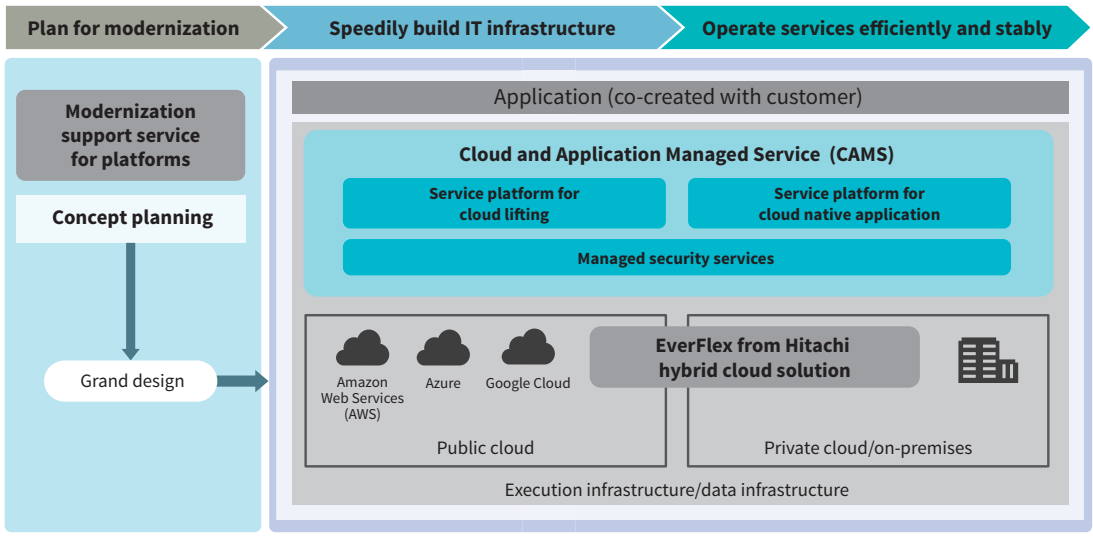
4 Overview of microservices platform

5 IT Platforms and Operation Enhancement Offerings to Accelerate the Modernization of IT Platform

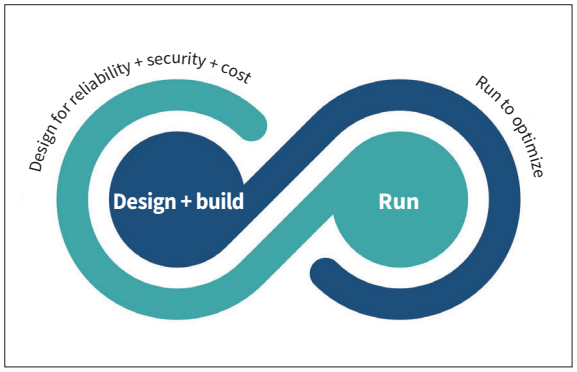
This offering is a one-stop service covering everything from consulting to design, construction, and operation in IT infrastructure modernization tasks based on the best practices Hitachi has cultivated over the years in the construction and operation of both public cloud and mission-critical systems.

Consultants with a wealth of experience work together with highly-skilled engineers to craft a grand design covering concepts, overall policies, and promotional programs to modernize IT infrastructure from the viewpoint of management strategy, human resources, and IT. Additionally, Hitachi supports asset utilization SI via service platform usage and advanced operations including security environments with its cloud and application managed service, which delivers comprehensive managed services for IT infrastructure in multi-cloud environments. Furthermore, this offering supports gradual operational automation using advanced artificial intelligence (AI) and coding technologies for continuous operational streamlining.

These services help with strategic modernization of IT infrastructure and contribute to improved customer business agility and the promotion of DX.



5 Overview of the IT platforms and operation enhancement offerings



6 Engineering-led operations to extend Dev and Ops integration

6 Hitachi Application Reliability Centers

The cloud is accelerating data-driven innovation and business agility, but capturing the full business value from the cloud has been a challenge. The complexity of today's hybrid and multi-cloud operating models is contributing to unexpected costs, outages, and compliance and security risks.

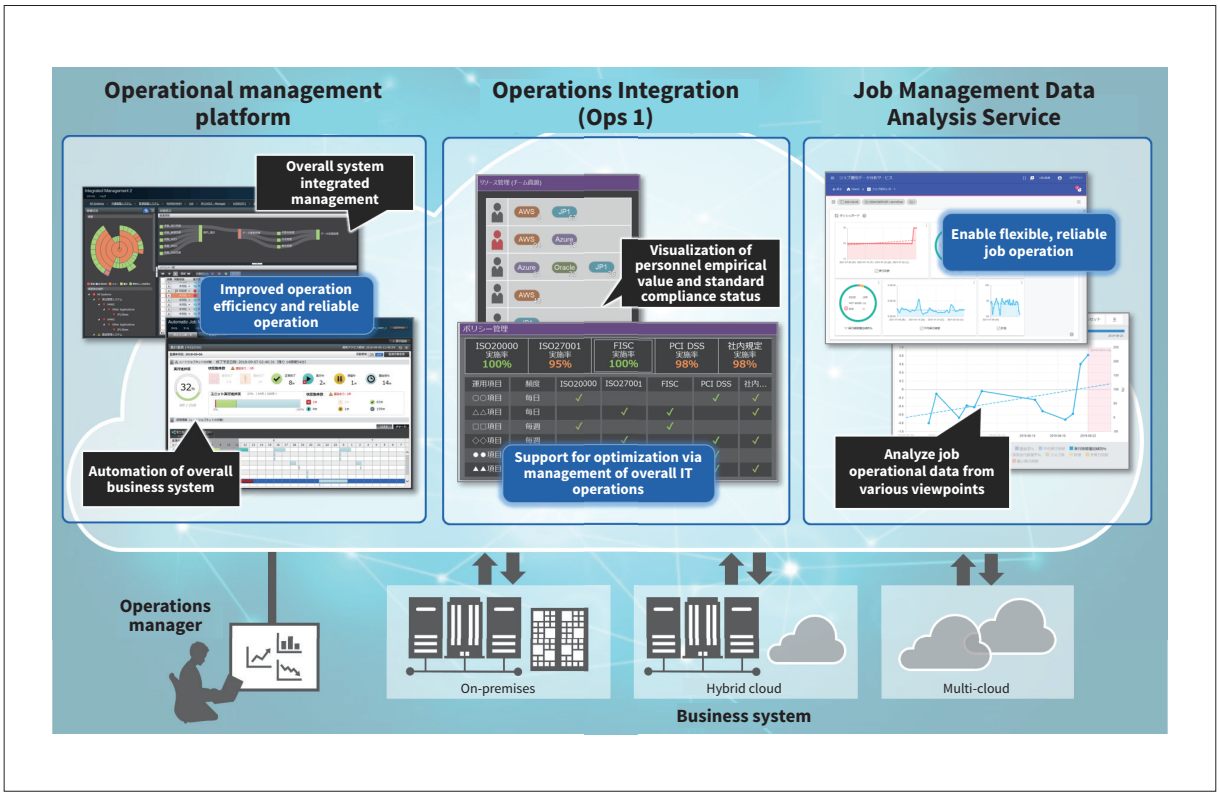
Hitachi Application Reliability Centers (HARC) is Hitachi Vantara's comprehensive integrated portfolio of cloud professional and managed services offering. HARC brings together best-in-class tools, frameworks, and automation with access to cloud experts to co-create customers' cloud transformation journeys and deliver the most advanced cloud workload operations management and support. HARC consists of geographically dispersed physical and virtual centers of excellence where cloud applications are monitored and optimized by its professional engineers to ensure client-defined key performance indicators (KPIs) are consistently achieved. Each site brings together best-in-class frameworks, design patterns, automated tools, and people to deliver SRE as-a-service and 24-hour/365 cloud management and operations.

The result* is significant improvements in application availability with up to 25%* improvement in the time it takes to detect and recover from faults, and 15%* improvement in change failure rate. Working with HARC, customers achieved a 35%* reduction in the ongoing cost of operations, 60%* reduction in business risk, 30%* improvement in their productivity, and 360-degree observability of their cloud assets.

* The improvement rates presented here are based on specific cases, not applicable to every application. The effectiveness of adopting HARC varies on a case-by-case basis. Results may vary depending on the customer's use-case.

7 JP1 Cloud Service for System Operational Efficiency and Reliable Operation

JP1 Cloud Service is a software as a service (SaaS) that integrates IT systems and operations on one platform. It



7 JP1 Cloud Service for system operational efficiency and reliable operation

aims to achieve IT operations that do not rely on human intervention by automating business operations on complex, diversified systems in hybrid cloud and multi-cloud environments, cohesively managing various types of data, relevance, and knowledge for standardization of overall operations. The features of the service are as follows.

(1) Operations Integration (Ops I)

By integrating IT operations that have been siloed by system, standardizing overall operational tasks across systems, and managing overall operations by facilitating the sharing of operational personnel, both efficiency improvements and quality assurance can be achieved overall for continuously evolving systems.

(2) Operational management platform

Job management that automatically executes operations in on-premises and multi-cloud solutions according to plan, and integrated management with bird's-eye-view monitoring of the overall system, achieves increased operational efficiency and reliable operation.

(3) Job Management Data Analysis Service

Automatically collecting, accumulating, analyzing, and evaluating job operation data, visualizing the health and maintainability of job operations facilitates improvements to achieve flexible and reliable job operations.

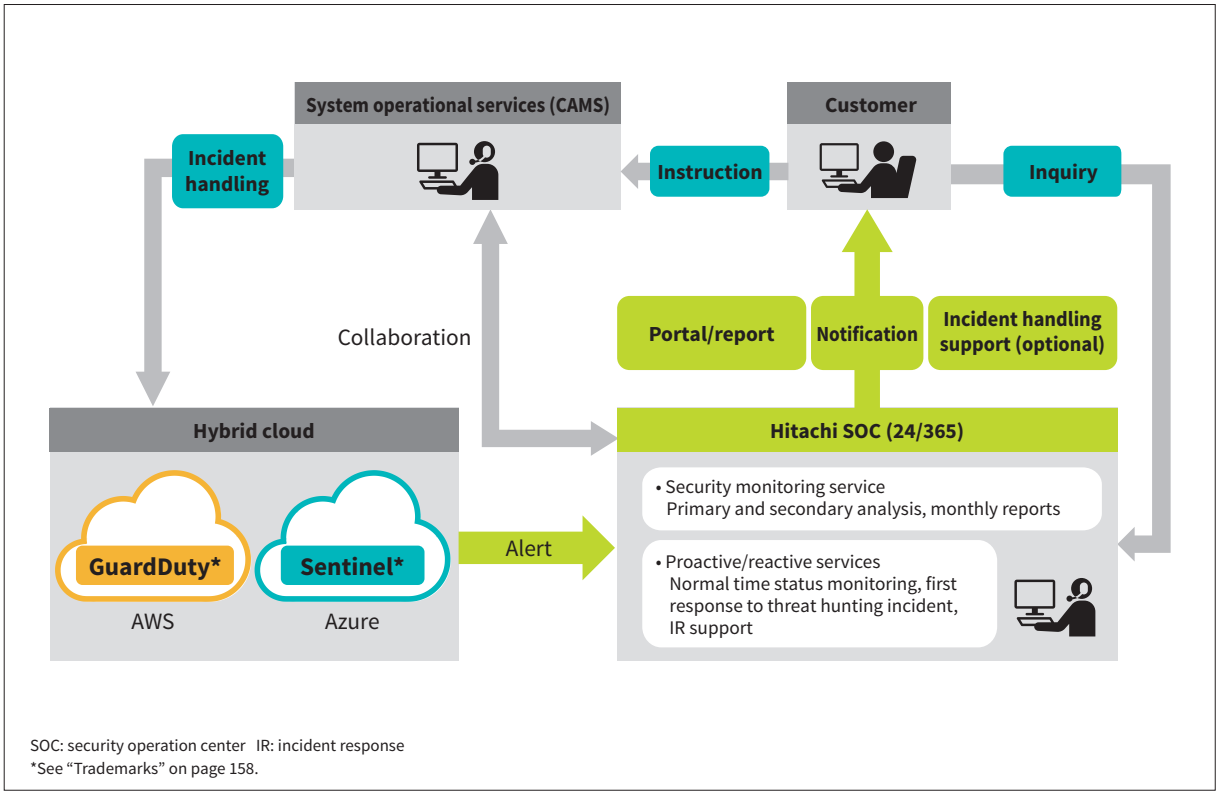
These features enable integrated IT system and operation management.

8 Outlook for Hitachi MSS

With security measures growing ever more important due to increasing cyberattacks, cloud lift and shift (L&S), and tightening regulations, Hitachi launched hybrid cloud and Zero Trust-network-compatible managed security services (MSS) and began offering them in December 2022. Based on Hitachi's track record of service to over 150 companies and over 20 years of operation services, MSS offers high-quality security monitoring and analysis services by analyzing the latest attack and threat information, in-house incident information, and implementing it in detection rules, all.

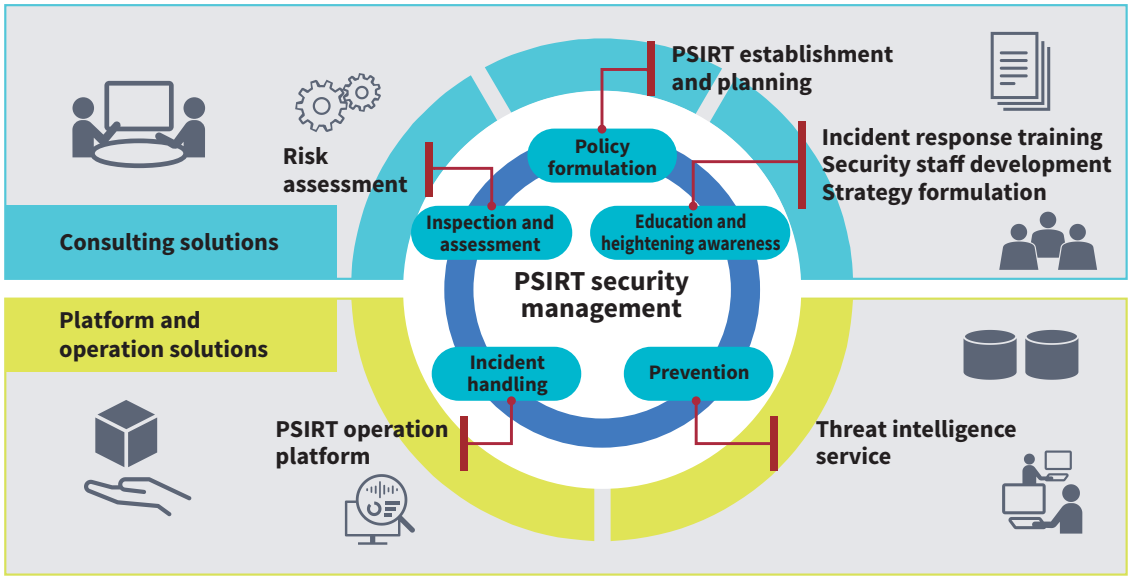
The services provide not only conventional security monitoring, but also an integrated security operation cycle support menu (proactive/reactive services) that covers all situations from normal operation to emergencies, helping lighten customers' workloads.

Additionally, MSS can be coordinated with the cloud and application managed service, the comprehensive managed service for IT infrastructure mentioned earlier, contributing to faster incident handling, and minimizing the area of impact through comprehensive monitoring analysis. Even customers without sufficient security personnel that are well versed in cloud solutions can feel safe and secure in their multi-cloud operations.



SOC: security operation center IR: incident response
*See "Trademarks" on page 158.

8 Overview of managed security services



PSIRT: product security incident response team

9 Hitachi PSIRT solution

9 PSIRT Security Solutions Bolstering Security Management

With the growth in Internet-connected home appliances and connected cars, comes increased cyberattacks on Internet of Things (IoT) devices using open-source code and other technologies. Furthermore, compliance with global security regulations to ensure product and service security is called for, with strong demands on companies to develop frameworks for investigating and dealing with security incidents and with vulnerabilities in their own products and services, and promptly disclosing information on such.

With a proven track record in providing solutions as an IT vendor and utilizing its knowledge in building security organizations and managing governance as a manufacturer, Hitachi offers PSIRT solutions helping customers bolster security risk management across the entire product life cycle from development to manufacturing, and introduction to the market, as well as the supply chain.

This solution consists of a one-stop consulting solution to support PSIRT management to strengthen governance in customer companies and a platform and operation solution that delivers a framework for threat and vulnerability information analysis and centralized management and rapid incident handling, and eliminates personnel-dependent factors.

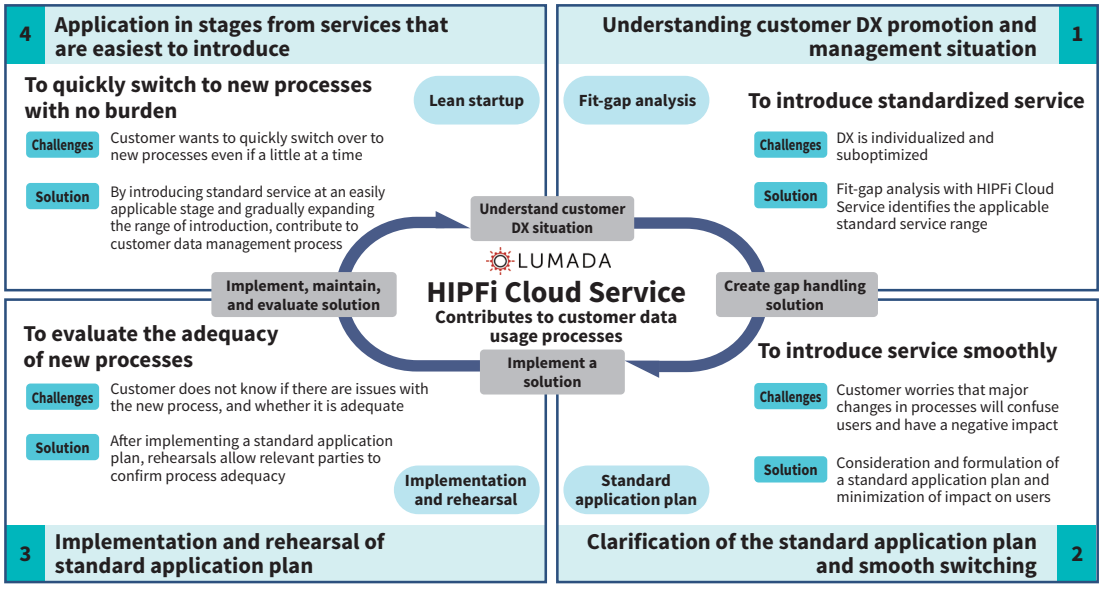
10 HIPFi Cloud Service Facilitates Customer Resource Shifting and DX

Together with Hitachi Construction Machinery Co., Ltd., Hitachi, Ltd. began offering support for construction machinery maintenance service (Global e-Service) in 2012, collaborating on the IT aspects in this endeavor.

HIPFi cloud service* was proposed and adopted in 2022 as part of Lumada solutions to enable business process reengineering and to support the development of its platform. This solution was adopted because various customer business operations such as data management required for DX promotion were included in the HIPFi Cloud Service menu, allowing Hitachi to offer total services without any preparation on the part of the customer, and because it provided a cost advantage over handling the task on its own.

To introduce HIPFi Cloud Service, the scope of services provided was gradually expanded by a repetitive process of (1) fit-gap analysis of customer desires with the HIPFi Cloud Service, (2) application planning for smoothly introducing the service to fill the gap, (3) implementing and rehearsing the application plan, and (4) launching the service. By offering the services in stages, the impact on operational business and users was successfully minimized, resulting in safe and secure introduction of the HIPFi Cloud Service.

* See "Hitachi IoT Platform for industry Cloud Service," Connective Industries: Industrial Digital Solutions No. 5 (p. 74 of this issue)



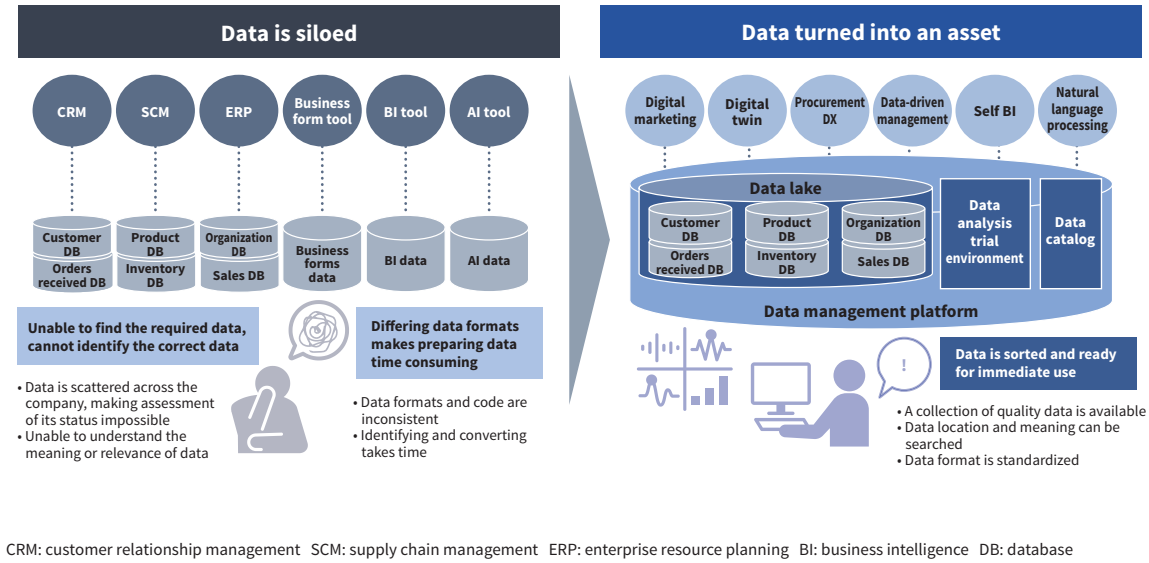
10 HIPFi cloud service introduction methodology

11 Data Management Services Using Scattered Data as Resources to Build a Management and Operation Platform

Lately, data management platforms that manage data as a resource are in demand as a way for companies to use their data. Construction of a data management platform is a particularly urgent need in promoting DX.

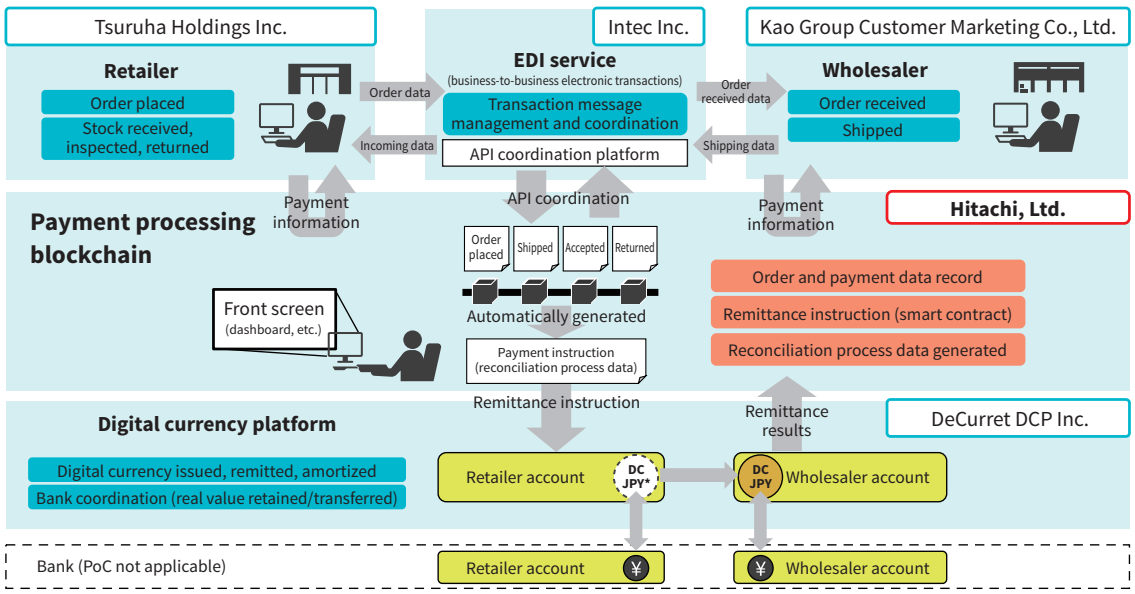
Existing business systems are built according to organization, business, and purpose, resulting in data silos that are optimized individually. This results in various issues when beginning DX efforts, such as the inability to find the desired data, the inability to identify the correct data, and the time required to prepare data that exists in various formats.

To resolve such problems, Hitachi builds data lakes for storing a variety of data and prepares data catalogs that show where specific data is stored. Also, providing a data analysis trial environment that enables data management allows Hitachi to support the construction of data management environments for immediate data utilization, from planning to design, construction, operation, and maintenance.



CRM: customer relationship management SCM: supply chain management ERP: enterprise resource planning BI: business intelligence DB: database

11 Turning data silos into data assets



API: application programming interface
*Digital currency DCJPY (tentative name): Yen-based dual-layer digital currency being worked on by the Digital Currency Forum

12 Overview of PoC

12 Proof of Concept Using Digital Currency in the Distribution Supply Chain

Together with sponsoring companies from the Digital Currency Forum Retail and Distribution Subcommittee, on June 2022 Hitachi conducted a proof of concept (PoC) about an integrated commercial and currency flow that completes the entire supply chain process between retailers and wholesalers, from ordering to payment, digitally.

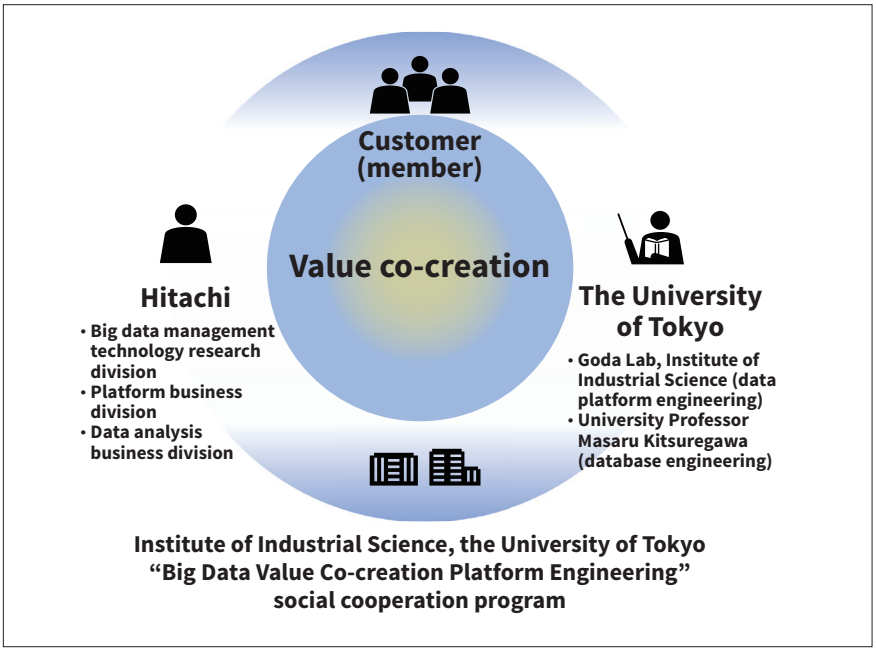
In the retail and distribution industries, the transfer-of-funds cycle is long due to commercial practices, resulting in various issues such as delays in receiving payments the further along in the chain a supplier is, and the necessity of human intervention to perform payment confirmation despite the prevalence of electronic data interchange (EDI). In the PoC, EDI data in the distribution business message standards (BMS) used in business-to-business transactions were stored in the blockchain in near real time, resulting in automatic payment using digital currency immediately after receiving the acknowledgment data.

The PoC was successful in shortening the transfer of funds and reducing the number of steps in the process by linking transaction information and payment information through digital currency in the payment process. The beneficial characteristics of blockchain, such as authenticity, transparency, and automatic processing, add value to business-to-business transactions, showing promise in new commercial possibilities in view of the coming Web 3.0 era.

13 UTokyo-IIS and Hitachi Set up "Big Data Value Co-creation Platform Engineering" Social Cooperation Program

Expectations for using data as a source of value for corporations and society is on the rise. The realization of digital innovation that creates value from onsite and business data is an urgent issue for sustainable growth in customer business. Toward achieving a sustainable society for happy and affluent life, Hitachi has promoted a digital solutions business called "Lumada" with its customers and partners; the aim is to create value from data by exploiting advanced digital technology, such as artificial intelligence.

Starting in 2021, Hitachi and the Institute of Industrial Science, the University of Tokyo (UTokyo-IIS) jointly launched the Value Co-creation Program Utilizing Big Data to promote co-creation initiatives in partnership with companies and organizations working with big data. In April 2022, they set up the "Big Data Value Co-creation Platform Engineering" social cooperation program* with the aim of establishing powerful data



13 Value Co-creation Program Utilizing Big Data

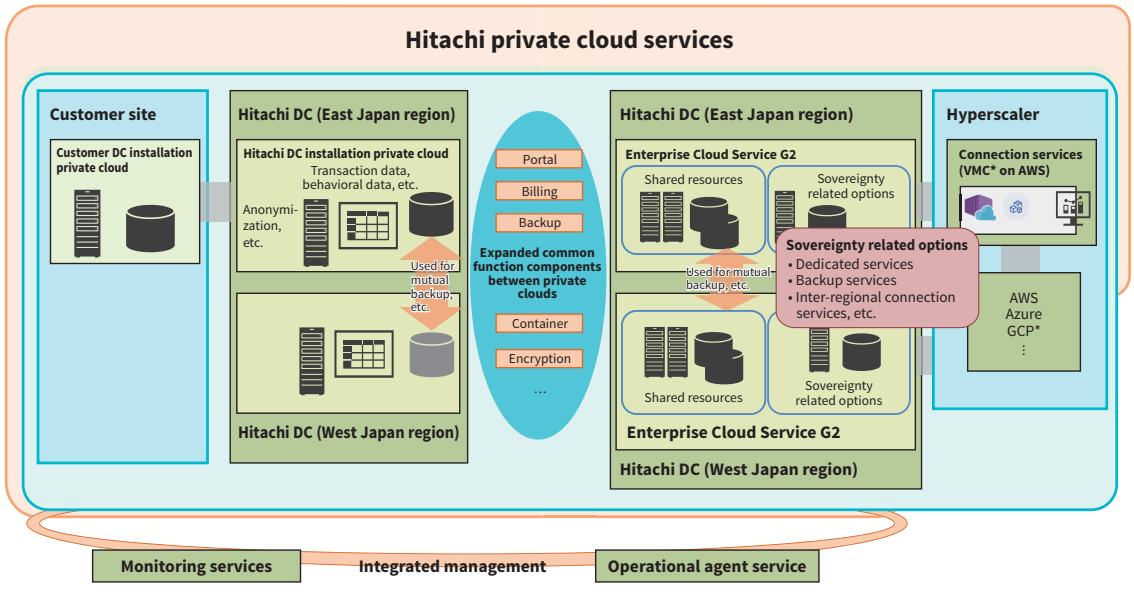
platform technology that allows in-depth analysis of the large-scale data being generated globally.

UTokyo-IIS and Hitachi will continue to promote value co-creation with industry and other stakeholders and offer solutions that accelerate digital innovation through IT, OT, and products.

* A research division established to enable the University of Tokyo and private institutions to engage in joint research on common issues with a high level of public interest.

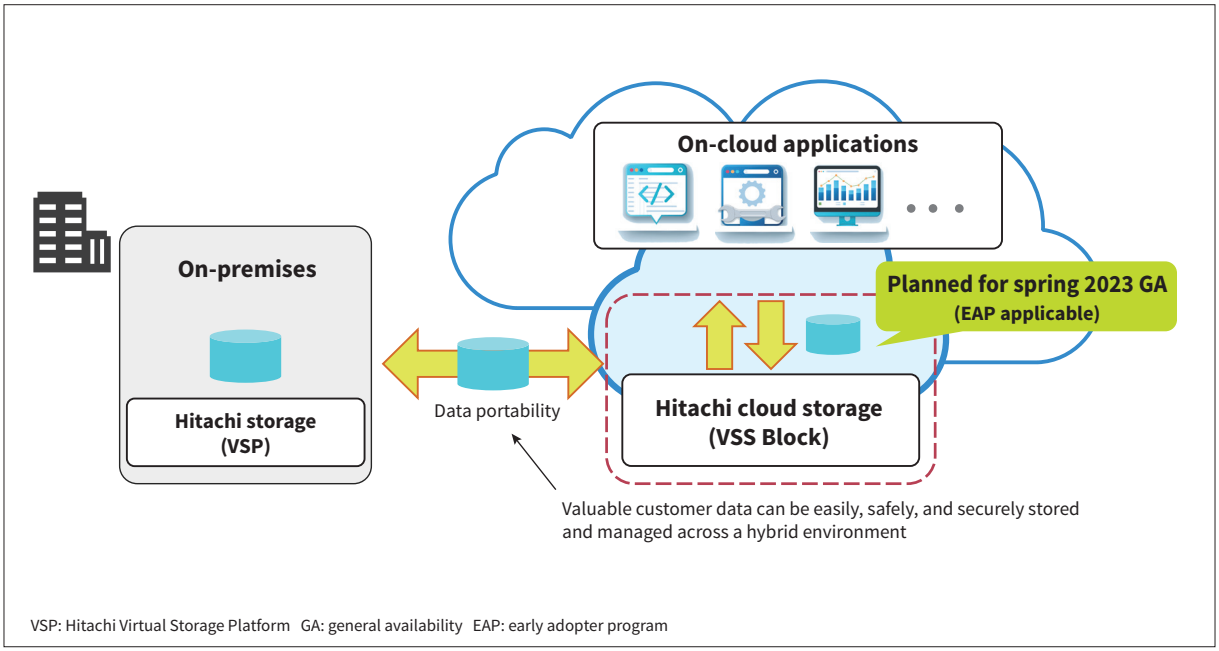
14 Hitachi Private Cloud – For Better Customer Convenience

With conventionally stable operation and carryover of past assets, expectations for private clouds are shifting to multi-cloud and hybrid cloud configurations, ushering in a new era. Hitachi views such changes as an opportunity and is attempting to transform its conventional private cloud offerings to deliver options that provide better customer convenience.



VMC on AWS: VMware Cloud on Amazon Web Services GCP: Google Cloud Platform
* See "Trademarks" on page 158.

14 Hitachi private cloud services



15 Hybrid cloud use with Hitachi storage

Until now, Hitachi has offered Enterprise Cloud Service G2 capable of handling data that requires sovereignty using dedicated services while remaining a multitenant service, single tenant private cloud solutions installed at a Hitachi data center, and private cloud solutions installed at the customer's data center. Such cloud services are conventionally operated and managed individually, however, integration of a portal for common functions, billing, monitoring, and operational services can improve customer convenience. Hitachi also believes that providing transparent services such as countermeasures and reporting during failures will allow private cloud use that provides better customer convenience.

Reference: International Data Corporation (IDC), "Japan Private Cloud Forecast, 2022–2026" (Nov. 2022), # JPE47882322

15 Early Adopter Program Delivers Advance Access to Highly Reliable Hitachi Cloud Storage

In recent years, more customers are considering hybrid cloud solutions that utilize cloud and on-premises features to place the workload and data in the right place at the right time.

In co-creation efforts with Amazon Web Services (AWS), Hitachi developed Hitachi Virtual Storage Software Block (VSS Block), using in-house know-how on proven mission-critical systems expanded to the cloud. Hitachi's original data protection technologies and a strong support framework driven by Hitachi and AWS enables safe, secure data management of key systems in the cloud. The early adopter program* was launched to allow customers to experience it through operation verification ahead of the official spring 2023 release in the Japanese market.

Hitachi plans to improve usability further and provide optimal hybrid cloud environments to customers by strengthening on-premises software and data collaboration and by expanding collaboration between databases and containers.

* A program that allows customers to connect to the application and verify operation by using actual data before the official release.

16 Global Evaluation of Hitachi Storage that Supports EverFlex from Hitachi

With accelerating use of data in recent years, Hitachi storage has supported developments in customer digital business through various unique technologies based on the EverFlex from Hitachi data platform, a hybrid cloud solution. Storage virtualization, a typical example of unique Hitachi technology, enables transparent data management and operations on multiple systems, including the cloud. Also, data compression processing performance improvement technology*1 maintains high-speed data access, delivering efficient management of the ever-increasing amount of company data while contributing to reduced environmental impact.

Hitachi provides such storage solutions globally. And the 2022 Gartner*2 Magic Quadrant*2 for Primary

Storage[*3] (hereinafter, research) issued by Gartner, Inc. has recognized US subsidiary Hitachi Vantara as a Leader for four years running. In 2022 Gartner Critical Capabilities for Primary Storage[*4], a supplementary report issued along with the research, Hitachi Virtual Storage Platform (VSP) 5600 was ranked second out of five use cases.

*1 "Hitachi's storage patent (Japanese Patent JP6802209), Compressed Data Write-processing Switching Method, won the Japan Patent Office Commissioner's Award at the Kanto Local Commendation for Invention" in Japanese (Nov. 2022), https://www.hitachi.co.jp/products/it/storage-solutions/pressroom/award/chihatsu2022/index.html

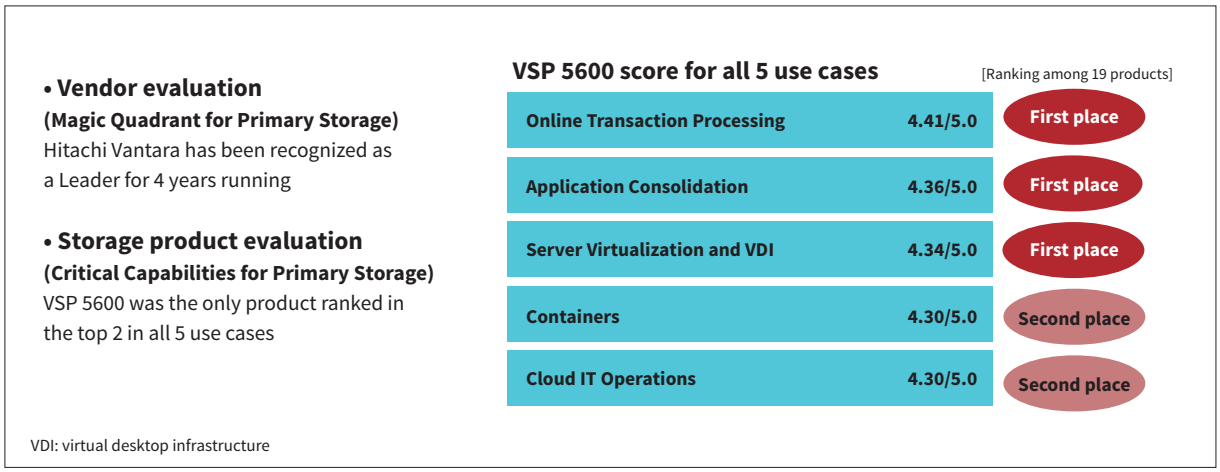
*2 See "Trademarks" on page 158.

*3 Jeff Vogel et al., "Magic Quadrant for Primary Storage," Gartner (Oct. 17, 2022)

*4 Jeff Vogel et al., "Critical Capabilities for Primary Storage," Gartner (Oct. 17, 2022)

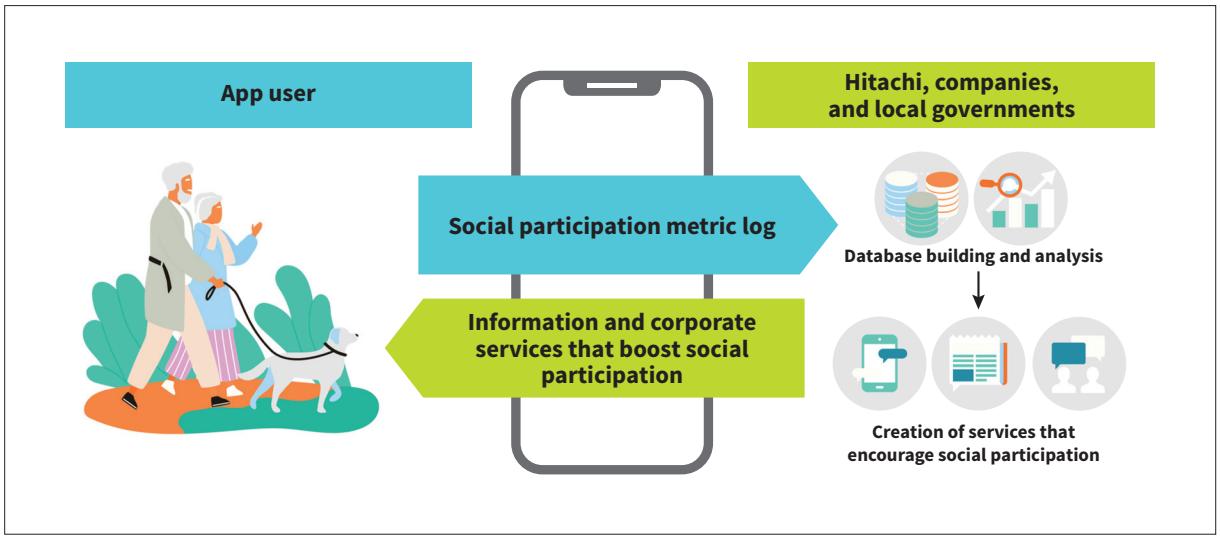
*5 Chart created by Hitachi based on Gartner research.

*6 Gartner disclaimer
Gartner does not endorse any vendor, product or service depicted in its research publications, and does not advise technology users to select only those vendors with the highest ratings or other designation. Gartner research publications consist of the opinions of Gartner's research organization and should not be construed as statements of fact. Gartner disclaims all warranties, expressed or implied, with respect to this research, including any warranties of merchantability or fitness for a particular purpose.



16 Global evaluation of Hitachi storage by Gartner, Inc.[*5]

Financial Systems



1 Data usage cycle by Encouraging Social Participation app

1 *Shakai Sanka no Susume* ("Encouraging Social Participation") Platform—Aiming to Ensure a Sustainable Social Security

When the elderly population reaches its peak in 2040, national long-term care expenses are estimated to reach JPY25.8 trillion, more than double the current rate, leading to calls for optimization of such expenses through preventative care for senior citizens. In addition to effective initiatives in preventative care, such as proper exercise and improved diet, social participation is being advocated in recent years with growing interest.

Social participation in this context is an all-inclusive term referring to going out of the house, participating in community and hobby gatherings, and interacting with friends and others. Hitachi developed the smartphone app *Shakai Sanka no Susume* ("Encouraging Social Participation") to estimate the level of social engagement and began offering it free of charge in June 2022. This app visualizes the level of social participation to promote changes in user awareness and behavior, and with the user's consent, social participation logs are provided to local governments and private companies, realizing a platform to support the development of products, services, and environments that help with social engagement.

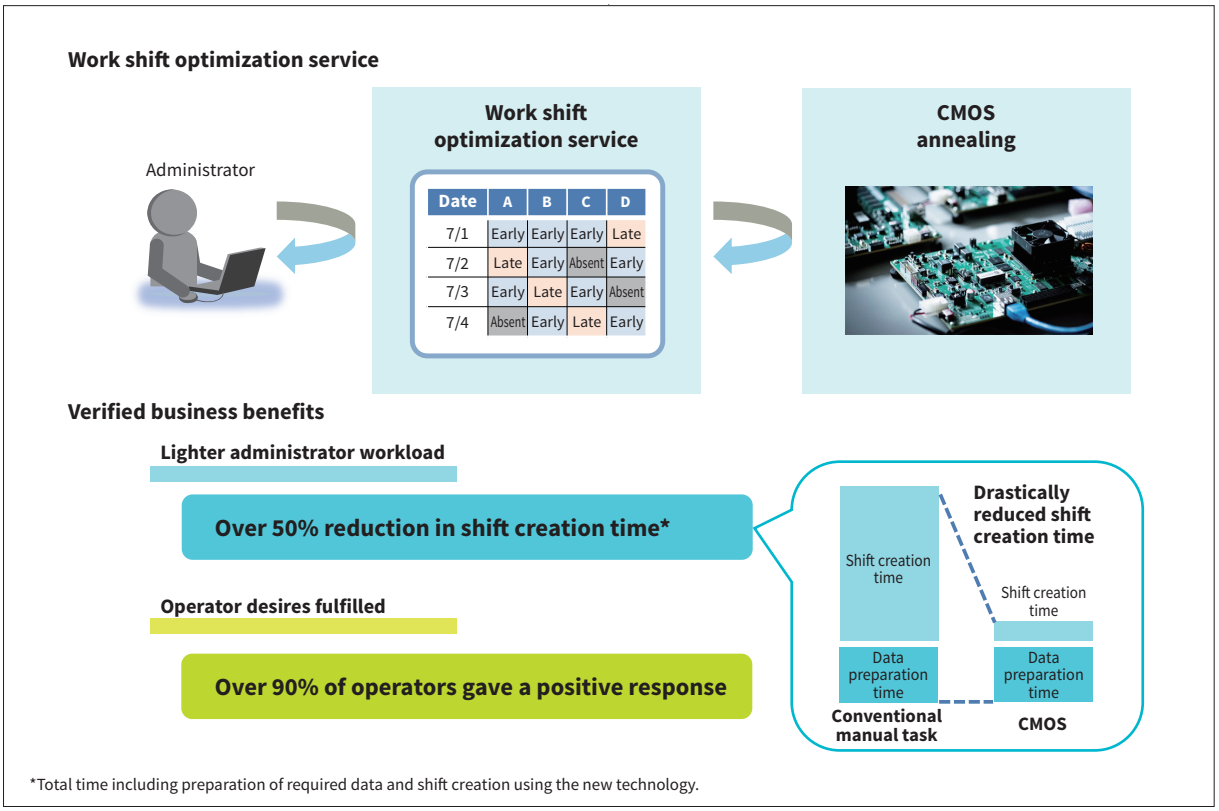
Use of the app among local governments and companies has already resulted in examples of social participation. Hitachi will continuously promote such activities in various industries.

2 Business Demonstration of Work Shift Optimization Using CMOS Annealing

With growing expectations for quantum technologies in recent years, Hitachi has recreated a pseudo-quantum computer framework and developed complementary metal-oxide semiconductor (CMOS) annealing capable of solving large-scale combinatorial optimization problems.

One usage example entails the launch of a work shift optimization service beginning in October 2021. This solution can handle complex conditions such as the required number of personnel per time slot and task, desired staff working dates, and frequency of work, etc.

In a demonstration experiment conducted with KDDI Evolva, Inc. and KDDI Corporation in July 2022, a work shift was created for a call center with nearly 100 staff members. The experiment confirmed that the system can reduce the time required by the administrator to create shifts by over 50%, with over 90% of staff giving positive responses in a post-experiment questionnaire. Because configurable conditions in many automatic shift-creation tools in this field are limited, requiring manual correction,



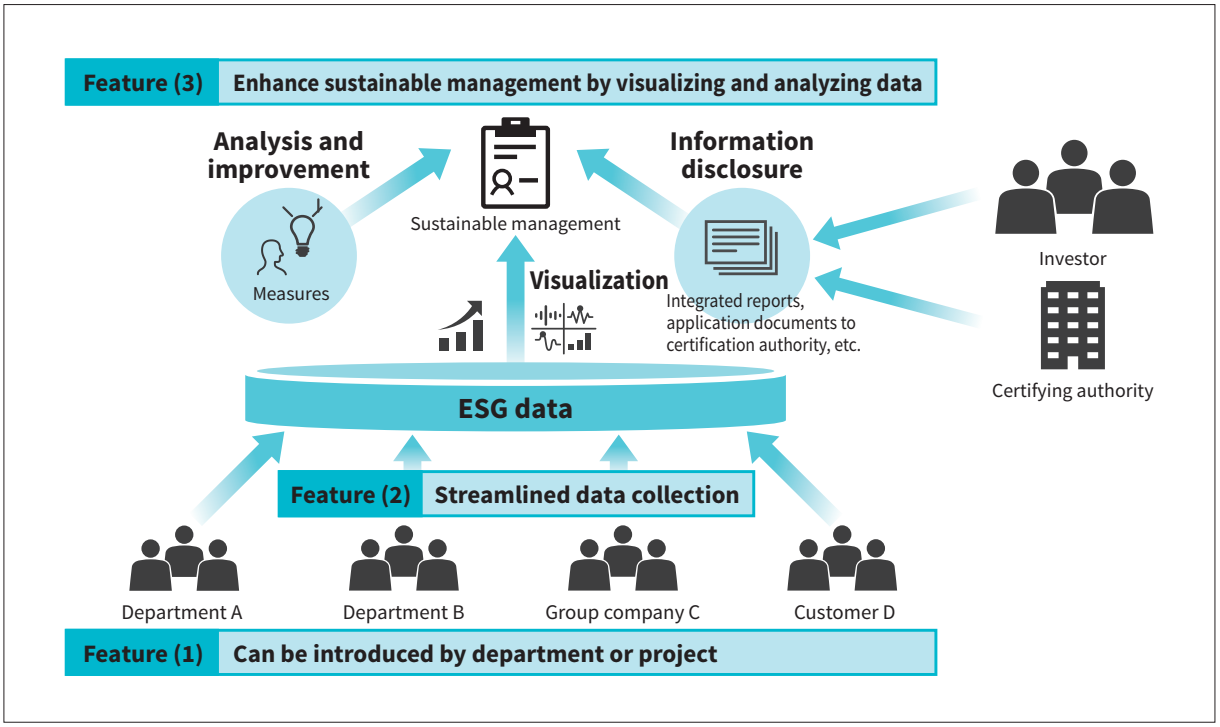
2 Work shift optimization using CMOS annealing

the ability to create a shift with minimal correction that accommodates staff desires is a significant feat.

Hitachi looks forward to contributing to solving personnel allocation optimization and streamlining challenges in the future.

3 Cloud Services that Promote Sustainable Management

Achieving sustainable management requires a process of setting goals, planning and executing improvement measures, monitoring progress, and disclosing results.



3 Overview of ESG Management Support Service

However, this process poses several challenges, such as collecting a wide range of data, integrating data during departmental consolidation, and managing changing disclosure items. To streamline the collection, visualization, and analysis of environment, social, governance (ESG) data and contribute to sustainable corporate growth, Hitachi launched the ESG Management Support Service in September 2022.

This service simplifies defining and recombining data by using familiar tools such as Excel* and email, making it easy and flexible for many users. Hitachi developed this service by verifying its effectiveness in the area of health and safety at Hitachi Construction Machinery Co., Ltd., which aimed to rebuild a safety culture. By automating labor-intensive error confirmation and reminders, this service successfully reduced data collection man-hours by approximately 34%. Furthermore, sharing data between departments contributed to improving safety awareness among employees.

Hitachi aims to continue improving this service to contribute to long-term corporate growth for its customers.

* See "Trademarks" on page 158.

4 Retail DX Initiatives Using CO-URIBA, a Compact, Unmanned Store Service

CO-URIBA is a compact, unmanned store service that uses product rack- and ceiling-mounted sensors to acquire behavioral logs, provide information based on data via digital signage, and enable automatic payments through identify verification utilizing biometrics, etc. to support retail digital transformation (DX) initiatives.

CO-URIBA was installed at three Shibuya-area shops in collaboration with Tokyu Department Store Co., Ltd. for a demonstration experiment from September to November 2022. To provide an exciting new purchasing experience on a real sales floor, the service provided information and conducted questionnaires linked to social media accounts and collected advanced behavioral data such as what items customers picked up from the product rack, what they put back, and what they ended up choosing, as well as displaying product descriptions of items that were picked up on signage.

Hitachi aims to continue working toward practical retail DX applications to promote data usage for sophisticated marketing purposes and to provide more wide-ranging purchasing experiences on real sales floors.

4 CO-URIBA

Social and Public Sector Systems

1 Improving Cold Chain Businesses Using Remote Monitoring and Remote Control

Hitachi Global Data Integration (HGDI) is a service for leveraging Internet of Things (IoT) data that recently started providing IoT device remote controlling functionality in addition to monitoring functionality. Lately, opportunities to use data remotely via the Internet have been increasing. Such data are used for streamlining business, increasing the value of services, and tackling social issues; leading to greater demand for remote monitoring and controlling in various business domains. This article covers HGDI's use case concerning remote monitoring and control in the cold chain business for the logistics industry.

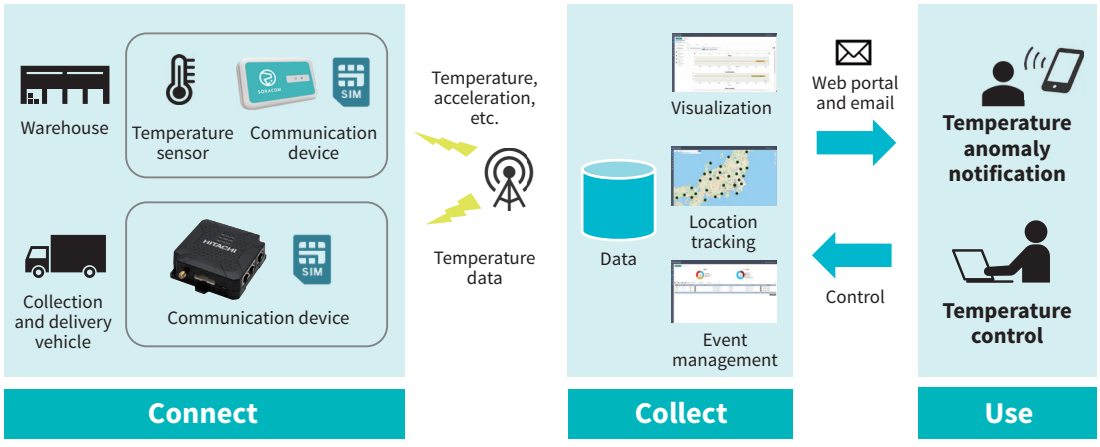
Temperature management in cold chains requires changing of refrigeration temperature settings and recording of actual temperatures. The usual way in which temperature management is performed involves truck drivers manually changing temperature settings according to environmental changes and recording measured temperatures. This way of temperature management has led to challenges regarding quality management, driver workload, and safety. To overcome such challenges, HGDI enables centralized temperature management of multiple trucks and their cargo (remote monitoring, control, and operation history) through a web portal from a monitoring and control center. The cargo's temperature can be monitored from when the cargo is in the warehouse until it arrives at the point of delivery.

Hitachi aims to contribute to solving customer challenges and business expansion efforts through HGDI by expanding its applications to other business domains in the future.

2 Efforts to Enhance Social Infrastructure Maintenance and Reduce Environmental Impact

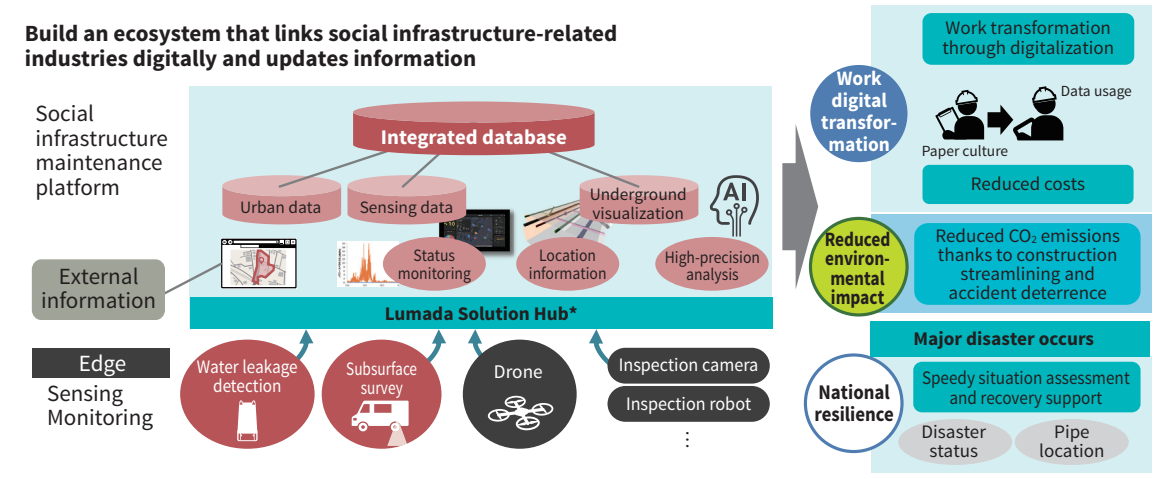
Social infrastructure underpins people's life, so stable, normal operation is required. However, in addition to social issues such as the deterioration of facilities and a lack of skilled workers, there is an increasing demand to reduce environmental impact.

One solution to such issues is the goal of providing water leakage detection service (to automatize the detection of water leakage using Hitachi's original ultra-sensitive vibration sensors), subsurface visualization service [using artificial intelligence (AI) analyze radar imaging and provide visual information about subsurface piping], and other solutions that deliver social infrastructure maintenance in terms of both service level and cost. Hitachi has already contributed to customer business in the field by collecting and analyzing data. Also, the



SIM: subscriber identity module

1 HGDI use case for cold chain remote monitoring and remote control



CO_2: carbon dioxide
*A platform for building an ecosystem to rapidly achieve customers' digital transformation efforts

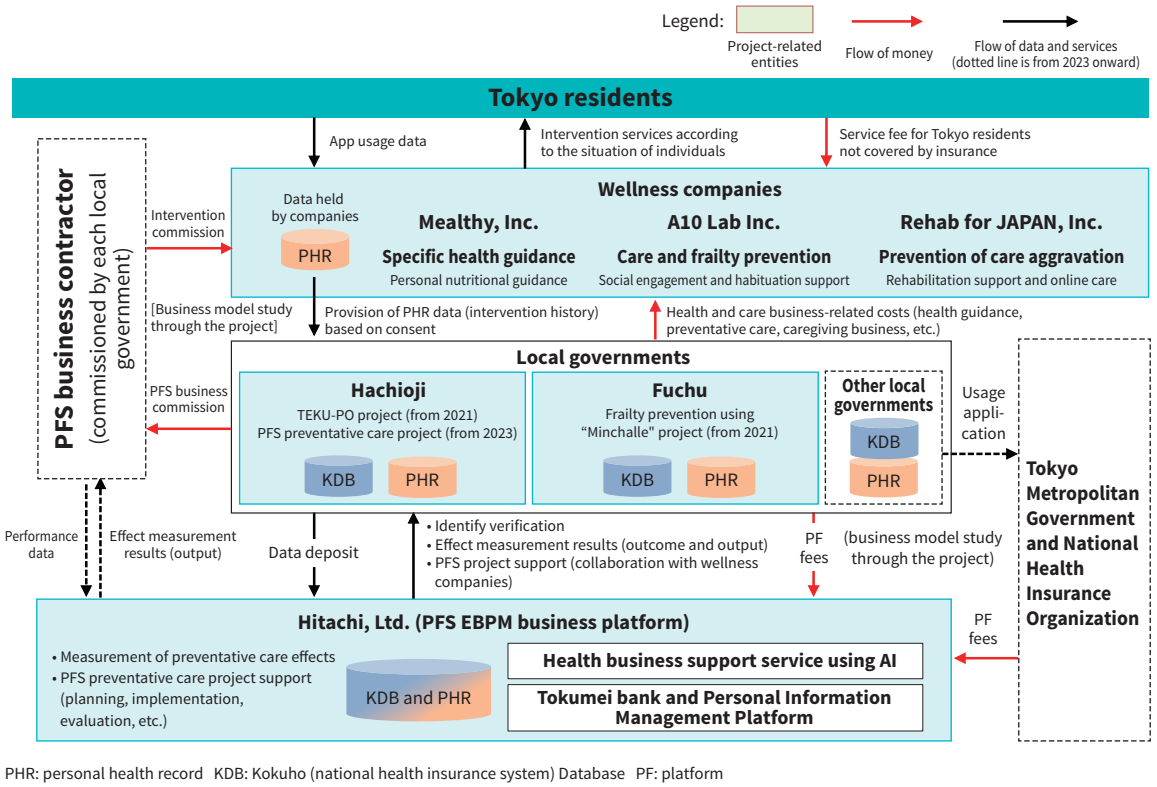
2 Concept of social infrastructure maintenance service

service is expected to reduce environmental impact, with efforts to provide visualization of reduced environmental impact level (reduce CO_2 emissions and waste) conducted in FY2022.

Going forward, the entire Hitachi Group aims to promote social infrastructure digital transformation efforts that contribute to social infrastructure maintenance management, national resilience (preparation for large-scale disasters), and reducing the environmental impact.

3 EBPM Business Platform via Co-creation between Local Governments and Startups

The government estimates that it can save JPY3.2 trillion annually in long-term care expenses through preventative care for senior citizens. In terms of both improving quality of life (QoL) over an individual's lifetime, and financial suitability, quality preventative services are highly significant, socially speaking. Contribution from



PHR: personal health record KDB: Kokuho (national health insurance system) Database PF: platform

3 Overview of target final project

the private sector is counted on in order for the government to effectively use business resources while providing a wide range of services to citizens. However, the inability to grasp preventative care cost effectiveness is a barrier to introducing private services and establishing appropriate market prices. Sharing the results of preventative care beneficiaries to accelerate the proliferation of services, and social implementation of a new framework has become an urgent matter.

With this in mind, Hitachi is now working on creating an evidence-based policy making (EBPM) business platform as part of the Tokyo Metropolitan Government's Project Support for Creating Next-generation Wellness Solutions for FY2022.

In the project, a new EBPM business platform utilizing a Hitachi secure personal data base and elderly care, health, and medical big data AI analysis technology is being created as part of efforts to verify the outcome evaluation of preventative care projects in Hachioji and Fuchu. By contributing to the promotion of local governments' evidence-based pay for success (PFS) preventative care projects, the initiative aims to achieve preventative senior citizen care that contributes to improved QoL for Tokyoites.

4 General-purpose Digital Contact Point for Use with Public and Private Contact Services

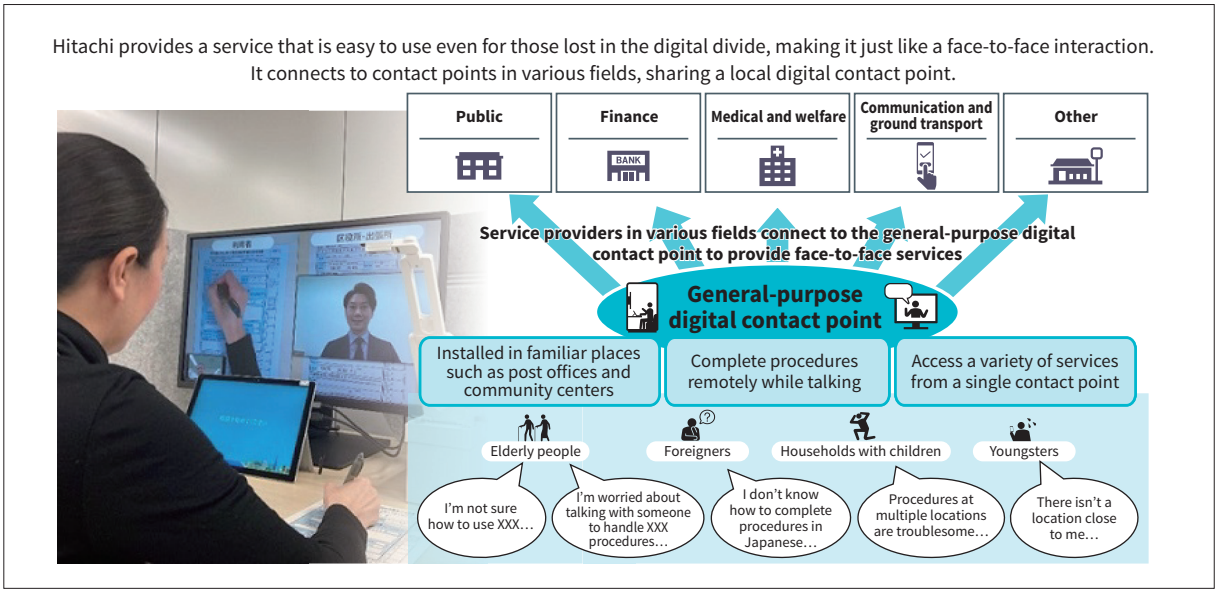
The low birthrate and aging population in recent years has resulted in a lack of workers, leading to consolidation of local government and private contact points and manned shops, making it difficult to provide face-to-face services, and driving digitalization with a focus on smartphone usage. On the other hand, to alleviate age and regional digital divides (information inequality), sluggish use of online applications, and heavy workloads at contact points, digital services that are easy for everyone to use are in demand.

One approach to such issues is installing booths in familiar places, such as local branch offices, community centers, banks, train stations, and mobile kiosks, along with development of various features that can access both local government and private enterprise contact point services online even in remote locations. The goal is to create a new form of service delivery that allows anyone to enjoy the same level of service as a manned contact point in a familiar place, with a large, immersive display and a digital user interface and user experience (UX) that can be easily operated even by the elderly and others unfamiliar with digital technology.

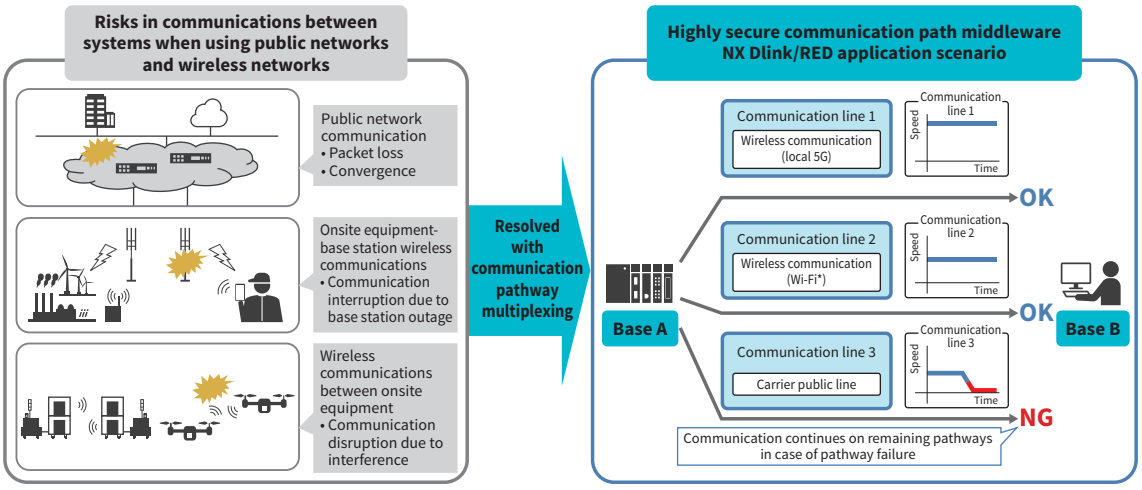
In the future, Hitachi aims to help achieve a digital society where no one is left behind, to expand the service to different industries as part of a new community service infrastructure in cooperation with the public and private sectors, and to help solve local issues and improve residents' QoL.

5 Highly Reliable Communication Path Middleware NX Dlink/RED

Hitachi has developed NX Dlink/RED (Reliable Enhanced multipath Distribution) communication



4 General-purpose digital contact point



5 NX Dlink/RED application scenario

middleware that incorporates symbiotic evolution architecture concepts to achieve mission-critical IoT.

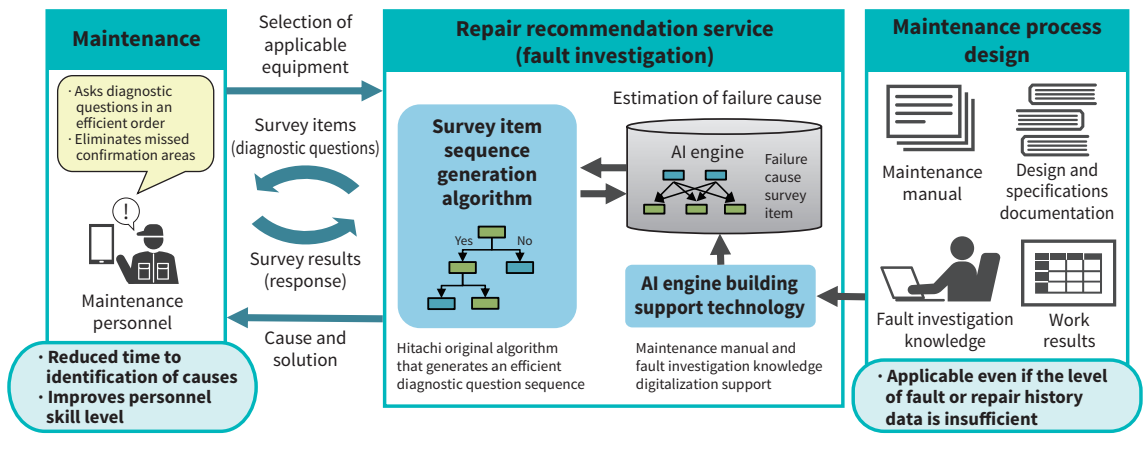
The greatest feature of NX Dlink/RED is that it provides multiplexing and redundancy of multiple network pathways without changing existing applications so that data on another system can instantly be selected to minimize communication downtime even when faults occur on a single pathway. Additionally, the system supports communication pathway protection via encryption, providing communication reliability and security, elements that are essential to mission-critical IoT.

NX Dlink/RED is particularly effective for wireless communications, which tend to pose security issues such as frame loss and convergence, and risk of wiretapping. This service aims to provide highly secure communications between onsite equipment over local fifth-generation (5G) and wireless local-area network (LAN) at production sites, and sites that have wireless communication needs such as public network applications on transportation (train cars, etc.). Hitachi will expand the utilization range of wireless technologies based on this product and contribute to achieving resilient social systems.

6 Digitalization of Fault Investigation Knowledge to Improve Social Infrastructure Maintenance Efficiency

Repair recommendation service (parts selection) use past fault and repair history data for machine learning so that an AI engine can appropriately recommend replacement parts according to the fault status.

This service is being applied to bank automated teller machine (ATM) maintenance tasks to verify the



6 Overview of repair recommendation services (fault investigation)

effectiveness of shortening the replacement parts selection time. However, in many cases the level of history data is insufficient, requiring a new approach to selection.

To deal with this situation, repair recommendation service (fault investigation) digitalize maintenance-related knowledge to cope with even projects that lack a sufficient level of fault and repair history data. The main features are shown below.

(1) Fault investigation knowledge gleaned from maintenance manuals, design and specifications documentation, and interviews with veteran maintenance staff is modeled using AI engine building support technology.

(2) When a fault occurs, responding to the order of diagnostic questions generated by the original Hitachi algorithm enables efficient estimation of the fault causes.

(3) The service delivers fault investigation according to on-site operation circumstances, enabling establishment of diagnostic questions that lock or prioritize a sequence of questions.

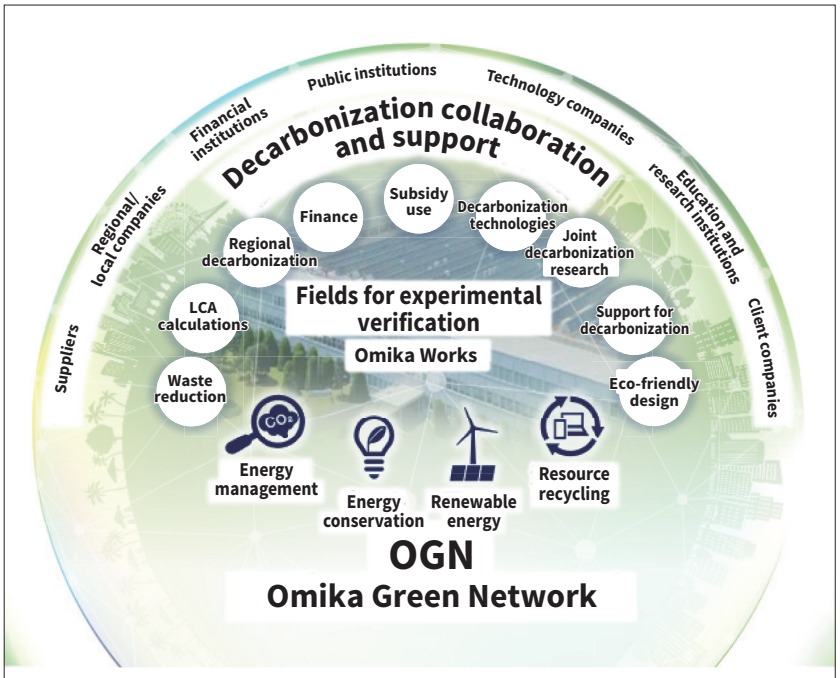
This process shortens the time to estimate the cause and is expected to improve the skill level of maintenance staff.

Currently, fault investigation repair recommendation service is being applied as a proof of concept (PoC) for particle therapy systems. Together with parts selection as a support service for maintenance tasks of complex, important equipment that serves as part of the social infrastructure, Hitachi plans to expand the scope of application.

7 Co-creating Decarbonization Growth with GX—Omika Green Network

Hitachi has set a goal of attaining carbon neutrality at its factories and offices by 2030 and across its entire value chain by 2050. This environmental goal is not Hitachi's alone, but a social issue that the community and the entire supply chain must work together to achieve. To tackle this issue head on, Hitachi, Ltd.'s Omika Works began working on the Omika Green Network in 2022.

Driven by years of onsite knowledge, digital technologies, and control technologies accumulated through production reform and factory digital transformation, Omika Works serves as the hub of a demonstration project for environmental management green transformation (GX) efforts, including the calculation, visualization, and reduction of CO_2 emissions in the production process, and efficient use of renewable energy sources. The Omika GX Model, regional energy management infrastructure, and environmental trusted digital infrastructure honed during this process will be rolled out to a variety of stakeholders outside the company, including supplier companies and financial institutions. To achieve carbon neutrality, Hitachi will engage in forming and developing a social infrastructure ecosystem in the region to help co-create a decarbonized society capable of sustainable growth.



LCA: life cycle assessment

7 Omika Green Network

IT Services

1 Rebar Inspection System Saves Labor in Inspection Tasks with Digital Measurement Technology

Hitachi Solutions, Ltd. promotes digital transformation (DX) in collaboration with companies in a variety of industries, one of which is construction. One task on a construction site is the inspection of rebar, requiring considerable time and effort for preparation, manual measurements, and creating reports. The Rebar Inspection System was jointly developed using Hitachi Solutions' special information technology and Sumitomo Mitsui Construction Co., Ltd.'s onsite expertise to help save on labor in rebar inspection tasks.

This system was adopted by the Ministry of Land, Infrastructure, Transport and Tourism's 2019 Project to Introduce and Utilise Innovative Technology to Dramatically Improve Productivity on Construction Sites, attaining the highest score, rank A. The use of general-purpose items making procurement easy and keeping costs low, and the use of an original algorithm to ensure sufficient inspection precision has been praised both inside and outside Japan, leading to the system receiving the Outstanding Tech Company Award at the 2022 ASOCIO Tech Excellence Awards, and the Winner at the JISA Awards 2022.

In the future, Hitachi Solutions aims to utilize the experience and knowhow gleaned from site construction efforts to contribute to DX in the construction industry. (Hitachi Solutions, Ltd.)

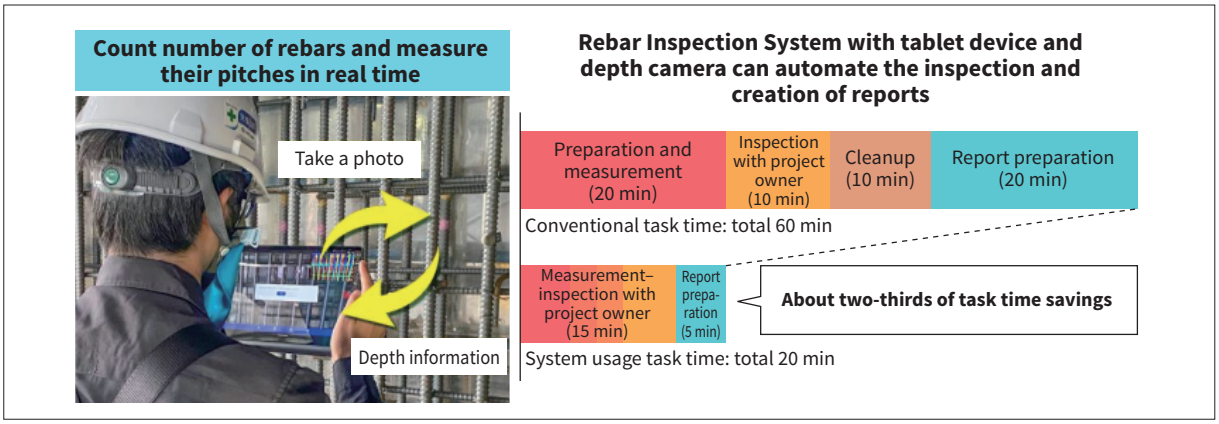
2 DX Lab.—Online Co-creation Space that Gives Shape to DX in Collaboration with Customers

The Hitachi Solutions DX Lab. (hereinafter, DX Lab.) is an online co-creation space for supporting customer DX promotion initiatives in this era of volatility, uncertainty, complexity, ambiguity (VUCA), where DX has grown ever more important in flexibly dealing with change.

At the DX Lab., consultants collaborate with customers on their DX promotion initiatives, supporting the entire process from idea creation to business model building. Combining customer's business domain knowledge with Hitachi Solutions DX promotion knowledge and technical abilities makes it possible to promote customer DX in an efficient manner.

For example, when a customer is considering a new business, staff from the Hitachi Solutions business and sales divisions gather online to brainstorm based on the study theme, create a service hypothesis through a repeated process of verifying value and making corrections, and then organize a business model. After this last step, a roadmap is developed in view of the service improvement and the scale of the project so that a smooth transition can be made to the development and operation support environment.

The DX Lab. is already collaborating with multiple customers in the manufacturing and service industries, producing results through co-creation such as new services. In the future, Hitachi Solutions aims to offer the



1 Labor saving thanks to the Rebar Inspection System

2 DX Lab. support

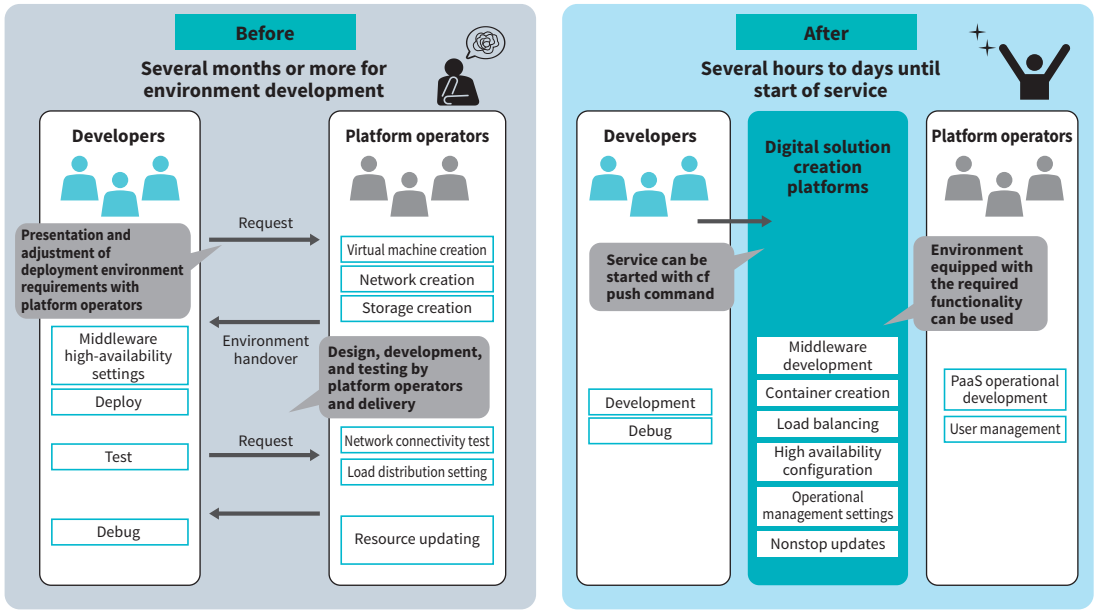
service not only online, but as a hybrid co-creation venue including face-to-face meeting.
(Hitachi Solutions, Ltd.)

3 Digital Solution Creation Platform for Promoting DX

The Hitachi Solutions digital solution creation platform is a co-creation service platform capable of repeatedly, quickly, and simply developing services required for DX promotion. The application developer simply prepares the source code and executes commands to automatically create, save, and launch containers[*1] so that users can access the application.

In a conventional system integration (SI) model, application environments are available for use after a process of various adjustments, design, development, and testing between the developer and the platform operator. On the other hand, the digital solution creation platform provides an environment for developing and operating applications by utilizing the VMware Tanzu[*2] software provided by VMware, Inc., which enables the automation and orchestration of Kubernetes[*2]. This frees the application developer from the process of going back and forth with the platform operator and from preparing an environment, and eliminates the need to apply patches and implement security measures, allowing them to focus on app development.
(Hitachi Solutions, Ltd.)

*1 Technology that provides a virtual software operating environment
*2 See "Trademarks" on page 158.



PaaS: platform as a service

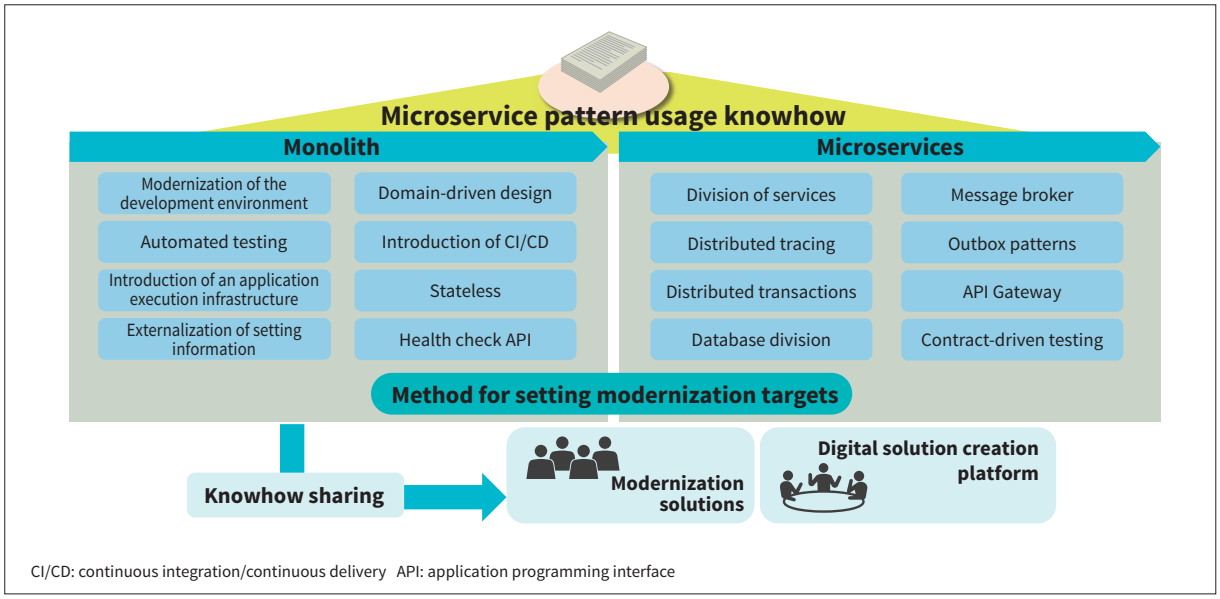
3 Digital solution creation platform

4 Development Method for Accelerating DX: Microservice Patterns

Key systems in DX acceleration are counted on to contribute to ensuring a company's competitive edge, and such systems require constant upgrades to maintain and improve their value. When aging systems, etc. make it impossible to do so, modernization with the goal of improving agility and streamlining operations is necessary, and microservices are one way to achieve this goal.

Microservices are complex architectures achieved through cross-cutting application and infrastructure environment design and development methods (microservice patterns), and it is important to formulate introduction strategies and to determine whether they are needed. In moving ahead with modernization, the introduction of microservice pattern components is effective even when selecting a monolithic architecture that provides overall functionality in a single application. With this in mind, Hitachi Solutions has organized in-house knowhow on how to set cost-effective modernization goals and how to introduce microservice patterns, and is supporting its customers through its digital solution creation platform and modernization solutions.

(Hitachi Solutions, Ltd.)



4 Microservice pattern usage guides and cooperative solutions

Green Energy & Mobility

Power Grids

Energy

Nuclear Energy

Railway Systems

Power Grids

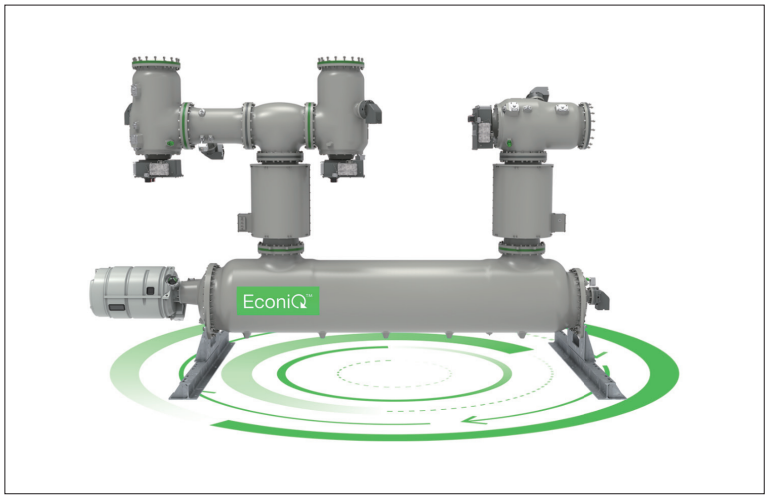
1 Moving towards Carbon-neutral HV Switchgear by Combining Eco-efficient Technologies

The transition towards a carbon-neutral energy system requires sustainable equipment and services for the power grid. Sulfur hexafluoride (SF_6) technology has been very successful by enabling compact, reliable, and scalable high-voltage (HV) switchgear. In more than a decade of research and development, Hitachi Energy Ltd. has developed an alternative technology to SF_6 for the EconiQ high-voltage portfolio. EconiQ metal-encapsulated switchgear uses an innovative gas mixture with 99% lower carbon dioxide (CO_2)-equivalent, while retaining the compact footprint, low material consumption, and scalability of modern SF_6 equipment. With excellent dielectric and arc quenching properties, the gas mixture of fluoronitrile, CO_2, and oxygen represents the solution for a complete platform of HV switchgear including circuit breakers. It can lead the way to an industry standard for new equipment. The gas mixture enables manufacturers and users to build on decades of experience with SF_6 in dielectric design, gas circuit breaker technology, material choice, operational health and safety, and gas handling. Additionally, an optimal service was developed and implemented for the installed base using the mixture of fluoronitrile, nitrogen, and oxygen. Large volumes of SF_6 in 420-kV gas-insulated lines can be "retrofilled" in existing installations, significantly reducing future CO_2-equivalent emissions.
(Hitachi Energy Ltd.)

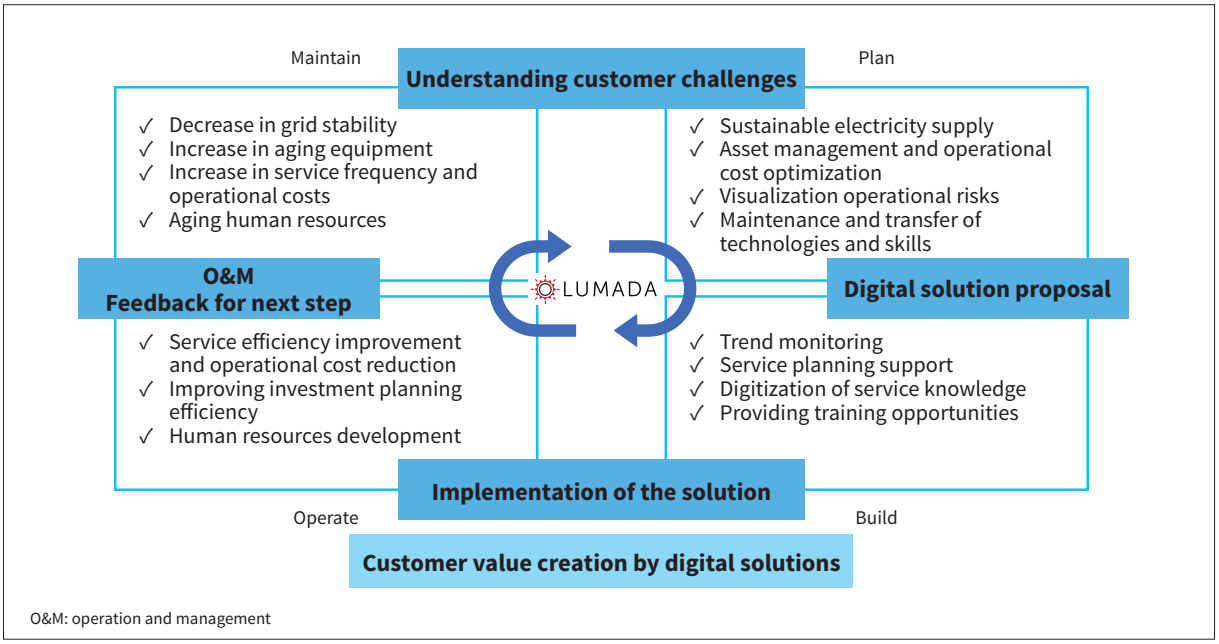
2 O&M Optimization, Operational Risk Reduction of Aging Equipment, and Technology Transfer Utilizing Digital Technology

In recent years, the importance of substation facilities for power plants and key substations has been increasing due to the decline in the stability of the power system owing to the increase in renewable energy and the tightening of power supply capacity. Furthermore, increasing aging equipment in the field conflicts with meeting revenue cap regulations, reducing equipment maintenance and renewal costs while maintaining a sustainable electricity supply. In addition, there is an increasing need for condition assessment for evaluating operational risks of aging equipment, and efficient measures to maintain and pass on expert skills to the next generation.

Hitachi provides the solution for these social issues with Hitachi Energy's online monitoring system, TXpert, and modular switchgear monitoring (MSM), which enables equipment condition analysis, operational risk



1 Eco-efficient circuit-breaker for application in SF_6-free EconiQ 420-kV gas-insulated switchgear



2 Hitachi and utility future vision

assessment, and maintenance rationalization solutions, as well as a maintenance knowledge support system utilizing artificial intelligence (AI) to improve operator efficiency with remote support, digitized know-how, and a knowledge database.

Hitachi also provides a global standard digitalized transmission and distribution equipment package, which realizes customer value for new substations and existing equipment renewal.
(Hitachi Energy Ltd.)

3 Installation of World's First 145-kV Dry-type Transformer in a Hydro Power Station

Hitachi Energy has collaborated with Duke Energy Corporation to renew an old substation at Jocassee Power Station, a 780-MW pumped storage plant located in Salem, South Carolina (USA). The target of the project, in addition to extending the life of the substation, was to eliminate the risk of oil-spill water contamination from the 50 year-old transformers located on the shore of the lake.

3 145-kV dry-type transformer after factory acceptance tests with customers

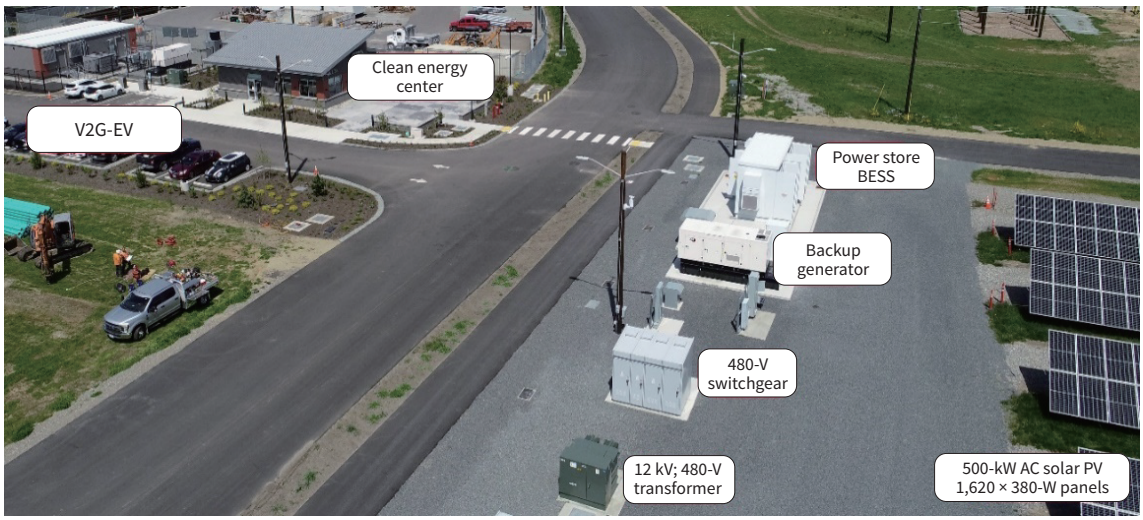
The solution involved the development of the first 145-kV dry-type transformer in the world.* It is a unit with a rated power of 3,000 kVA and a nominal voltage of 100 kV. The project is the culmination of several years of development related to the high-voltage insulation in dry-type cast-coil transformers.

The old outdoor substation was converted into an indoor one, freeing the footprint for other uses. The result is the safest solution for people, property, and the environment; with an excellent response to short-circuit mechanical efforts and reduced maintenance costs.
(Hitachi Energy Ltd.)

* Based on research by Hitachi Energy Ltd.

4 Microgrid Platform for V2G: Lessons Learned from the Arlington Microgrid

The year 2022 may be remembered as the year of the electric vehicle (EV). Recognizing the importance of EVs, one of the USA's largest public electric utilities, Snohomish County Public Utility District (SnoPUD), unveiled a state-of-the-art microgrid demonstrating how digital technology supports a sustainable future. The Arlington Microgrid pairs Hitachi Energy's e-mesh PowerStore grid-forming battery energy storage system (BESS) with onsite community solar photovoltaic generation, integrated with a vehicle-to-grid (V2G) enabled



AC: alternating current PV: photovoltaic system
Photo courtesy of Snohomish County Public Utility District.

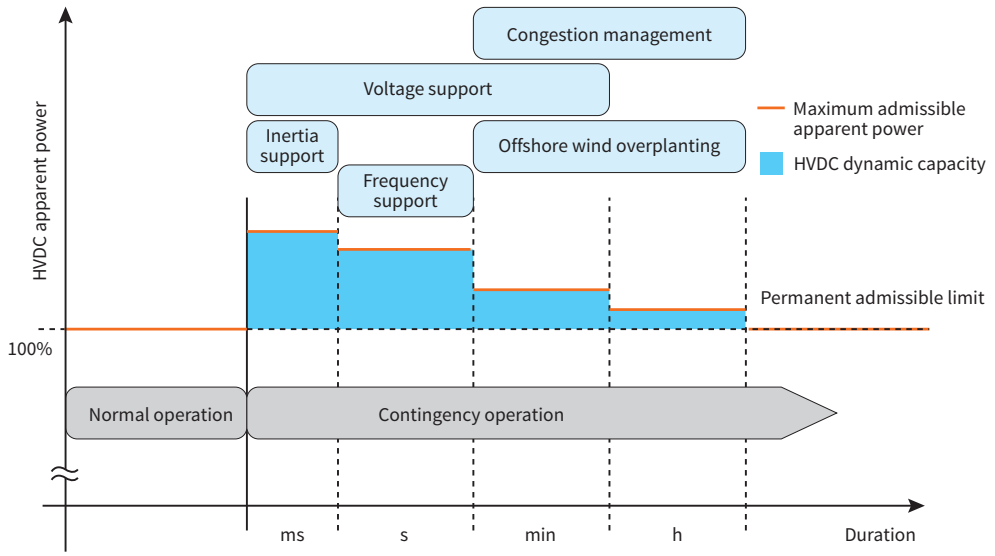
4 Overhead view of the Arlington Microgrid

EV fleet. Automation from Hitachi Energy's e-mesh portfolio delivers on the promise of an electrified future—from resilient power and V2G EVs to critical infrastructure operating on 100% renewable power.

With Hitachi Energy's grid edge solutions, SnoPUD unlocked the benefits of pairing EVs with local solar; the vehicles serve as distributed energy resources (DERs) for the microgrid while the microgrid serves as a resilient, renewable hub for EVs. In addition to hardened EV infrastructure, the microgrid hosts critical facilities receiving secure, failsafe power. The Arlington Microgrid is a milestone in SnoPUD's journey to catalyze grid edge technologies across its service territory and beyond. (Hitachi Energy Ltd.)

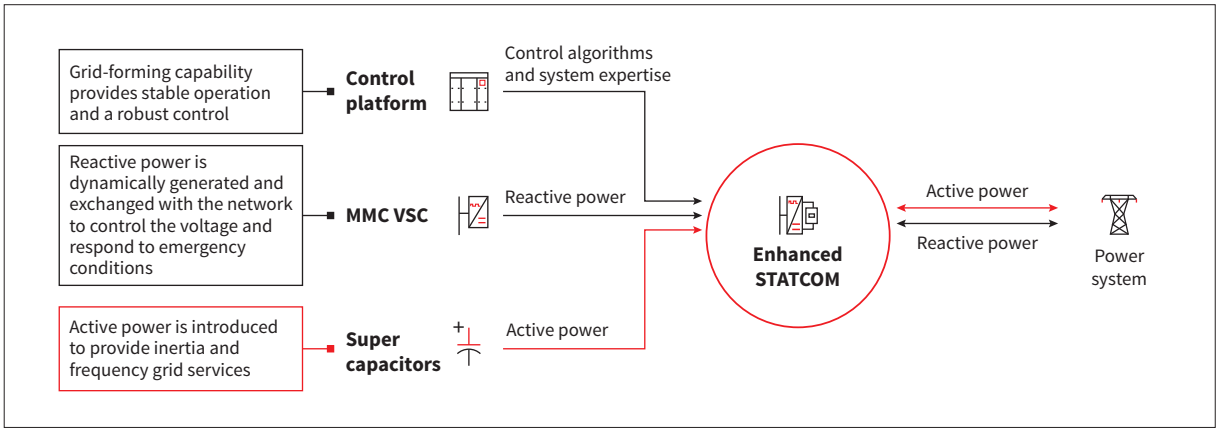
5 Online Estimation of Dynamic Capacity of VSC-HVDC Systems

More efficient use of power system assets is becoming increasingly important on the path towards a fossil-free power system. Hitachi Energy's pioneering HVDC Light is utilized for various applications around the world to accelerate the energy transition. The dynamic capacity*



VSC: voltage sourced converter

5 Power system use cases for dynamic capacity of VSC-HVDC systems



6 SVC Light Enhanced key building blocks

of HVDC Light addresses emerging challenges in the power systems of the future, such as flexibility, controllability, and resilience, and in general, helps operate the power system more efficiently.

Dynamic capacity was tackled from a system perspective with respect to the influence of multiple components and their interaction to provide a proof-of-concept relying on real-time operational data from MACH information management system (MIMS) data loggers installed at the high-voltage direct current transmission system (HVDC) interconnector, NordLink, in Germany. A software prototype was developed to estimate the dynamic capacity depending on ambient temperature and grid voltage to improve transmission system operators' (TSO's) system operations of curative congestion management. In the future, such a feature could be utilized as a curative remedial action to reduce the need for preventive redispatch measures among others.

*Temporary capability to perform beyond their guaranteed capabilities.

6 Energy Storage Enhanced STATCOM for Secure and Stable Power Grids

The modern power system is facing stability and reliability challenges due to lack of inertia. These new challenges create great opportunities to support Hitachi Energy's customers with power quality solutions. The company launched SVC Light Enhanced in 2021 with active power capability and grid-forming behavior. It is expected to play a contributing role in supporting its customers to achieve required inertia levels in the transmission grid. SVC Light Enhanced consists of the following building blocks:

(1) Modular multilevel converter (MMC) solution enables high power and high voltage integration to transmission grid

(2) Power-intensive energy storage technology extends the conventional MMC static synchronous compensator (STATCOM) with an active power capability

(3) Hitachi Energy's power modular advanced control for HVDC (MACH) control platform facilitates system integration and control

(4) Grid-forming control capability provides instantaneous inertia response and voltage response

SVC Light Enhanced is designed to be:

(1) an all-in-one solution for the transmission grid that can provide diverse functionalities including, but not limited to, inertia response, frequency response, voltage regulation, etc.,

(2) a highly flexible, modular, and scalable solution,

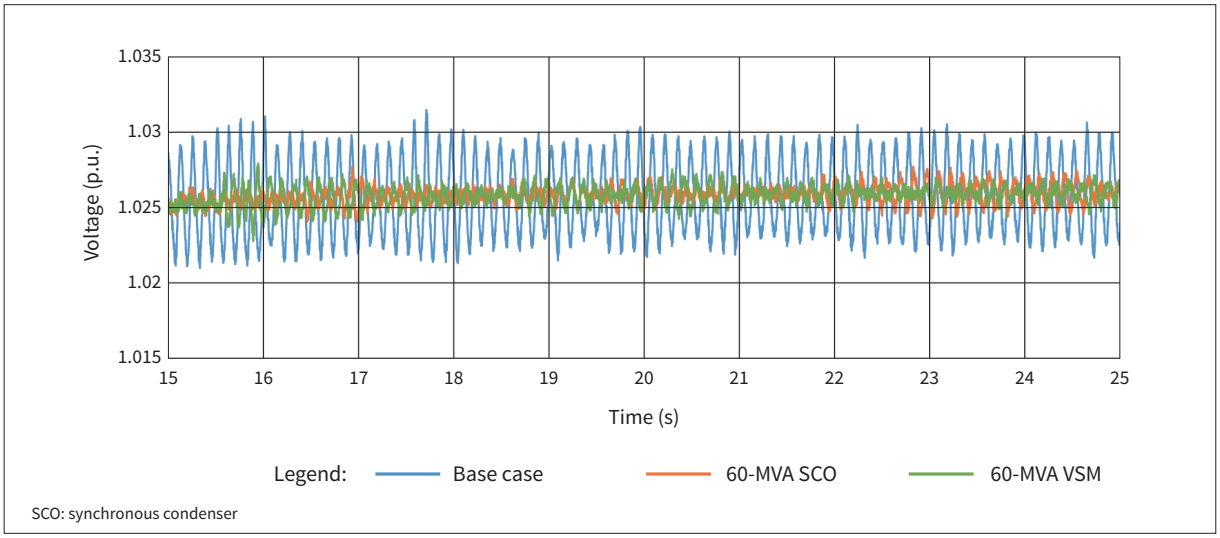
(3) a preferred solution from the ownership perspective—compact footprint, low power loss, long lifetime, and simple maintenance.

(Hitachi Energy Ltd.)

7 System Strength Support Using Grid-forming Energy Storage for High Penetration of Inverter-based Resources on Weak Networks

Hitachi Energy and the Australian Energy Market Operator (AEMO) collaborated in early 2021 to conduct one of the first studies globally into the effectiveness of virtual synchronous machine (VSM), advanced inverter technology to support system strength and enable high penetration of renewable energy to operate on weak electricity networks. The study was motivated by the performance of the Dalrymple BESS – the first National Electricity Market (NEM) connected advanced inverter BESS and the system strength challenges seen in the West Murray Zone (WMZ).

According to the study, a 60-MVA VSM and a 60-MVA synchronous condenser were found to provide



7 Post-disturbance voltage oscillations suppressed by VSM to same extent as SCO

similar system strength support in damping post-fault voltage oscillations in the WMZ. As such, a VSM is a viable solution for connecting and operating large amounts of renewable energy in weak areas of the NEM, with the added ability to provide market services. The results have moved the industry's understanding of advanced inverter technology forward significantly and reinforced this technology's key role in enabling a zero-emissions grid.

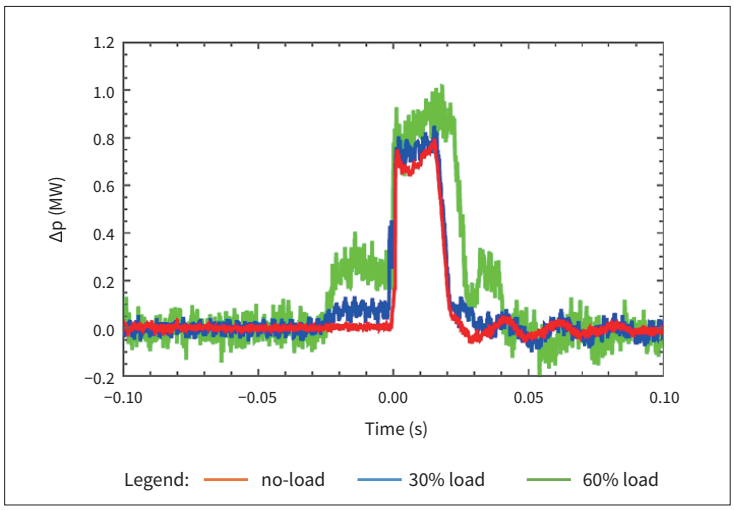
(Hitachi Energy Ltd.)

8 On-load Tap Changer Monitoring and Protection by Extra Power Loss and Circulating Current Analysis

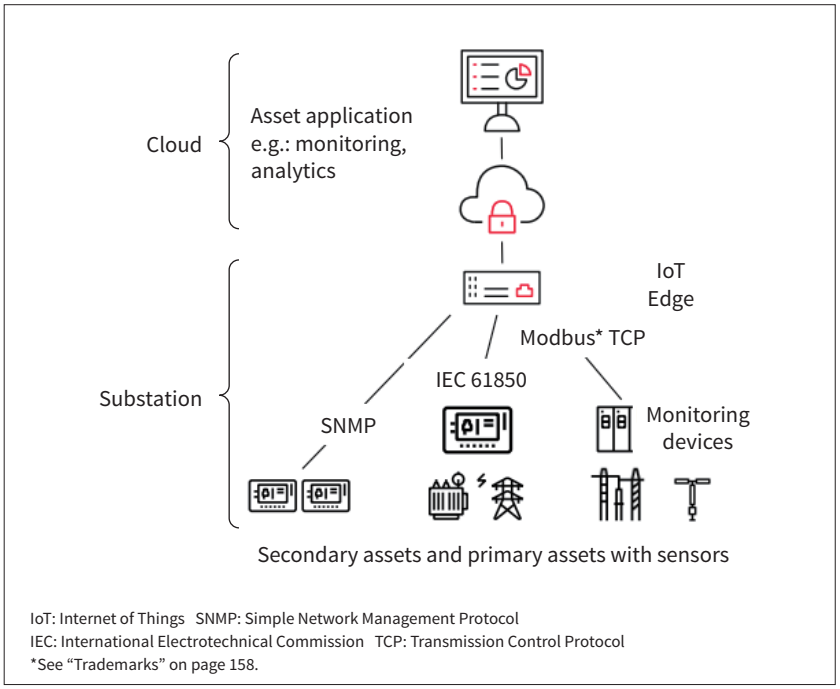
The on-load tap changer (OLTC) used for voltage regulation is the only moving part of a transformer, accounting for more than one third of transformer failures every year, and thus requires frequent care and maintenance.

Hitachi Energy Research has developed a novel method for OLTC operation monitoring on-line and a protection function against incomplete tap operations based on ordinary protection grade instrument transformer signals digitized by modern substation numerical protection relays or disturbance recorders. Thus, in most cases, no additional sensors, acquisition hardware, or outage is required for the implementation.

The monitoring algorithms were tested and verified based on more than 20,000 field-recorded tap operations of a few different tap changer models and they are able to extract monitoring parameters with enough precision to observe subtle differences in each contact position of certain tap changer models and also to monitor long-term trends. The protection function is designed in such a way that it can be implemented on a modern numerical



8 Instantaneous extra power loss during a tap change operation of a 63-MVA transformer



IoT: Internet of Things SNMP: Simple Network Management Protocol
IEC: International Electrotechnical Commission TCP: Transmission Control Protocol
*See "Trademarks" on page 158.

9 IoT reference architecture

protection relay, meeting the standard requirements for such an environment.
(Hitachi Energy Ltd.)

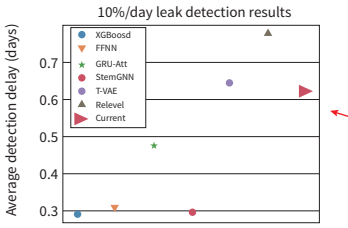
9 Integration of Digital Substation IoT Sensor Data into a Digital Enterprise

With the increasing interest and implementation of digital substations, the amount of digital information coming from substations has dramatically increased. Asset owners are realizing that intelligent electronic devices (IEDs) are becoming an equally important asset to be managed with full support of enterprise asset management and online connectivity to the installed base. Their health condition must be analyzed from cybersecurity and other aspects with full traceability of condition monitoring and changes happening in the asset lifetime. The fleet of IED assets will further increase. Therefore, it is crucial to focus on assets with highest risk and importance. This will ensure that resources and people are used more effectively.

Additionally, cybersecurity regulation is one of the main drivers and requires asset owners to ensure they know the asset status and risk related to it. Connecting digital information to utility enterprise business processes enhances the operation and maintenance of assets in the substation. For digital assets like IED, this is required to comply with cyber-security regulations. The proposed concept of integrating IEDs into existing Lumada Asset Performance Management (APM) will create new visibility and insights of the assets in the substation that will require operation and maintenance during the entire life cycle of the substation.
(Hitachi Energy Ltd.)

10 Computing Intelligent Insights about Station Subsystem Health with Data Analysis and Lean IIoT

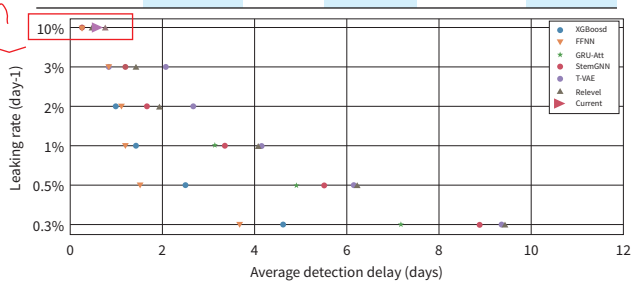
With the main focus on ensuring availability, the topmost priority for transmission network operators is to ensure a high level of in-service availability in HVDC stations. Thus, more work is needed towards condition monitoring and predictive maintenance for HVDC systems considering the latest technology improvements. The traditional scheduled maintenance approach is a weak concept and new approaches and strategies are being explored and adopted. With the industrial IoT (IIoT) as an enabler for digital transformation, new business models and services are emerging on data analytics platforms for both greenfield and brownfield stations. One such computationally promising solution is the application of data-driven approaches using machine learning (ML) algorithms where several advanced, efficient, and intelligent learning algorithms are developed based on many real use cases. These algorithms are used to analyze the condition of equipment and its components in complex HVDC domains such as to detect anomalies upfront in transformer tap changers based on tap switching data,



Leak detection delays on new data validation

Methods	0.3%	0.5%	1%	2%	3%	10%
XGBoost	5.33	2.07	1.31	0.76	0.38	0.19
FFNN	6.81	2.05	1.22	1.01	0.74	0.22
GRU-Att	6.23	4.24	2.96	1.54	1.06	0.33
StemGNN	10.52	5.44	3.94	2.72	1.85	0.58
T-VAE	6.51	4.03	2.92	1.94	1.78	0.58
Relevel	11.46	5.67	3.60	2.60	1.79	0.83

Methods	XGBoost	FFNN	GRU-Att	StemGNN	T-VAE
Training time (min)	< 1	< 1	up to 3	up to 10	up to 30
Device	CPU	CPU	CPU	GPU	GPU



Pink shade denotes big leak detection is first triggered, while blue shade denotes small leak detection is first triggered

CPU: central processing unit GPU: graphics processing unit

10 Sample results on leakage detection

a deep learning classifier to detect faults in the station, quick leakage detection in HVDC valve cooling systems with the goal of developing a robust ML algorithm to detect small leaks accurately, detecting large leaks more quickly than traditional methods, avoiding false positives, and many other use-cases.

Such methods to detect anomalies could be used to create advanced maintenance services spanning a wide range of areas including not only HVDC power assets, but also at the system level since health indicators may vary depending on the application [e.g. flexible alternating current transmission systems (FACTS)] and location profile (e.g. offshore, onshore). Thus, maintenance can be carried out in response to the observed degradation in the component condition.

(Hitachi Energy Ltd.)

Energy

1 TCP Offshore Wind Farm: 5.2-MW Wind Turbine Generators

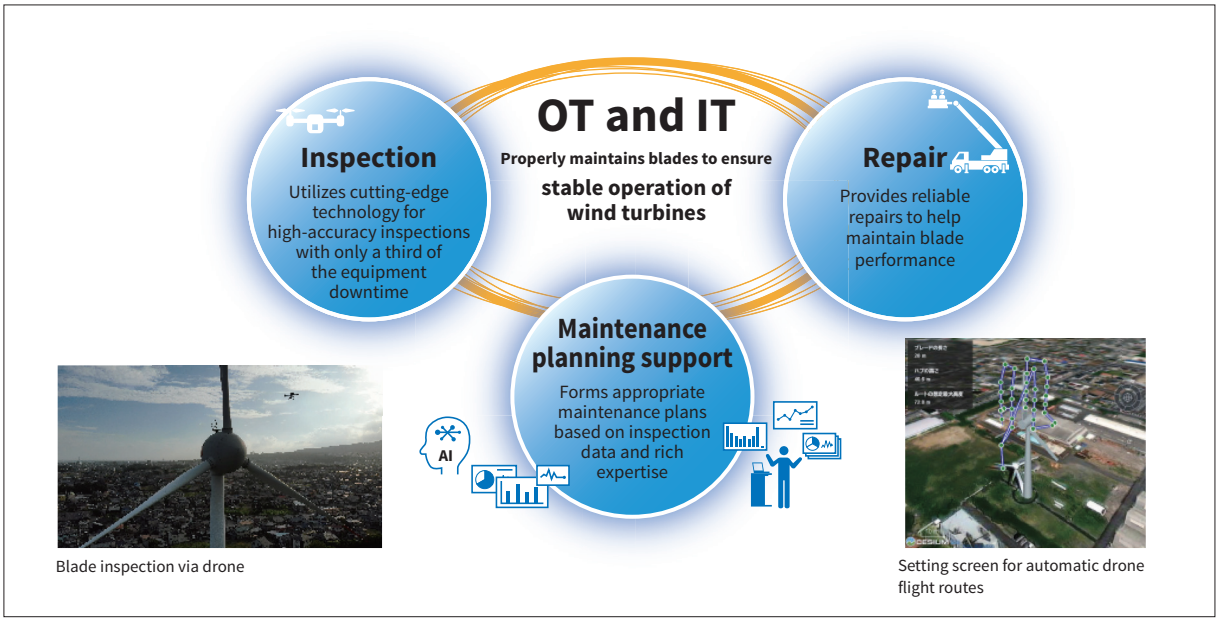
At the TPC Offshore Wind Farm – Phase 1 Demonstration Project (the Project), for which Hitachi, Ltd. and its consortium partner, Jan De Nul nv (JDN), were awarded the engineering, procurement, and construction (EPC) contract from Taiwan Power Company (TPC), the installation and commissioning of 21 units of Hitachi's 5.2-MW wind turbine generators (HTW5.2-127) have been completed, and all 21 units have been in operation since December 2021. As the Project is the first oversea and first offshore project for Hitachi's wind turbine generator division , it has encountered various challenges, some of which were exacerbated owing to the COVID-19. Hitachi believes that these experiences can be utilized not only in the future offshore projects in the Japanese domestic market but also in the construction and operation and maintenance (O&M) of larger wind turbines.

In this Project, the consortium of Hitachi and JDN was also awarded with the 5 years of O&M scope, and today, the consortium continues to accumulate and digitize the technical knowledge related to the operation, maintenance, and preventive maintenance of the offshore wind farm. Hitachi, by integrating such data into the Lumada model and using it, aims to contribute to the development of businesses related to the stable operation of wind power generation facilities, the life extension of existing wind turbines in Japan, and improvement of their availability.

1 Taiwan offshore 5.2-MW wind turbine generators

2 Blade Total Service: Servicing Wind Turbine with Drones and AI

Wind turbines are being increasingly deployed to help achieve a decarbonized society. Many accidents involving the blades of these facilities have occurred due to poor maintenance and the natural environment (lightning strikes, typhoons, etc.), as well as deterioration over time due to operation. To prevent these accidents, in



2 Offerings and benefits of blade total service

March 2021, the Japan Wind Power Association issued "Guidelines for the Inspection and Repair of Wind Turbine Blades." In April of the same year, the Ministry of Economy, Trade and Industry issued the "Revised Interpretation of the Technological Standard for Wind Turbines," which strengthened the safety standards for blades.

Hence, as blades must be reliably inspected and repaired to ensure their safety and stable operation, Hitachi developed the blade total service. This service integrates IT with operational technology (OT); the former consists of digital robotics technology such as drones and artificial intelligence (AI), while the latter comprises maintenance-related expertise and repair technology. This one-stop service covers everything from blade inspection to maintenance planning and repair.

For inspections, based on a flight route for each facility created with a dedicated cloud-based application, a drone automatically captures high-definition photos of each blade from five different directions. The acquired data is uploaded to the cloud and automatically classified based on power station, unit, blade, etc., after which the AI determines the location of damage. This data is used for optimal repair planning and highly reliable repairs, thus enhancing inspection quality, reducing equipment downtime, and improving post-repair durability to reduce the number of repairs. Overall, this contributes to the equipment's stable operation.

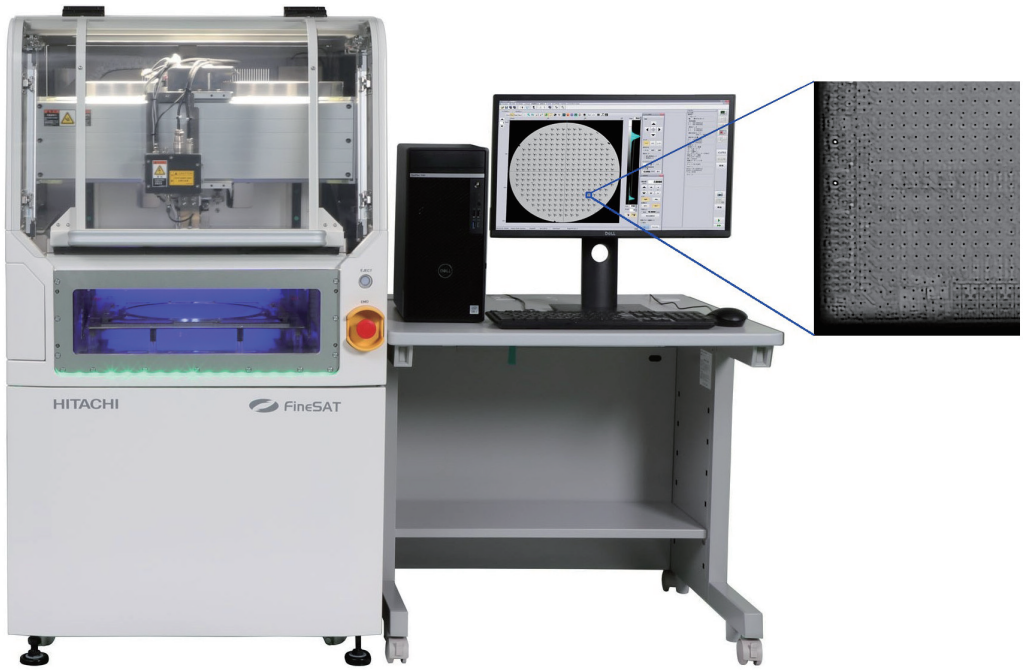
(Hitachi Power Solutions Co., Ltd.)

3 Ultrasonic Imaging System to Improve Productivity and Inspection Accuracy of Semiconductor Devices

In the electronic components and devices market, there is demand for miniaturized, high-performance semiconductor devices and electronic components used in electronic devices. To meet these needs, technologies to detect and analyze microdefects in high-density devices are growing in importance.

FineSAT, an ultrasonic imaging device, uses ultrasonic waves to nondestructively inspect defects within objects. FineSAT 7, the latest model, utilizes a new analog-to-digital conversion board developed in-house, increasing the sampling resolution 16-fold and doubling the measurement period compared to the conventional model. Through this, it improves the detection performance for defects using inspection images with higher resolution. Moreover, by enlarging the measurement tank where the inspection object is placed and employing the through-transmission method, which can inspect complex shapes such as multilayer devices, the new system can measure an entire 300 mm-wafer at once improving operating efficiency. With constant waveform recording, Hitachi will develop software functionality to extract useful information from the complex waveform data of the received ultrasonic waves, enabling advanced analysis of the object's internal structure.

(Hitachi Power Solutions Co., Ltd.)



3 FineSAT 7, the latest FineSAT ultrasonic imaging system, and inspection image inside a semiconductor device

4 Eurus Kamikatsu-Kamiyama Wind Farm Begins Commercial Operation

Eurus Kamikatsu-Kamiyama Wind Energy Corporation's Eurus Kamikatsu-Kamiyama Wind Farm (34,500 kW), the highest capacity wind farm in Shikoku, began operation in July 2022. Hitachi Power Solutions Co., Ltd. supplied 15 ENERCON GmbH-manufactured 2,300-kW wind turbines, which can provide electricity for nearly 20,000 average households and are expected to reduce carbon dioxide (CO_2) emissions by 31,000 t per year.

As the construction site is located about 40 km from Tokushima Port, in a region with mountains over 1,000 m high, it was necessary to transport large wind turbine components through steep and narrow areas. Adapting to these conditions, Hitachi performed road widening work in the mountainous areas and used special blade lifters to transport the blades at an incline. This made it possible to complete the construction in a previously inaccessible area and launch commercial operation. Hitachi also signed a 15-year comprehensive maintenance service contract for the wind farm, and will provide constant support to ensure the equipment's high availability.

The company will continue to offer full support for wind turbine projects throughout their entire life cycle, from project planning to implementation design, construction, maintenance, and management, helping to realize a zero-carbon society through the stable supply of renewable energy.
(Hitachi Power Solutions Co., Ltd.)

4 Operation of blade lifter

Nuclear Energy

1 Development of Operation Monitoring Method to Improve Plant Availability

The Sixth Strategic Energy Plan of the Ministry of Economy, Trade and Industry, approved by the Cabinet in October 2021, set the goal of 20–22% nuclear power generation in the domestic power supply mix by 2030. To achieve this, it is important not only to restart existing plants, but also to shorten periodic inspections and operate long-term cycles to improve their availability.

To meet these needs, Hitachi has been developing the Hitachi Advanced Plant Performance Diagnosis System (HAPPS), which monitors and diagnoses plant performance during operation to enhance reliability and efficiency. Unlike methods based on statistical analysis of data, HAPPS is based on plant design information. It can constantly monitor equipment deterioration and instrument abnormalities during operation and helps improve the reliability and efficiency of nuclear plants by providing various values, such as drift monitoring of various flow meters; detection of steam leakage from normally closed valves; improvement of heat output calculations; extension of the instrument calibration period due to long cycle operations; reduction of calibration volume; and optimization of auxiliary power for large-capacity loads.

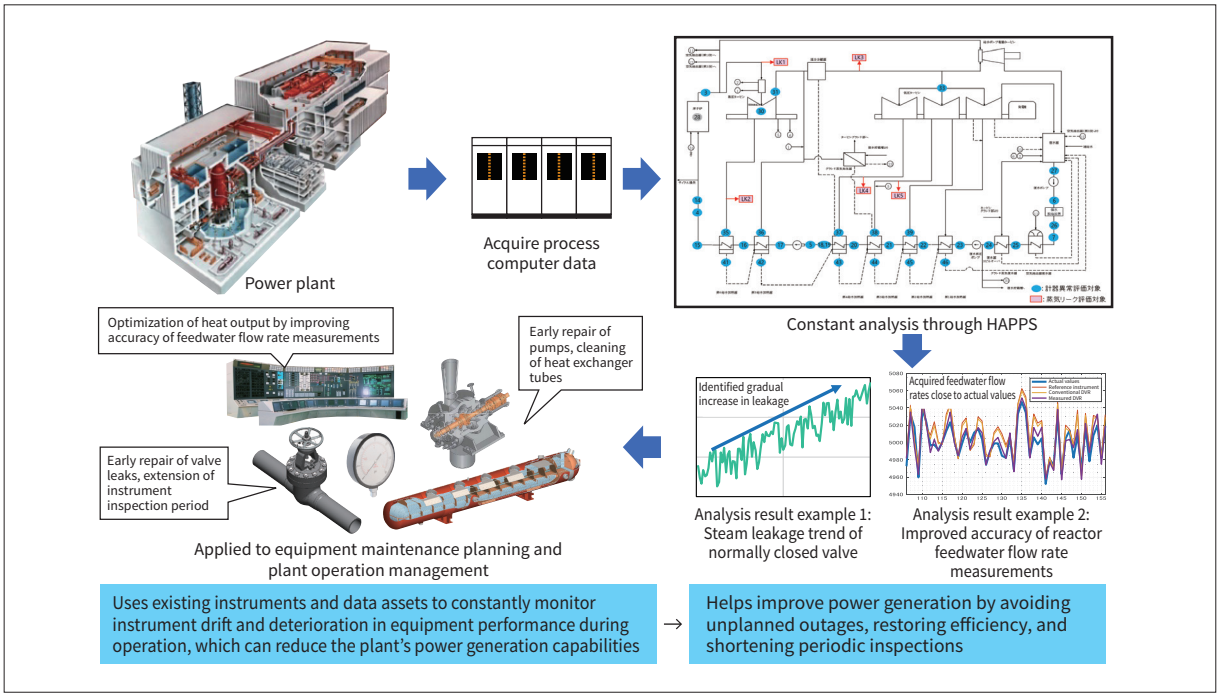
To help plants operate with high efficiency after being restarted, Hitachi is promoting collaborative creation with customers.

(Hitachi-GE Nuclear Energy, Ltd.)

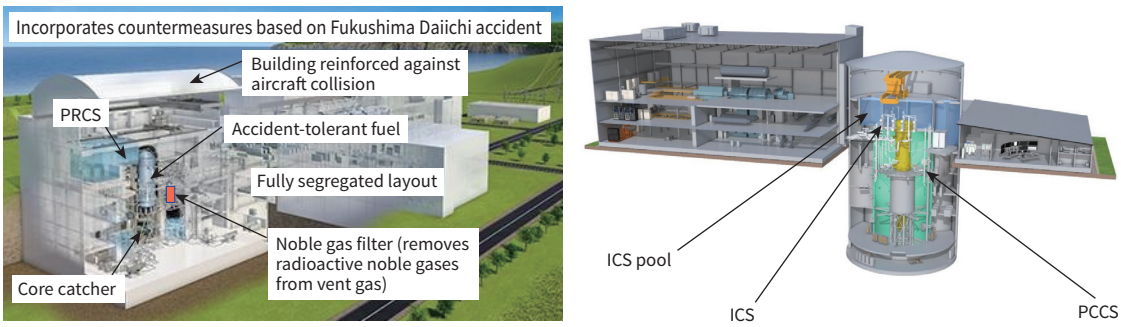
2 Development of Innovative New Reactors that Contribute to Carbon Neutrality

As the goals of carbon neutrality and a stable energy supply rapidly gain societal importance, Hitachi has been developing various innovative new reactors, ranging from large to small reactors.

In terms of large reactors, based on the already constructed advanced boiling water reactor (ABWR), Hitachi continues to develop countermeasures and new safety techniques considering experience from the Fukushima Daiichi Nuclear Power Station accident, with the goal of realizing the high innovative ABWR (HI-ABWR), a large light-water reactor that implements these safety mechanisms.



1 Diagram of HAPPS applied to power plant



Large innovative light-water reactor HI-ABWR

Highly economical small light-water reactor BWRX-300

PRCS: passive reactor cooling system ICS: isolation condenser system PCCS: passive containment cooling system

2 Innovative new reactors developed by Hitachi

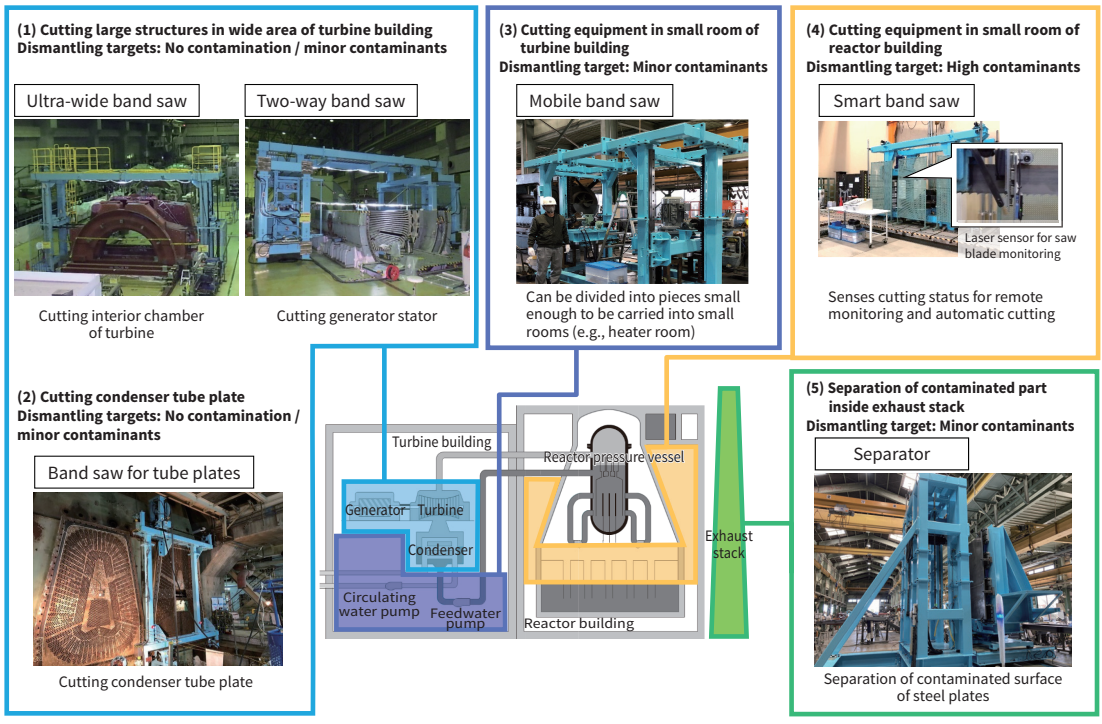
At the same time, in collaboration with its US partner, GE Hitachi Nuclear Energy, and overseas academia, Hitachi is developing BWRX-300, a highly economical small light-water reactor; resource-renewable BWR (RBWR), a light-water-cooled fast reactor that utilizes quasi-domestic resource plutonium through fast neutrons; and power reactor innovative small module (PRISM), a metal-fueled sodium-cooled fast reactor. Of these, the BWRX-300 combines a novel reactor pressure vessel isolation valve design with a passive safety system to achieve a high level of safety. Design is ongoing, with the goal of completing construction of the first unit in Canada as early as 2028.

(Hitachi-GE Nuclear Energy, Ltd.)

3 Initiatives to Reduce Radioactive Waste in Nuclear Power Plant Decommissioning

Of the 60 nuclear power plants in Japan (including those under construction), 18 (excluding Fukushima Daiichi) have been designated for decommissioning, which is the process of dismantling a nuclear power plant that has finished generating power and reducing its radioactive waste. Hence, it is necessary to reduce the large amounts of radioactive waste that will be generated in the future.

The facilities to be dismantled include large equipment, such as turbine generators installed in controlled areas, which must be cut into sizes that can be carried out from the installation area. However, conventional flame



3 Fire-free mechanical cutting and separating equipment

cutting using gas causes contaminants on the surface of the equipment to spread inside it when cut. Accordingly, Hitachi developed a mechanical band saw that cuts without using fire and can handle various conditions, such as the size, shape, and installation location of the object, and expanded its models for different applications.

Moreover, the company developed and applied a new separator that significantly reduces radioactive waste. After separating the contaminated surface (e.g., exhaust stacks), the separated waste is treated as contaminants and the remaining material is no longer considered radioactive waste.

Utilizing its core technologies of fire-free equipment cutting and separation, Hitachi will continue to support decommissioning projects of high social value while promoting collaborative creation with customers.
(Hitachi Plant Construction, Ltd.)

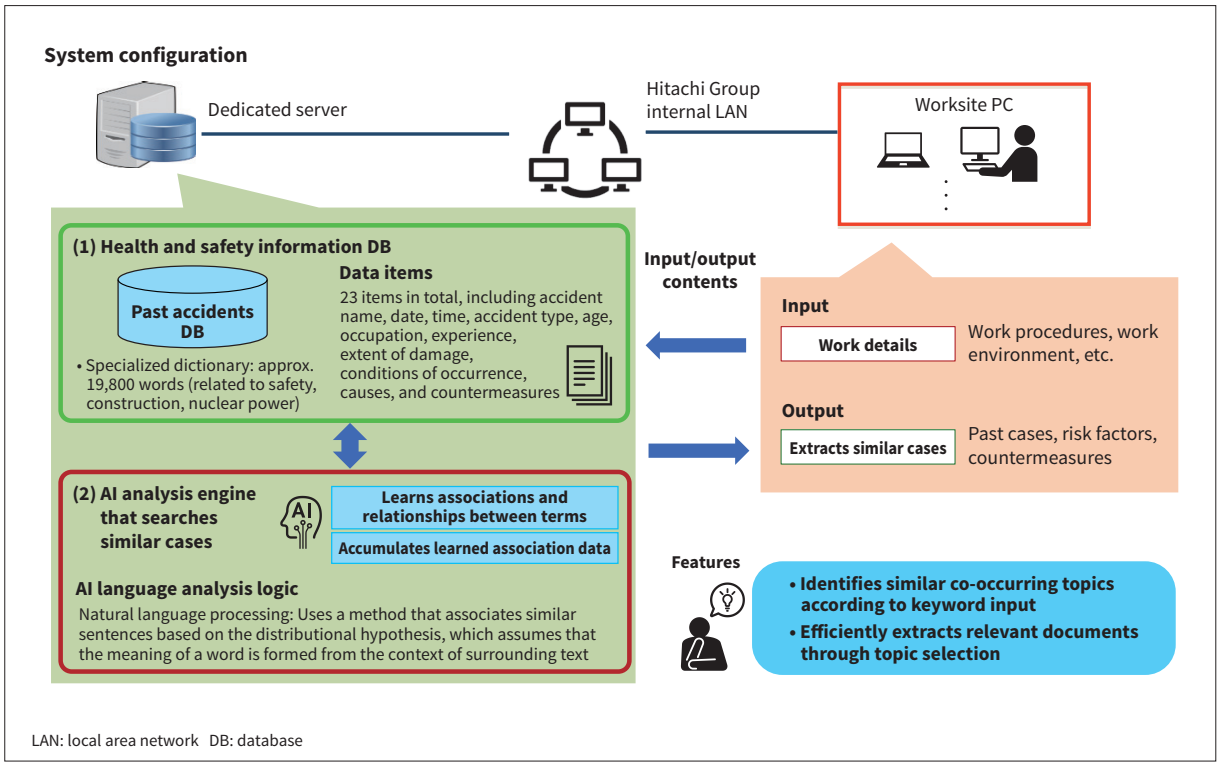
4 Industrial Accident Search Navigation and Safe Behavior Support to Improve Construction Site Safety

The construction industry has recently seen a decrease in skilled engineers and an increase in the number of inexperienced workers. Consequently, ensuring safety at construction sites and reducing the occurrence of occupational accidents has become a pressing and top-priority business challenge.

Accordingly, Hitachi is accelerating its digital transformation (DX) efforts to completely eliminate accidents and has developed an industrial accident search navigation system that uses natural language processing artificial intelligence (AI) to efficiently search past accidents and effectively determine relevant accident risk factors and countermeasures. Thus, by referring to past accidents that occurred in similar work, operators can identify hazards and comprehensively review corresponding countermeasures before performing work, leading to much safer work planning and procedure selection.

Hitachi also developed a safe behavior support system using AI object detection technology, which detects and issues alerts when people enter dangerous areas on site. The system uses a control device with edge AI processing and cameras to detect when people enter restricted zones or dangerous work areas such as elevated locations and openings on site, and then issues an alert.

Hitachi will continue to utilize this system at power plant construction sites and worksites, and further deploy it to various companies within the Hitachi Group to help achieve fundamental workplace safety.
(Hitachi Plant Construction, Ltd.)



4 Configuration of industrial accident search navigation system and input/output contents and features

Railway Systems

1 East Japan Railway Company Hydrogen-hybrid Train (FV-E991 Series)

Decarbonization efforts are accelerating worldwide to achieve a sustainable society.

As part of these efforts, East Japan Railway Company developed the FV-E991 series (HYBARI: hydrogen-hybrid advanced rail vehicle for innovation), a hydrogen-hybrid train that uses fuel cells, with the goal of diversifying energy sources.

Hitachi greatly contributed to the project. It was contracted to develop the main circuit[*1] system of the FV-E991 series; produced the power conversion equipment[*2], main circuit battery, and traction motor; and managed the hybrid system including the fuel cell system. The main circuit system of the FV-E991 series covers various functions such as vehicle driving control, charge and discharge control of the main circuit battery, and output control of the fuel cell system. Hitachi collaborated with East Japan Railway Company, who manages the entire project, and Toyota Motor Corporation, the fuel cell manufacturer, to implement and operate the vehicles on the main line.

Since March 2022, it has been conducting verification tests (e.g., vehicle performance evaluations) on the Nambu Line (between Kawasaki and Noborito), the Tsurumi Line, and the Nambu Line Shitte Branch Line, and continues to work with East Japan Railway Company to promote the practical use of hydrogen-hybrid trains.

*1 Circuit involved in driving the vehicle
*2 Equipment including inverters, auxiliary power supply, and control devices for driving

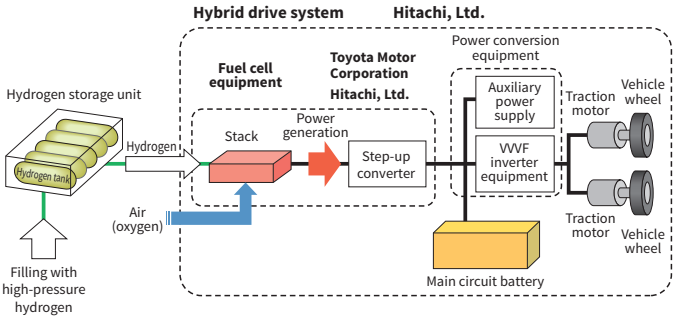
2 Order for EMU3000, a New Intercity Express Train, from Taiwan Railways Administration

The Taiwan Railways Administration, Ministry of Transport and Communications (TRA) established the "TRA Train Purchasing and Renewal Plan (2015–2024)" to increase its railway transport capacity and renew the aging fleet. To this end, it is promoting the large-scale procurement and expansion of new vehicles.

This is the largest procurement project in the history of TRA, involving the bulk purchase of 600 intercity express train cars (50 trainsets with 12 cars each). Hitachi implemented full three-dimensional (3D) design using digital technology to seamlessly link the design and manufacturing processes, and in design and development, it utilized 3D models and virtual reality (VR) to facilitate consensus-building with customers. Compared to the traditional 8-car intercity express trains, this train features a 12-car configuration that enhances its transport capacity, and introduces new concepts such as TRA's first-ever business class car, which comprises one of the 12 cars.

The first trainset delivered to Taiwan in July 2021, underwent a trial run period, and began commercial

Photo courtesy of East Japan Railway Company



VVVF: variable voltage variable frequency

1 Hydrogen-hybrid train (FV-E991 series) and mechanism of fuel cell hybrid drive system

2 New intercity express train, EMU3000

operation on December 29, 2021. Since then, it has been in daily operation as an intercity express train running throughout Taiwan.

3 Masaccio Multimode Train

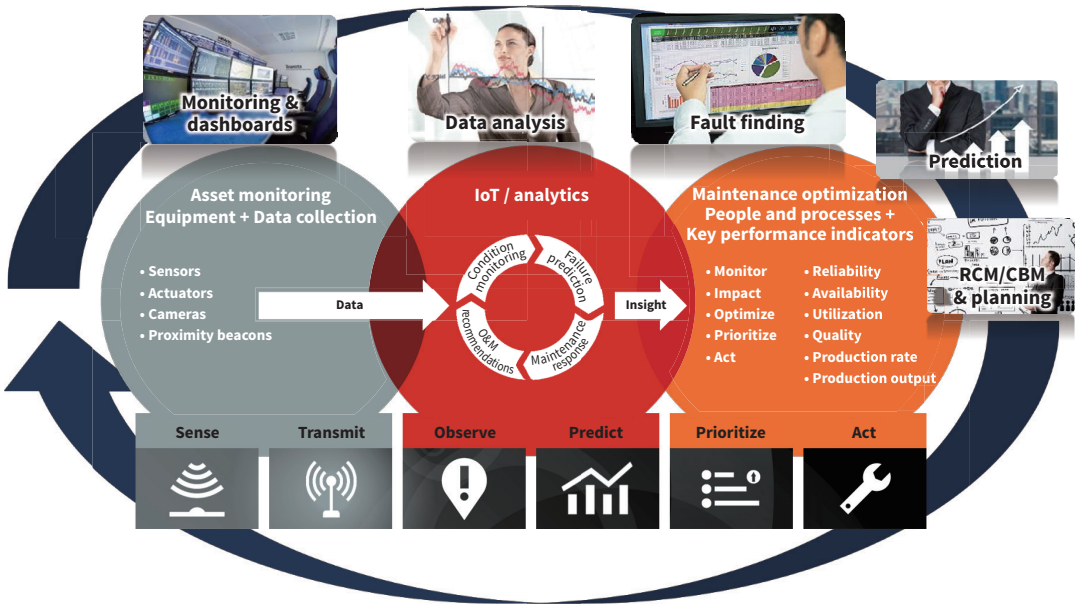
Masaccio is the new multimode single deck train for the regional transportation. A framework contract with Trenitalia S.p.A, Italian railway company, foresees up to 135 trainsets, two configurations: 3 cars able to carry 220 seated passengers and 4 cars up to 300 seated passengers.

The sustainability is one of the key goals of the Masaccio development, not only through the use of highly recyclable materials in the cars, but also through a four mode operation to optimize energy consumption as well as to reduce noise and pollution in urban areas without electrified lines. Masaccio can run as an electric train in the sections with overhead wire, also as a diesel train, a hybrid train to reduce the fuel consumption and operate in battery only mode when entering in town with start and stop function of the diesel engine. The energy management technology has been developed by a joint engineering team of Hitachi Rail Ltd., based both in Japan and Italy.

4 HFMT Lumada + IoTrain

Hitachi Fleet Management Tool (HFMT), one of the Lumada digital platform, is one of world first integrated solution developed in collaboration between partners in UK, Japan, and Italy and Hitachi Vantara LLC. HFMT is Hitachi Rail's strategic digital asset monitoring

3 Masaccio single deck



O&M: operation and maintenance RCM: reliability-centered maintenance CBM: condition-based maintenance

4 Advanced IoT and big data technologies come together to efficiently maintain assets

platform, powered by Internet of Things (IoT), condition based maintenance methods that delivers advanced wayside remote capabilities to customers to assist passenger service trains in service and enable effective and efficient methods for fleet maintenance and asset reliability. HFMT has been in operation in the UK since 2019.

Key innovative solutions include:

(1) Train operation and control functions

Headline and map view of all units, energy monitoring and usage, passenger counting, remote commands, seat reservation and timetable data feeds, and driver advisory

(2) Train maintenance functions

Events triggered based on asset condition, fault finding, advanced signal viewer, maps, system of concern, overhauls driven by asset condition and usage, reliability reports, and predictive maintenance

(3) Assets management functions

Infrastructure track monitoring, closed-circuit television (CCTV), infrastructure alerts, pantograph and overhead lines, and asset reliability reports

Integration of all these capabilities enables Hitachi Rail to deliver trains with high performance reliability, availability, safety at the same optimizing on maintenance.

Capitalizing on HFMT, battery as a service (BaaS), and maintenance as a service (MaaS) business models supported with unified platform generate significant business opportunities in the market. Software as a service (SaaS) business has been implemented via Perpetuum Ltd.'s platform.

257 trainsets in the UK are currently connected and are benefiting from HFMT digital capabilities, more than 100 trainsets are being planned as the company deliver more trains to its customers.

5 360Pass with Lumada Intelligent Mobility Management

In July 2022, Hitachi Rail released a new service called 360Pass, which uses Lumada Intelligent Mobility Management. 360Pass is currently offered under the local brand name GoGoGe in Genoa, Italy.

Through a mobile app that utilizes Bluetooth* sensors, the service enables hands-free use of all public transportation within a city while automatically charging the cheapest possible fare. Users can also hire electric vehicles, pay parking lot fees and find an e-moped through the app. Moreover, it can provide passengers with information related to travel conditions, such as the level of congestion on the route, and provide transportation operators with detailed data related to passenger movement.

In addition to 360Pass, Lumada Intelligent Mobility Management includes control of passenger and vehicle flows along with e-mobility solutions, accelerating the transition to sustainable transportation.

*See "Trademarks" on page 158.

5 360Pass with Lumada Intelligent Mobility Management

6 ETCS Onboard Equipment as a Global Product

In the early 2000s, Hitachi entered the European Train Control System (ETCS) market, a standardized railroad signaling system in Europe. In 2013, the company obtained certification for ETCS onboard equipment in the UK and began manufacturing products for the UK intercity express railway, for which it had received an order the previous year.

Hitachi then expanded its business beyond the UK and developed ETCS onboard equipment for existing Waratah trains and new Sydney Growth Trains in Australia from 2018 to 2020, successfully delivering 119 trains. Since then, the company has been expanding its share in the market for ETCS onboard equipment, which has become a global product.

Queensland Rail in Australia is improving transport capacity by constructing new railway lines and introducing ETCS Level 2 to alleviate congestion in the central area of Brisbane. Hitachi is participating in this project in collaboration with Hitachi Rail STS S.p.A. (HRSTS), which became a member of the Hitachi Group in 2019. Hitachi is responsible for the ETCS onboard equipment and part of the operation management system, and HRSTS for the scope including the ETCS ground-based equipment. They successfully integrated the entire signaling system and are conducting running tests in preparation for the start of commercial operation.

The company plans to implement automatic train operation (ATO) over ETCS, which will operate in coordination with ETCS, and continue to contribute to the construction and development of railway infrastructure.

6 ETCS onboard equipment

Connective Industries

Buildings Systems

Smart Life & Ecofriendly Systems

Semiconductor Device Manufacturing & Inspection Equipment

Industrial Digital Solutions

Water & Environment

Industrial Products

Healthcare & Analytical Systems

Buildings Systems

1 Building a Maintenance IoT Service Platform to Expand Recurring Business

The elevator and escalator maintenance business, which is a recurring revenue business, is supported by remote monitoring and various maintenance systems centered around a control system. First built 25 years ago, this aging control system was completely revamped with a configuration suited to new business models and business expansion.

The new control system adopts a hybrid cloud and promotes service quality improvements, operational efficiency, and other improvements and extensions through cloud-based applications. As a specific example, it automatically selects the engineer to dispatch when a failure occurs based on requirements such as skills and site distance to improve operational efficiency through the systematization of ancillary work including dispatching instructions for the purpose of shortening product downtime and improving the quality of customer service when a failure occurs. In addition, an artificial intelligence (AI) technical support system was developed to provide the dispatched engineer with optimal investigation and recovery procedures to shorten the failure recovery time. Moreover, the "BUILLINK" service was established, which allows users to check and control the equipment operating state as well as maintenance service details such as inspections, repairs, and reports on a PC or smartphone. By connecting with customers and continuing to provide high-quality services, the company will contribute to the expansion of the elevator and escalator maintenance business.

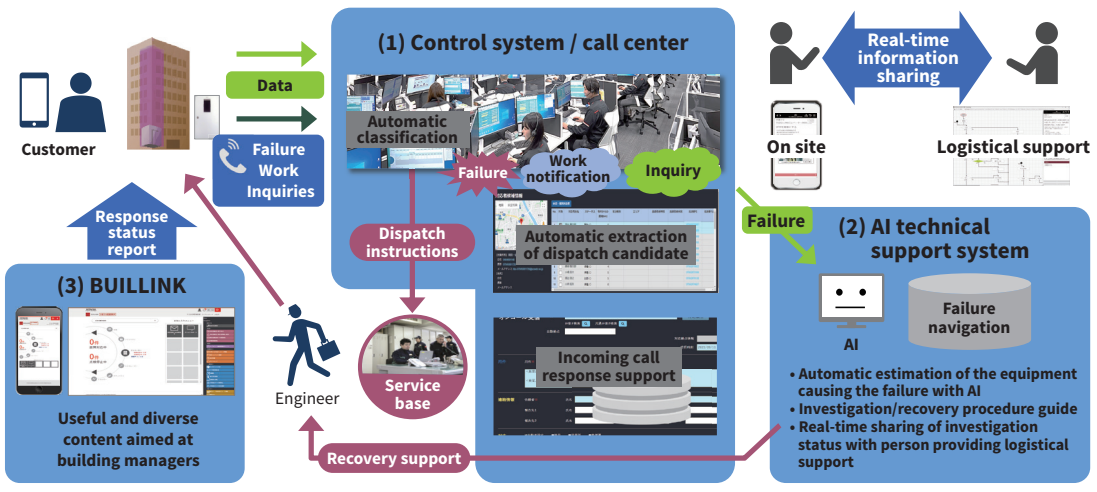
(Hitachi Building Systems Co., Ltd.)

2 V2X System Utilizing Hybrid PCS

A vehicle to X (V2X) system utilizing a hybrid power conditioning system (PCS), which enables continued use of an elevator even during a power outage using electric vehicles as a power source, was developed and is being demonstrated at the Kameari General Center of Hitachi Building Systems Co., Ltd.

When the company externally announced the system at the start of the demonstration ahead of productization for the purpose of verifying market needs, creating deals, and other forms of marketing research, it received many inquiries and mentions from major construction companies and architectural offices, leading to new business opportunities such as cooperative studies with partner companies, etc.

The hybrid PCS can be utilized as a charger for electric vehicles during normal operation, linked to photovoltaic



1 Overall view of maintenance Internet of Things (IoT) platform centered around a control system

2 V2X system utilizing a hybrid PCS introduced at the Kameari General Center

power generation, and can be expected to be adopted in charging facilities for electric vehicles, condominiums promoting the introduction of renewable energy sources, and nursing homes, etc. Moreover, it is also equipped with a feature that can interface with the new standard elevator to strengthen resilience during a power outage and provide high-value-added elevator features.
(Hitachi Building Systems Co., Ltd.)

3 Touchless Operation Panel for Realizing a New Elevator Experience

Hitachi has developed a touchless operation panel that enables touchless elevator use as a replacement for physical destination floor buttons. This recently developed operation panel replaces the destination floor buttons found in conventional elevator cars and allows users to register their intended destination floor just by holding a finger over the display on the operation panel (liquid crystal display) to enable touchless elevator use.

The display on the operation panel consists of two screens to increase user convenience. One screen is a direct registration screen that can display frequently used destination floors (for example, the lobby floor) and information for up to six floors. The other screen is a keypad registration screen, which shows a 10-key display that enables users to enter the number of any destination floor.

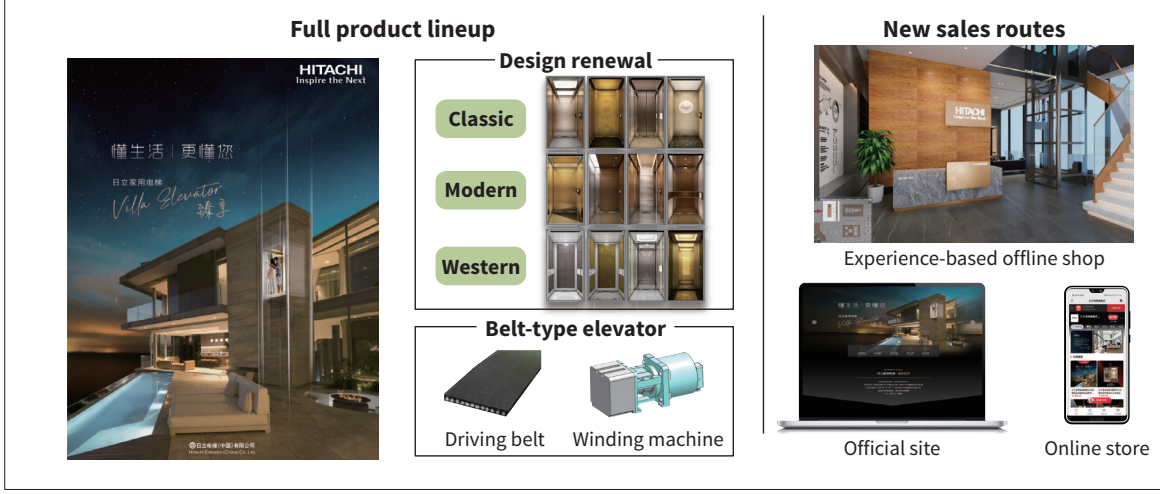
Moreover, when a card reader is installed in the elevator car and linked to the operation panel, users can wave a card* with their registered destination floor over the card reader to display only the specific floor that is registered on the card on the operation panel, which can be expected to increase user convenience.
(Hitachi Building Systems Co., Ltd.)

* Since the card automatically registers one destination floor, there is no need for the user to hold their finger over the operation panel.

4 Expansion of the Home Elevator B2C Business for the Chinese Market

With the continuous rise of the Chinese economy and people's living standards, the home elevator market is also actively developing. In particular, requests from individual customers to add home elevators to existing

3 Touchless operation panel (prototype) demo operation and display screen



4 Overview of home elevators for B2C

vacation homes and multi-family residential buildings, etc. are increasing, and development such as the individuation of product demand and the diversification of sales modes continues.

To increase the advantage of its VGE home elevators in this market environment, Hitachi has enhanced the features related to the creation of a sense of luxury, safety, security, and comfort with a revamped design and has optimized the elevators for the business-to-customer (B2C) market (released in March 2021). Moreover, the company has developed a new belt-type of home elevator to achieve a reduction in elevator dimensions and low noise and enhanced the product lineup (released in July 2021). In addition, it is working to contribute to the developing home elevator market in China by formulating a comprehensive B2C business strategy for home elevators by adopting new sales channels such as advertising and sales through its official website and online store, and providing product experiences through a hands-on offline store.

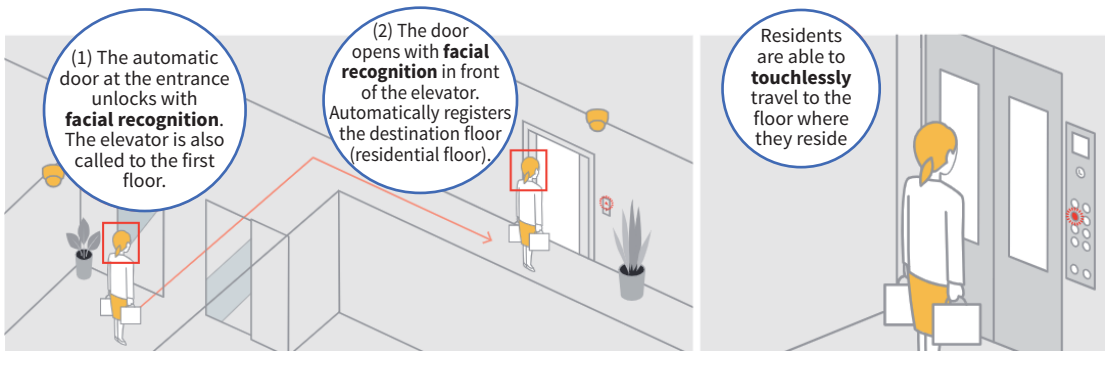
[Hitachi Elevator (China) Co., Ltd.]

5 Condominium Security that Provides Comfortable Movement with Touchless Features

Hitachi added facial recognition to the authentication methods of its "double security" system for condominiums, which controls security at two locations, at the automatic entrance door and the elevator landing door.

The previous double security system unlocked doors with authentication devices such as keys and cards with a built-in integrated circuit (IC) chip, but the adoption of facial recognition makes it possible to touchlessly travel from the entrance to the residential floor elevator without using an authentication device. This allows residents to smoothly travel to the floor where they reside even when their hands are full, such as when returning from a shopping trip, etc. Moreover, as a feature of this system, images from security cameras installed at the entrance and elevator landing can be used for recognition to provide new forms of value to condominium users as a new service for condominiums that combine convenience and security.

(Hitachi Building Systems Co., Ltd.)



5 Touchless travel in condominium security

Smart Life & Ecofriendly Systems

1 Connected Appliances: Camera-equipped Refrigerator

Hitachi has released the HXCC-type of large-capacity refrigerator connected home appliance which is equipped with a refrigerator camera[*1] that allows users to check the foodstuffs in the refrigerator with a smartphone app from outside the home.

The key features are as follows:

(1) The camera installed in the upper part of the refrigerator unit automatically films the refrigerator shelves and the left and right door pockets when the refrigerator door is opened, and the images can be checked from the application for Hitachi refrigerators. This reduces the number of cases where the user forgets to buy something or repurchase food ingredients already on-hand to support daily foodstuff management.

(2) Featuring a thin wall design in the ceiling section and other areas, it expands the rated internal capacity by 15 L over existing units while maintaining a width of 685 mm to achieve a large capacity size of 617 L[*2]. To improve usability, the top shelf of the refrigerator can now store 500 mL plastic bottles in an upright position.

(3) The refrigerator adopts the moisture cooling feature[*3] to keep the entire shelving space at a temperature of approximately 2°C and a humidity of approximately 80%. The low temperature storage of approximately 2°C maintains freshness for a long period of time no matter where food is placed, and the high humidity reduces dryness. (Hitachi Global Life Solutions, Inc.)

*1 Depending on the location where foodstuffs are stored, some areas may not be recorded by the camera.
*2 Based on a comparison of the R-HXCC62S FY2022 product (rated internal capacity of 617 L) and the R-HX60R (rated internal capacity of 602 L) FY2021 product.
*3 Moisture cooling does not include the door pockets.

2 New Refrigerator Concept "Chiiil"

Hitachi has released a new concept for refrigerators, called "Chiiil," which can be placed in places other than the kitchen such as the living room or bedroom, combined with multiple units*, and used according to user lifestyle and preferences.

The key features are as follows:

(1) In addition to a design with a depth of 420 mm that makes it easy to match with furniture, this refrigerator can be installed flat on the back against the wall and has specifications that make it easy to place in various locations such as the living room, bedroom, dining room, and workspace. Two units can be combined horizontally or vertically.

1 HXCC-type refrigerator equipped with refrigerator camera

2 New refrigerator concept “Chiiil” R-MR7S

(2) Ten color variations selected for compatibility with different interiors create a space according to user preferences. They are easy to match with various spaces such as the living room and bedroom and can be coordinated with the individuality of the interior.
(3) Choose temperature modes from refrigerator (approximately 2°C, 4°C, or 6°C) and cellar (approximately 8°C, 12°C, or 16°C) according to the type of food that users wish to store. Moreover, the inside layout can be adjusted by changing the shelf positions according to food size.
(Hitachi Global Life Solutions, Inc.)

* Clearance of 5 mm or more must be maintained on the left and right sides of the unit as space for heat dissipation.

3 Front-loading Washer/Dryer

Hitachi has released a front-loading washer/dryer that reduces the hassle of cleaning the dryer filter, which had to be performed each time the dryer was run, by adopting a filterless drying structure.

The key features are as follows:
(1) Adopts a filterless drying structure which eliminates the drying filter on the top of the unit, washes away dust and lint[*1], with three automatic cleaning features consisting of automatic drying duct cleaning, automatic washing machine tub cleaning, and automatic door gasket cleaning, and captures it with its large capacity lint filter. By increasing the capacity[*2] of the lint filter, the frequency of lint removal is decreased by throwing away one month’s worth of dust and lint all at once[*3].
(2) Aluminum plates were adopted to increase the heater capacity of the drying unit and improve the dehumidifying performance to achieve a shorter drying time than conventional models[*4]. Moreover, a humidity sensor was added to reduce uneven drying, and the Wind Iron function blows on the clothing with a high-speed wind of roughly 300 km/h to smooth out wrinkles and leave clothes looking beautiful.

3 BD-STX120H front-loading washer/dryer

(3) Users can now select the course from the smartphone app, based on operation time.
(Hitachi Global Life Solutions, Inc.)

*1 May not be able to wash away dust, lint, and dirt depending on the type and degree.
*2 Capacity was increased by changing the shape from the conventional comb-type to a box-type of filter.
*3 Tested by Hitachi Global Life Solutions. When operated once a day in a washer-dryer cycle with 6 kg. Results may differ depending on the volume and type of clothing.
*4 Based on a comparison of the new BD-STX120H product (approximately 98 minutes) and the BD-STX110G 2021 model (approximately 132 minutes).

4 Cordless Stick Vacuum Cleaner

Hitachi has released the PV-BH900SK cordless stick vacuum cleaner, which has a recycled plastic usage rate of 40% or more.

The key features are as follows:

(1) Through the active utilization of recycled plastic, the usage rate was increased to 40% or more[*1]. In addition to using recycled plastic in the charging stand, cleaning tools, and other accessories and exterior parts, the product was designed with recyclability in mind by eliminating painting, printing, and other secondary processing as much as possible.

(2) Equipped with the newly developed powerful fan motor to increase the static pressure by approximately 20%[*2] compared to conventional models while maintaining a light standard weight[*3] of 1.7 kg. The newly equipped turbo operation firmly picks up dust inside carpet.

(3) The charging time[*4] was shortened from the conventional time of approximately 3.5 hours to around 2 hours. Moreover, it incorporates a new telescopic crevice tool, which easily cleans crevices in furniture and other narrow spaces by extending and contracting according to how it is used.

The PV-BH900SK earned the Good Design Gold Award at the GOOD DESIGN AWARDS 2022 hosted by the Japan Institute of Design Promotion.
(Hitachi Global Life Solutions, Inc.)

4 Cordless stick vacuum cleaner PV-BH900SK (left), state when stored in the charging stand (right)

*1 Uses 40% or more recycled plastic compared to the weight for the plastic materials used in the product unit handle cover, charging stand, and other accessories.
*2 Tested by Hitachi Global Life Solutions. Measures the static pressure of the unit inlet at maximum power. PV-BH900J FY2021 model: approx. 12,500 Pa, PV-BH900SK: approx. 15,000 Pa
*3 Total weight of body, extension pipe, head, and battery. Measurements based on the voluntary standards (HD-10) of the Japan Electrical Manufacturers' Association.
*4 Measured at a room temperature of 20°C under the voluntary standards (HD-10) of the Japan Electrical Manufacturers' Association. The charging time may differ depending on conditions such as the usage, ambient temperature, and remaining battery charge.

5 Health-conscious Superheated Steam Microwave Oven

Hitachi has released the MRO-W10A health-conscious superheated steam microwave oven in its series of connected home appliances.

The key features are as follows:

(1) Equipped with Hitachi's custom[*1] ceramic tray and convection & grill cooking which wraps food in a hot blast of air and heats it all at once with high heat to seal in the meat flavor and cook it to juicy perfection. It uses a new structure in which the ceramic tray is installed on the pan stop shelf and places an iron grid tray with a new shape on top of it. Placing the seasoned ingredients on the iron grid tray, it will automatically control the range, oven, superheated steam, and grill to cook food at any heat level. Because it determines the surface temperature of the food with a sensor, it can cook according to the portion size, whether it is frozen or refrigerated.

5 MRO-W10A health-conscious superheated steam microwave oven

(2) It incorporates three new menus in the crunchy vegetable menu which cooks deliciously crisply vegetables for a total of 11 available menu options. Rapidly heats up food with a high heat at a maximum of 1,000 W*2 and finishes in a short period of time to reduce the vegetable water content and cook while maintaining the crispy texture and nutrients*3.
(3) Links to a smartphone with the app to suggest recommended recipes each day based on user preferences.
(Hitachi Global Life Solutions, Inc.)

*1 The ceramic tray can be set on the bottom of the oven, upper, middle, and lower levels to be used for direct cooking.
*2 The 1,000 W maximum output of the auto cooking range is a short-term output feature, and the output automatically changes during operation. This feature only works during limited auto-cooking menus.
*3 Compared with the MRO-W10X model, which is not equipped with the crunchy vegetable menu feature.

6 Remote Monitoring/Predictive Diagnosis IoT Solution "exiida" for Air Conditioning

As a result of the amendment*1 to the Act on Rational Use and Appropriate Management of Fluorocarbons (hereinafter, Fluorocarbon Emission Control Act) which was enacted in August 2022, continuous monitoring systems for commercial freezers and refrigeration equipment*2 have become positioned as a replacement for the simple inspections that were visually performed until now.

The Fluorocarbon Emission Control Act requires one or more simple inspections every three months for the advance prevention of leaks of fluorocarbon gas, which is used as an equipment refrigerant. Therefore, the manager (customer or facility manager, etc.) must observe the requirement to perform a visual inspection of the equipment as well as record and store the inspection results. In the event of a violation, the manager may be subject to punishment.

The remote monitoring and predictive diagnosis IoT solution "exiida" for air conditioning can replace the simple inspections of commercial freezers and refrigeration equipment established by the Fluorocarbon Emission Control Act. As a result, this solution helps to reduce the workload.

*1 Act on Rational Use and Appropriate Management of Fluorocarbons (Act No. 64 of 2001), Article 16, paragraph 1 partially amended
*2 Class I specified products established in the Act on Rational Use and Appropriate Management of Fluorocarbons
*3 This service is available only in Japan.

7 Connected VRF Equipped with High Energy Efficiency and Functionality

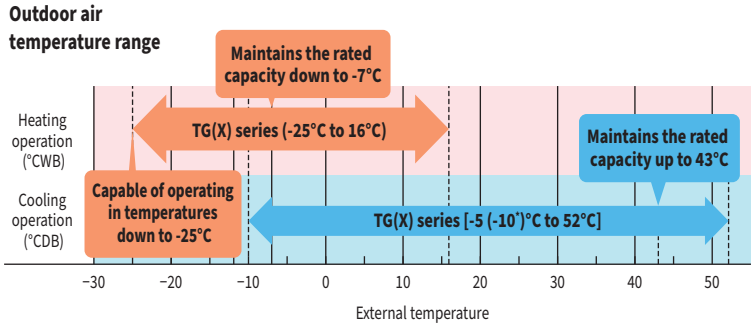
Hitachi has released variable refrigerant flow (VRF) that improves energy efficiency as an initiative for carbon neutrality, adds features for cold regions, and supports built-in exiida communication units in the outdoor unit (service scheduled to start in the first half of 2023).
(1) High coefficient of performance (COP) models recommended for the promotion of net zero energy buildings (ZEBs) were added to the lineup (TZ and TZX series).
(2) They maintain the rated capacity down to an outdoor temperature of -7°C while heating*1. In addition, heating operations can be continued down to a temperature of -25°C*2 (TG and TGX series).
(3) The exiida communication unit can be built into the outdoor unit, which eliminates the need for mounting space and a dedicated power supply (service scheduled to start in the first half of 2023).

In addition to limiting lost business opportunities due to sudden failures, the exiida remote monitoring and predictive diagnosis service can take the place of the simple inspections of the Fluorocarbon Emission Control Act.
[Hitachi Global Life Solutions, Inc. (sales), Hitachi-Johnson Controls Air Conditioning, Inc. (manufacturing)]

*1 When the cold region feature is set. The TG and TGX400 models maintain the rated capacity down to a temperature of -4°C.
*2 When the TGX is in full heating operation.

Type of inspection	Previous/ Current	All class I specified products	Air conditioners		Refrigerator and freezer equipment	Personnel dispatch requirement
		Less than 7.5 kW	7.5 kW or more, less than 50 kW	50 kW or more	7.5 kW or more	
Simple inspection	Previous	Required (one or more times in three months), visual verification (qualifications not required)				Required
	Current	Can be replaced by exiida remote monitoring and predictive diagnosis				Not required
Periodic inspection	Unchanged	Not required	Visual verification by a qualified person is required			Required
			One or more times in three years	One or more times per year		

G Inspection details established by the Fluorocarbon Emission Control Act



*Using the low outdoor air setting.

7 Connected VRF equipped with high energy efficiency and functionality

8 New Water-cooled Screw Chillers Using Low-GWP Refrigerant with Global Warming Potential of One

Hitachi has assembled a lineup of models that adopt a low global warming potential (GWP) refrigerant [Hydrofluoroolefin (HFO) R1234yf] in the MATRIX ADVANCE water-cooled cold screw for the sake of energy efficiency and serviceability.

The key features are as follows:

(1) Adopts a low GWP refrigerant (HFO R1234yf)

R1234yf is a refrigerant that reduces the global warming potential by more than 99% compared to the previous R134a refrigerant and has a GWP value of 1[*1].

(2) Support for the Fluorocarbon Emission Control Act is not required[*2]

Equipment that adopts R1234yf is not covered by the Fluorocarbon Emission Control Act. Therefore, inspection and maintenance records do not need to be saved, and legal compliance for leakage reports is not required.

(3) The product height was reduced from the 2,000 mm of the previous model to 1,670 mm to make it easier to transport.

(4) The screw compressor with continuous control specifications does not require harmonic countermeasures.

Because it is equipped with a screw compressor with continuous control specifications through a slide valve that does not use an inverter, harmonics are not generated. [Hitachi Global Life Solutions, Inc. (sales), Hitachi-Johnson Controls Air Conditioning, Inc. (manufacturing)]

*1 Source: JRA GL-08_2020R "Guideline for Shapes of Service Ports and Indications on Air Conditioning and Refrigeration Equipment" 100 years of GWP values

*2 Legal compliance is required for equipment that uses R134a

Note: The left side of the photo shows two units installed consecutively with the cover specification while the right side shows the no-cover specification (frame side cover option sold separately). This unit is designed to be installed indoors.

8 MATRIX ADVANCE water-cooled cold screw

Semiconductor Device Manufacturing & Inspection Equipment

1 Cutting-edge Semiconductor Device Technology Trends and Diversifying Customer Needs

The demand for semiconductors is growing as a core technology for supporting a digital society utilizing the Internet of Things (IoT), artificial intelligence (AI), fifth generation (5G) mobile network communication, and autonomous driving, etc. Moreover, semiconductors are an important strategic technology for which many countries are deploying large-scale industrial policies from the perspective of economic security.

Further miniaturization of cutting-edge semiconductor devices is proceeding with the implementation of extreme ultraviolet (EUV)*1 lithography. In terms of advanced logic, more complicated transistor structures and chip-level integration techniques are being introduced. Moreover, an increase in the number of layers in 3D-NAND flash memory and the dimensional scaling and three-dimensional (3D) structure of dynamic random access memory (DRAM)*2 are required to improve the memory storage density.

Sub-nanometer-order processing accuracy and the metrology and inspection accuracy to control that processing are required in manufacturing, metrology, and inspection systems for such cutting-edge semiconductor devices. Moreover, stricter controls are required for the management of defects and variations caused by EUV lithography and the particles that occur during processing by each manufacturing system. To shorten the development time and improve the yield, the demand for high-precision analysis to identify device fault locations is also increasing.

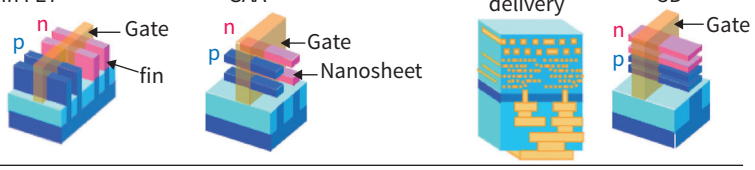
The Hitachi Group is committed to providing solutions for diversifying customer needs.

(Hitachi High-Tech Corporation)

*1 Extreme ultraviolet light source with a wavelength of 13.5 nm.
*2 Memory element that stores electric charge in a capacitor to retain information.

Cutting-edge logic device

Year	2021	2022	2023	2024	2025	2027	2030
Technology node (nm)	7–5	5–3		3–1.8		1.5	1.0
Gate pitch (nm)	51	48		45		42	40
Metal pitch (nm)	30	24		20		18	16
Transistor structure	Fin FET		GAA		Backside power delivery		3D



Memory device

Year	2021	2022	2023	2024	2025	2027	2030
DRAM technology node (nm)	15		13	12–11	10		3D
Number of 3D-NAND layers	128	–176		200–400	400–600		600–

Estimated by Hitachi High-Tech based on the International Roadmap for Devices and Systems 2022 and other sources.

Fin-FET: fin field-effect transistor GAA: gate-all-around, a field-effect transistor with channel sidewall surrounded by gates on all sides

1 Progress in cutting-edge semiconductor devices

2 Electron beam area inspection system GS1000

2 Electron Beam Area Inspection System GS1000 Responds to Growing Inspection and Metrology Needs with EUV Lithography

Cutting-edge device manufacturers providing advanced server/mobile processors to the market are increasing the application of EUV lithography processes in the high-volume manufacturing (HVM) of 5-nm generation devices and the research and development (R&D) of 3-nm generation devices. Miniature and high-precision patterning processing is possible with an EUV lithography technique, but the metrology of EUV-specific pattern width variations and the inspection of randomly occurring minute stochastic defects[*1] are required. In addition, the needs for high throughput inspection and metrology are increasing to realize high-quality EUV mask transfer processes.

Hitachi High-Tech Corporation developed the electron beam area inspection system, GS1000, which supports high-speed, high-sensitivity, and wide-area scanning to help solve such issues in processes that apply EUV lithography processing. This product achieves wide-area imaging through an aberration correction technique and high-speed beam scanning technique based on a cutting-edge electron optics system design. Moreover, by combining a high-resolution, large-current beam, it performs high-speed and high-precision inspection measurements while maintaining high resolution within a wide field of view without the need for frequent sample stage movements as in the past. In addition, it uses a dedicated high-speed image processing system for parallel processing of high-speed image capture and image transfer in real time to achieve high throughput with ultra-high-speed data transfer. Furthermore, it also incorporated die to AI (D2AI) inspection[*2] using AI technology to enable high-speed and high-precision recognition of process variations and minute defects.

Hitachi High-Tech will respond to the various needs of semiconductor device R&D and HVM through inspection and metrology systems that apply electron beam technology to continue supporting the evolution of the semiconductor industry.
(Hitachi High-Tech Corporation)

*1 Stochastically induced defects that are attracting attention as a technology issue particularly in the development of EUV lithography technology.
*2 Algorithmic method that inspects part of the wafer area (die) using AI

3 Wafer Surface Inspection System LS9600 Responds to the Need for High-efficiency Inspection

Semiconductor devices for supporting digitization [digital transformation (DX) and IoT], high-speed communications and AI are manufactured with newly designed process manufacturing technology for realizing line widths of 10 nm or less. Semiconductor manufacturing makers require high-speed inspections for particles and defects on wafers with a sensitivity of 20 nm or less to control manufacturing yields during mass production. Wafer surface inspection systems can inspect micro particles and defects using a non-patterned wafer with higher sensitivity and speed, which are difficult to detect on patterned wafers. Regular process monitoring demands for the particles generated from manufacturing equipment are increasing. To respond to process control demand,

3 Wafer surface inspection system LS9600

Hitachi High-Tech Corporation developed and released a wafer surface inspection system, LS9600, which achieves the highest sensitivity of 15 nm (on a bare-silicon wafer) and a maximum throughput of 120 wafers per hour with a newly adopted deep-ultraviolet (DUV) laser and a new optical detection system. In addition, extraction performance of killer defects with an optimized high-precision signal processing algorithm by multi-detection sensors, and a utilization rate of 95% or more in mass production with newly designed laser lifetime prediction technology have been realized. The LS9600 wafer surface inspection system has been introduced to mass production lines for major customers in Europe, North America, and Taiwan for realizing excellent manufacturing quality with reasonable production costs.
(Hitachi High-Tech Corporation)

4 Nanoscale Device Characteristics Analysis System Nano-Prober NP8000

The nanoscale device characteristics analysis system (Nano-Prober) is a scanning electron microscope (SEM) based analysis system that is used to measure the electrical characteristics of transistors and to identify the location of device faults by directly probing the semiconductor device using a microscopic probe with a diameter of several tens of nanometers. With the evolution of semiconductor devices in recent years, the advancement of technology to narrow down fluctuations in the electrical characteristics of devices and the location of faults within circuits due to electron beam irradiation damage have become issues for nano-probers.

The recently developed new Nano-Prober NP8000 achieves high-resolution SEM images under low-acceleration voltage conditions and minimizes the damage due to electron beam irradiation by adopting a new optical system that combines a Schottky electron gun with the boosting deceleration method. In addition, it enables the visualization of low-resistance defects which could not be analyzed with previous equipment by updating the electron beam absorbed current (EBAC)* amplifier function.

Solutions realized with the NP8000 can be expected to be deployed not only for cutting-edge semiconductor device manufacturers, but also for emerging semiconductor companies in China and other fault analysis fields where the demand is likely to significantly increase going forward.
(Hitachi High-Tech Corporation)

* A technology that visualizes fault locations by using a probe to detect and image the current (absorbed current) flowing in a circuit that is generated when an electron beam is irradiated on a semiconductor device.

4 Nanoscale device characteristics analysis system Nano-Prober NP8000

Industrial Digital Solutions

1 Motor Current Predictive-diagnosis Solution for Stable Equipment Operation and Maintenance Costs Reduction

In recent years, Japan's workforce has been declining, and the digitalization and streamlining of tasks utilizing various sensors and the Internet of Things (IoT) is required in the manufacturing industry. In the facility maintenance field as well, labor-saving initiatives are being advanced through digital transformation (DX) for inspection work which was previously carried out by having a maintenance worker go around and check each piece of equipment.

Amidst these changes, Hitachi has developed a solution for diagnosing equipment anomalies that utilizes the current data of the motors used to drive equipment. This solution measures motor current and uses a proprietary Hitachi algorithm that utilizes artificial intelligence (AI) to diagnose anomalies in the motor itself and in the equipment driven by the motor. Moreover, the solution contributes to stable equipment operation and reduced maintenance costs with the following three features.

(1) Diagnosis based only on current sensor data

Since the only data required for diagnosis is the current data supplied to the motor, the system can be implemented comparatively easily.

(2) Able to diagnose motors with variable speed and load

Equipped with an algorithm that automatically extracts current data that is suitable for diagnosis, it enables diagnosis during normal operation even for motors with variable speed and load.

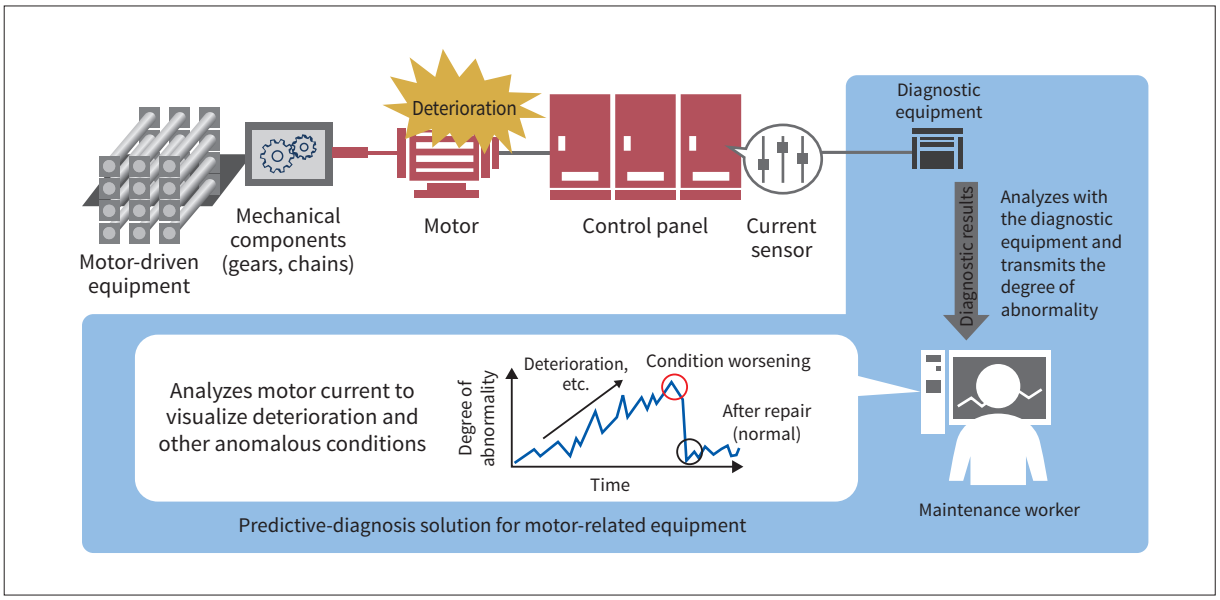
(3) Solves the issue of task individualization in equipment diagnosis

By quantifying the anomalous conditions of equipment (degree of abnormality), it can eliminate variations in human judgment, thereby resolving the problem of a lack of maintenance personnel with advanced skills.

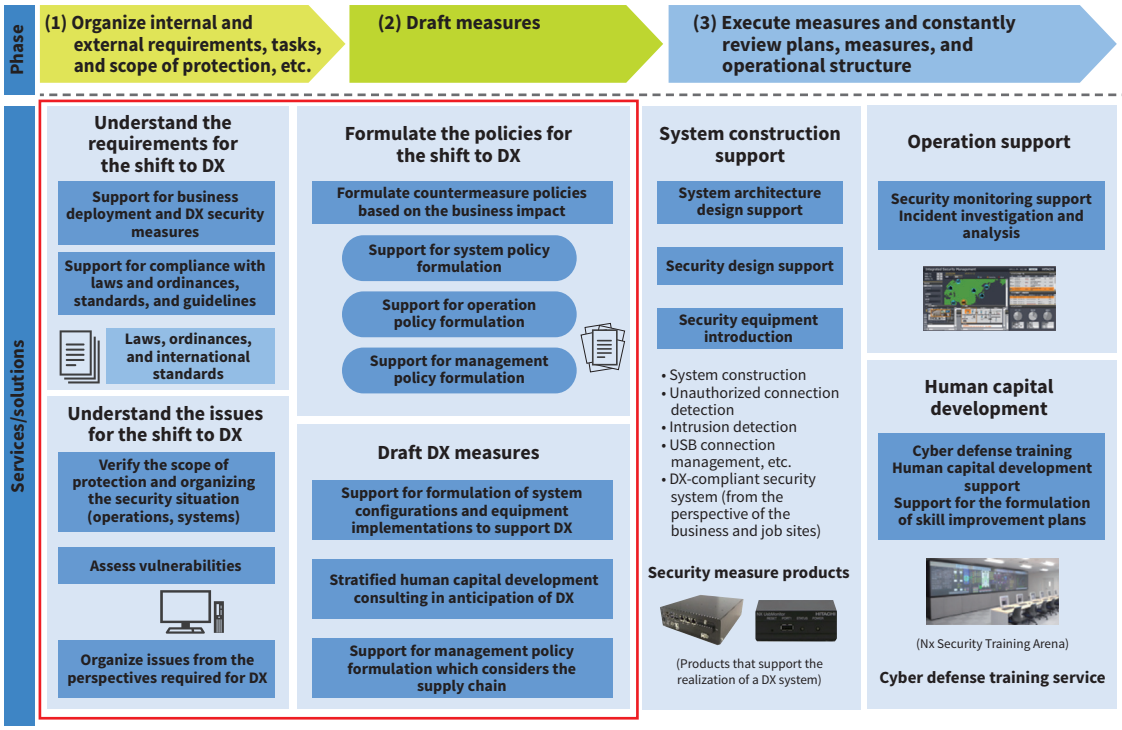
2 Advanced DX-compliant Security Services that Protect Control Systems from New Threats

When it comes to utilizing DX, it is essential to introduce equipment with standard interfaces and the capability of linking internal and external systems. However, the introduction of such equipment comes with security threats, which have a greater impact on business continuity, safety, quality, production planning, and costs than ever before.

Under such conditions, Hitachi considered the business continuity and safety, quality, delivery time, cost (SQDC)



1 Overview of motor current predictive-diagnosis solution



USB: universal serial bus

2 Providing advanced security services for DX upstream processes

which should be protected from new security threats and broadly provides everything from (1) organization of internal and external requirements, tasks, and scope of protection, to (2) drafting measures and (3) executing measures and constant reviewing of plans, measures, and operational structure as solutions to support DX based on the Cyber and Physical Security Guidelines for Factory Systems from the Ministry of Economy, Trade and Industry. In particular, Hitachi provides advanced security services which support the creation of new guidelines and the evaluation of vulnerabilities (penetration and fuzzing tests, etc.) for the DX planning phase and other upstream processes [Phases (1) and (2)]. Phases (1) and (2) each include the following features.

(1) Understanding the requirements for the shift to DX (linking security-related laws and ordinances, standards, guideline requirements to business planning and understanding the requirements) and understanding the issues in the shift to DX (objectively understanding the current system and operation while also organizing the issues in the shift to DX)

(2) Formulation of policies for the shift to DX (considering the business impact and supporting the formulation of security policies aimed at the shift to DX) and draft measures under DX (proposing measures from the perspective of systems, human capital, and management based on the security policies)

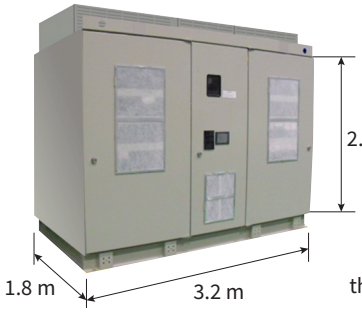
3 Universal Main Motor Drive System for Steel Plants

A quarter of a century has passed since the application of the cell concept* to motor drive systems for steel plants. During that time, through continuous technological advances, Hitachi has achieved high functionality, miniaturization, and retrofitting of motor drive systems, and has contributed to customers' facility management through the optimization of system installation and operation costs. The company recently universalized functional cells that enable the application of three types of insulated gate bipolar transistors (IGBTs) and commercialized its universal main motor drive system with a selection of three levels of alternating current (AC) output voltages, 2.25 kV, 3.31 kV, and 4.50 kV. The key features of this system are as follows.

(1) By adding the 3.31 kV AC output voltage to the lineup, Hitachi expanded the voltage range of main motors that can be driven, enhancing the system's ability to support customers' facility planning.

(2) Applies the global standard module types of 3.3 kV, 4.5 kV, and 6.5 kV IGBTs to achieve long-term stable supply for systems.

(3) The capacity for the same system was serialized through a combination of functional cells.

Model name	MH2A plus	H2LA plus	H2A plus
AC output voltage (kV)	2.25	3.31	4.5
Output capacity (MVA)	4.3–18.0	4.2–15.0	5.8–18.0
Main circuit system	Three levels		
Cooling system	Water-cooled		
Overload specifications	150% (for one minute)		
Conversion efficiency	98% or more (during rated output)		
System (converter + inverter)	 All models share the same appearance		

3 Overview of universal main motor drive system for steel plants

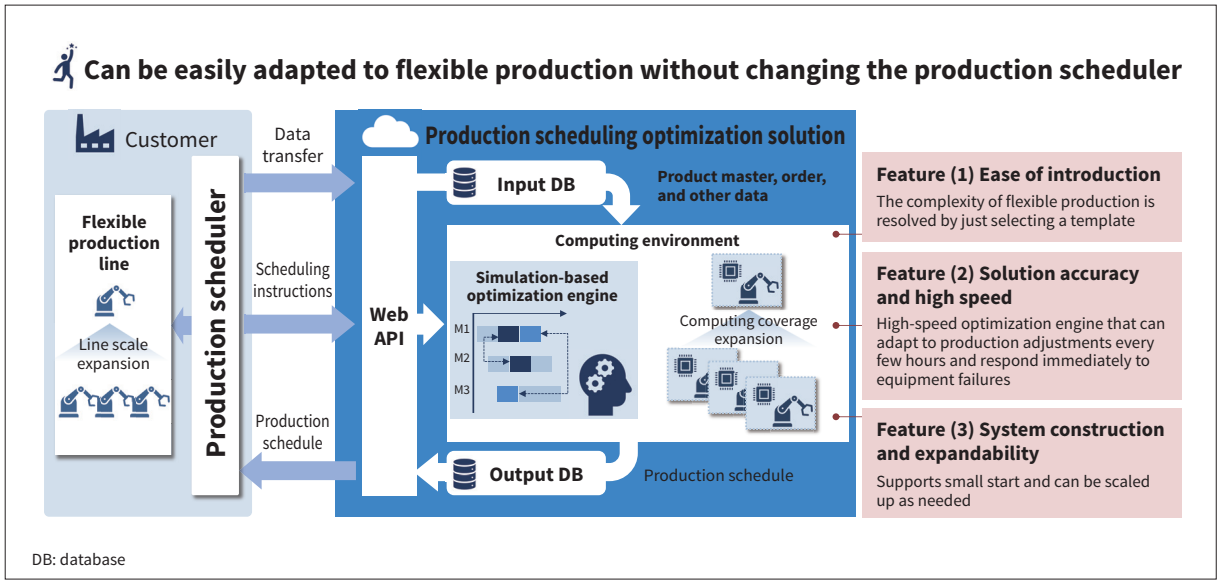
Going forward, Hitachi plans to evolve this product into a motor drive system that can deeply contribute to customers' facility management.

* A design philosophy that achieves overall functionality through the selection and combination of cells by function.

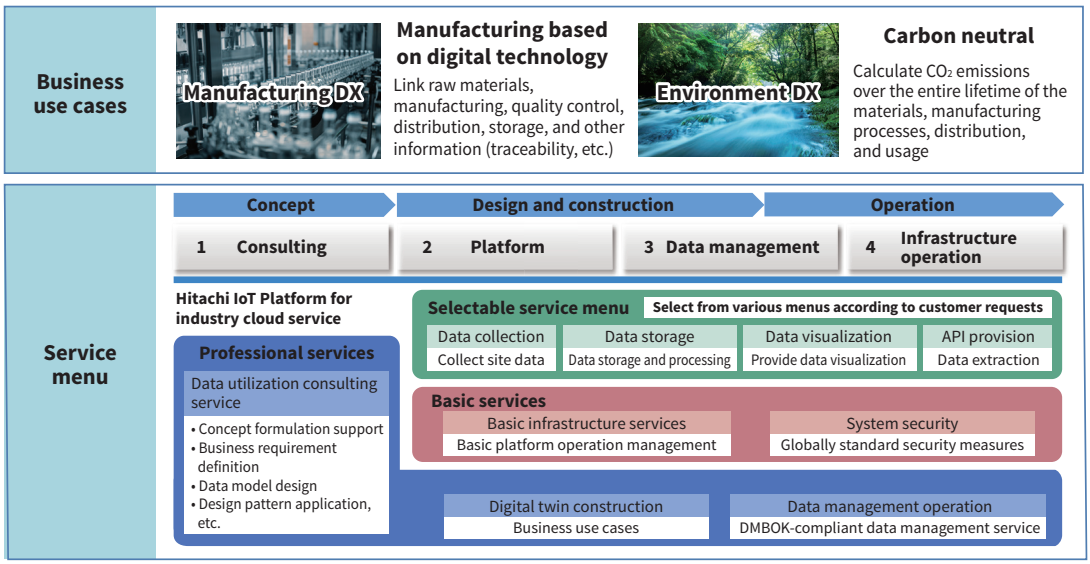
4 Simulation-based Production Scheduling Optimization Solution for Flexible Production

In order to adapt to rapid changes in the business environment, including worldwide parts supply shortages, diversification of customer preferences, and support for environment, social, and governance (ESG), variable-mix, variable-volume production is required to produce and supply a diverse range of products in the quantities required, and in a timely manner. Therefore, flexible production is gathering attention as a new production method that can flexibly respond to demand fluctuations and production adjustments in the manufacturing industry. To achieve flexible production, it is necessary to ensure that it can support the complexity of production scheduling and the immediacy of demand fluctuations and equipment failures in terms of operations, and that the system can start small and scale up flexibly in accordance with production line expansion.

In response, Hitachi is developing a simulation-based production scheduling optimization solution that is useful for production scheduling in flexible production. This solution can provide fast and optimal production



4 Overview of production scheduling optimization solution



DMBOK: Data Management Body of Knowledge, a reference book published by DAMA International that is a non-profit organization made up of international data experts

5 Hitachi IoT Platform for industry cloud service business use case examples and service menu

scheduling even for such a complex production schedule as flexible production by combining the application of scheduling logic libraries and simulation-based search according to the features of the production line.

Moreover, this solution provides a Web application programming interface (API) as a microservice to easily link with existing production schedulers and achieves flexible scaling up according to production line expansion through container implementation for the simulation-based optimization engine.

5 Hitachi IoT Platform for industry Cloud Service

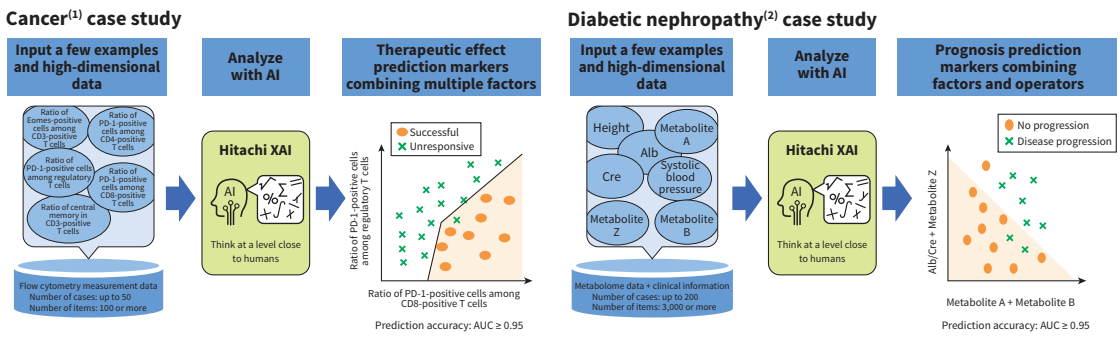
With the spread of COVID-19, the fragmentation of supply chains in the industrial world and other inter-operational and inter-business *kiwa* (gap) issues have become more apparent and a hindrance to integrated analysis and total optimum decision-making.

In response, Hitachi has developed the Hitachi IoT Platform for industry cloud service to understand the actual site conditions and use site data to model operations in cyberspace (data models) as well as to support system construction in cyberspace to realize a gapless system utilizing the model. In this service, DX professionals delve into the customer's management and operational issues and realize DX concepts with proven business use cases, such as production traceability and calculation of carbon dioxide (CO_2) emissions throughout the product lifecycle. Moreover, they prepare a data utilization platform and data model that suit the customer's environment by putting together a menu of services prepared in advance, and provide this platform as a fully-managed service so that the customer can focus on business execution.

6 AI Solutions Increasingly Being Used in the Medical Field

In recent years, the development of AI solutions for the medical field has been advancing to support medical treatment and drug discovery research and development work at medical care, drug discovery, and other sites.

Hitachi's AI solution, Hitachi Digital Solution for Pharma/Biomarker Discovery Service, extracts important factors that characterize each disease, side effect, and various other symptoms and factors that are important for the prediction of treatment efficacy with evidence by using Hitachi's proprietary explainable AI (XAI) technology to analyze clinical research as well as electronic medical charts and other patient data. In addition, by combining the extracted factors with simple formulas, new indicators that can predict the therapeutic effect with high precision can be automatically generated in a short period of time. Compared to existing AI, the system has been praised for its superior interpretability of results, and it is being increasingly utilized in various areas of disease such as cancer, lifestyle diseases, other intractable diseases, and infectious diseases.



CD: cluster of differentiation PD: programmed death receptor AUC: area under the curve Alb: albumin Cre: creatinine

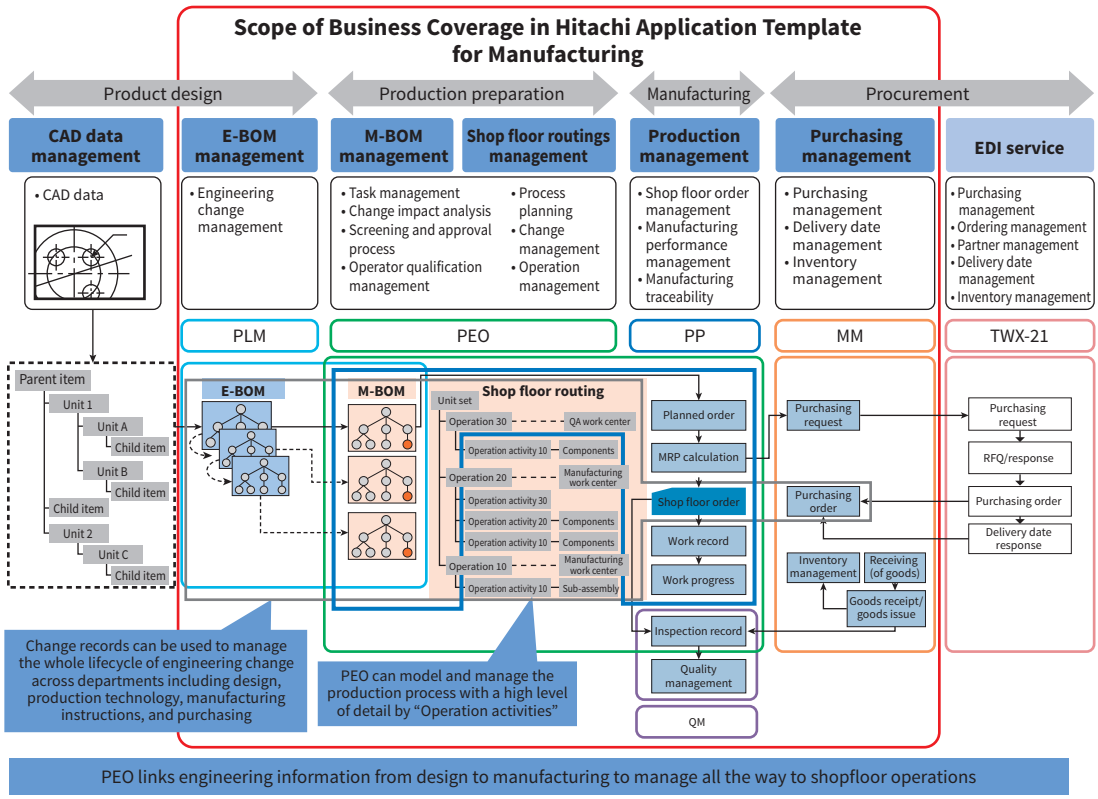
6 XAI solution case studies

Hitachi is planning to release an analysis platform service that will allow users to directly use this XAI analysis feature within 2023 to broadly contribute to the progress of the medical field.

References
1) S. Kumagai et al., "The PD-1 expression balance between effector and regulatory T cells predicts the clinical efficacy of PD-1 blockade therapies," Nature Immunology (2020).
2) Y. Hirakawa et al., "Potential progression biomarkers of diabetic kidney disease determined using comprehensive machine learning analysis of non-targeted metabolomics," Scientific Report (2022).
3) Y. Kanatani, Y. Sato, S. Nemoto, M. Ichikawa, & O. Onodera, "Improving the Accuracy of Diagnosis for Multiple-System Atrophy Using Deep Learning-based Method," Biology (2022).

7 Hitachi Application Template for Manufacturing Seamlessly Connects ECM and SCM

In the manufacturing industry, the desire to link engineering chain management (ECM) and supply chain



CAD: computer-aided design PLM: product lifecycle management PP: production planning MM: material management BOM: bill of materials
E-BOM: engineering-BOM M-BOM: manufacturing-BOM EDI: electronic data interchange QA: quality assurance MRP: material requirements planning
QM: quality management RFQ: request for quotation

7 Scope of business coverage in Hitachi Application Template for Manufacturing

management (SCM) in a seamless and timely manner is a challenge, and initiatives to eliminate the gaps between tasks are continuing through the promotion of DX. In response, the Hitachi Group is using SAP S/4HANA* Manufacturing for production engineering and operations (PEO) to tie together the information from design to production preparation and manufacturing to build a seamlessly linked system.

Utilizing this experience, Hitachi completed development of its Hitachi Application Template for Manufacturing in September 2022 and started providing it as a service to customers in the manufacturing industry to support systematization studies and requirements definition.

Based on the fit to standard approach, this template provides a business process flow that reflects Hitachi's manufacturing know-how and an environment in which typical business processes can be verified. Using this template makes it possible to walk through customer requirements and issues while checking them in a more specific manner, and to efficiently examine business processes and systems across departments without omissions.

*See "Trademarks" on page 158.

8 Hitachi Digital Solution for Retail/Demand Forecasting Automated Ordering Service

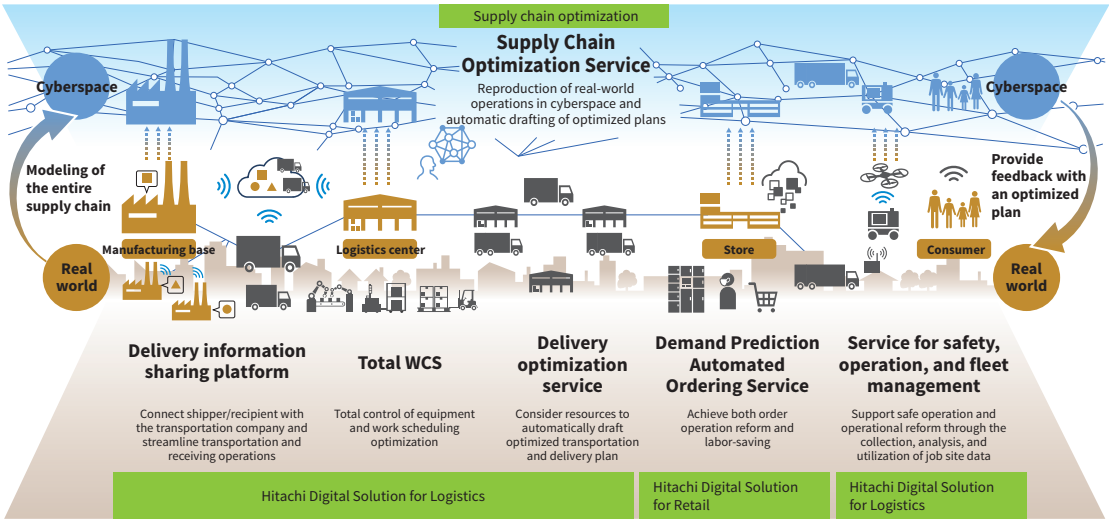
The Hitachi Digital Solution for Retail/Demand Prediction Automatic Ordering Service predicts the amount of demand based on consumer needs, events, weather, and other causal factors and recommends order quantities by also taking inventory into consideration to achieve a transformation of shop and sales floor operations.

In a case study of wholesale company A, Hitachi introduced the Hitachi total logistics management system and the Hitachi Digital Solution for Retail/Demand Prediction Automated Ordering Service together to deal with social issues such as task individualization and food loss in ordering and inventory management operations to achieve automated ordering and inventory management centralization. By forecasting the amount of demand and the amount of arriving goods, they were able to reduce costs through improvements in truck loading efficiency and dispatching through the system, resource conservation, reduction of Scope 3 emissions through controlling exhaust gas, and reduction of food loss. In addition, this will also lead to Hitachi's goals of contributing to the environment and realizing a happy society.

These IT solutions, including the Demand Prediction Automated Ordering Service, will help solve onsite issues and reduce environmental load by realizing a cyber-physical system (CPS) for supply chains, logistics centers, and transportation and delivery operations.

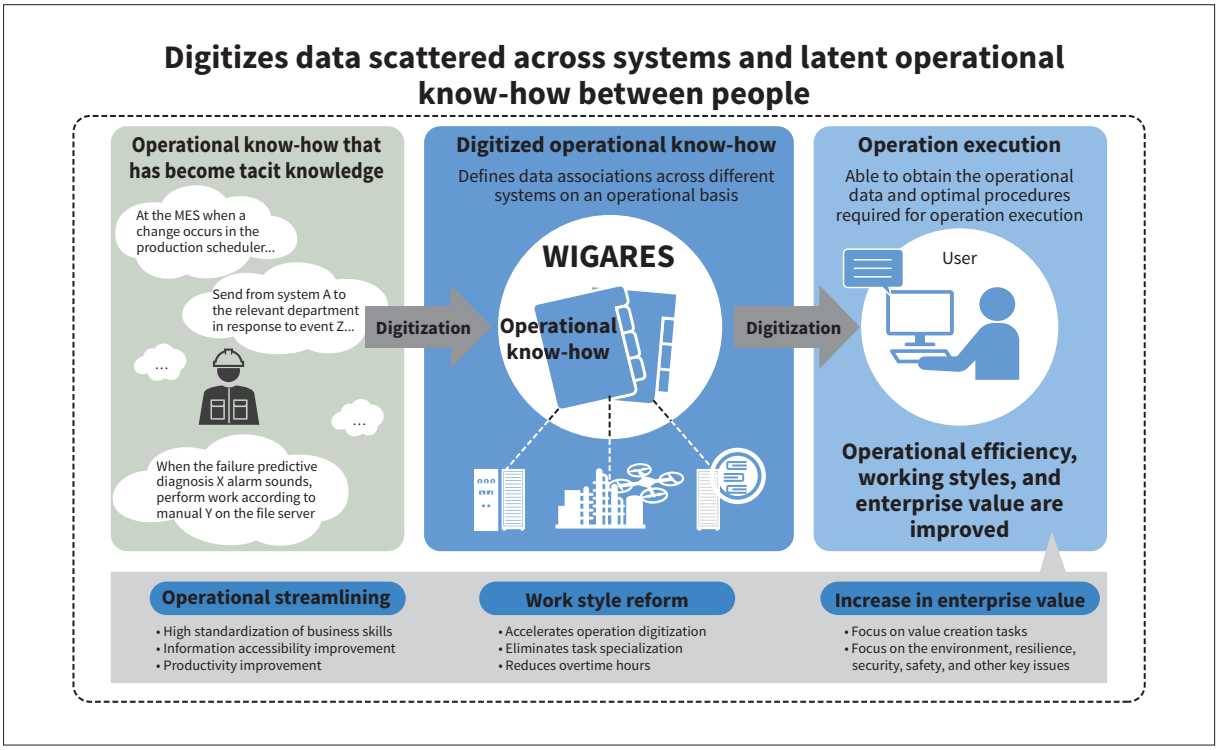
9 WIGARES Platform for Achieving Plant Operation Automation

Realizing plant operation automation requires coordination between systems as well as the digitization of the latent operational know-how in legacy systems and experienced workers to utilize them. This is thought to be one factor hindering the realization of plant operation automation.



WCS: warehouse control system

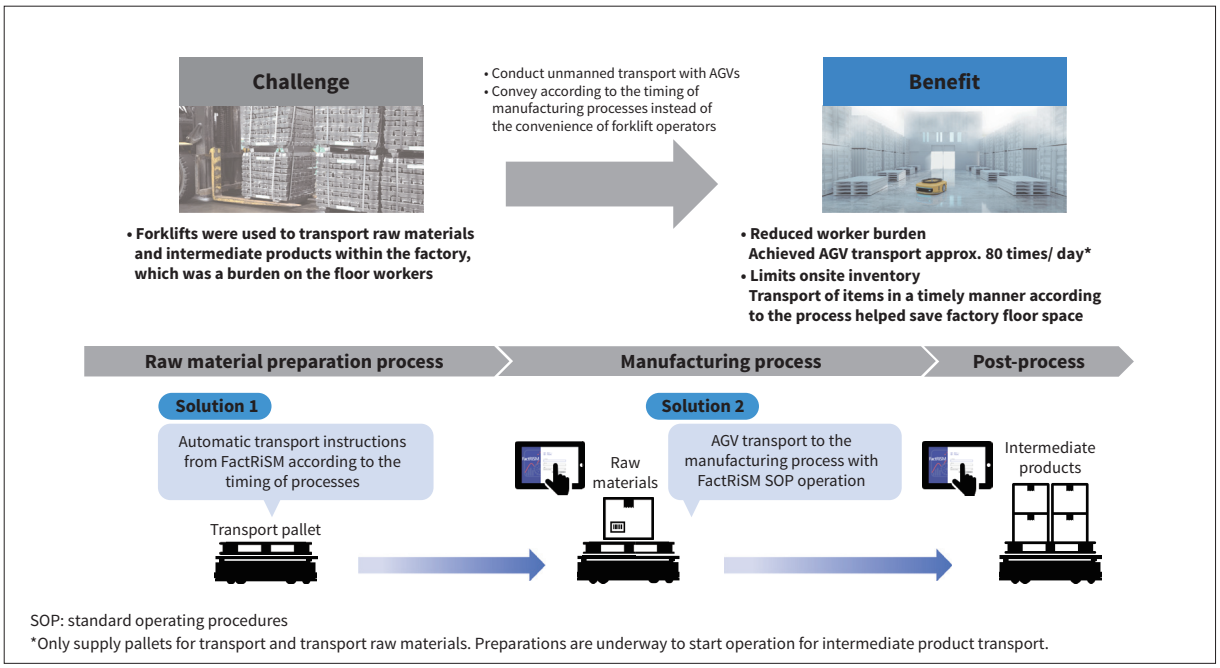
8 Logistics IT solution to support supply chains



9 WIGARES centralized information management platform digitizes operational know-how of the manufacturing industry

To overcome this challenge, Hitachi started offering WIGARES, a centralized information management platform that automatically provides the necessary information from scattered systems and digitizes the specialized operational know-how of the manufacturing industry. This product is characterized by its ability to correlate data from different systems and to define it based on operations. The defined operational know-how can be presented to users from systems in an event-driven push notification. As a result, useful information based on expert experience can reach anyone, which can be expected to provide forms of value such as skills transmission and business efficiency.

Going forward, the company aims to provide WIGARES to a wide range of manufacturing companies in Japan while also realizing automation of plant operations through feature expansion.



10 FactRiSM and AGV linkage

10 Case Study on Introduction of FactRiSM and AGV Linkage to Promote Automation

The promotion of automation is an inevitable trend in the manufacturing industry, and the movement toward linking manufacturing execution systems (MES) with the manufacturing equipment on the factory floor to collect results is gaining momentum.

Recently, Hitachi simultaneously introduced the Hitachi MES package, FactRiSM, and automatic guided vehicles (AGV)* to a customer aiming to implement a smart factory.

Before the introduction of this solution, forklifts were used to transport raw materials and intermediate products within the factory, which was a burden on the floor workers. However, that burden was reduced with unmanned transport by AGVs according to instructions from FactRiSM, which understands production plans, process progress, and transport constraints. In addition, automatic transport of items in a timely manner when they were needed on the factory floor helped to reduce onsite inventory and limit temporary storage space.

* The AGVs were delivered by Hitachi Industrial Equipment Systems Co., Ltd.

11 Construction of a Picking Robot System for Logistics Warehouses

As workloads increase in the logistics industry due to the increase in electronic commerce (EC) businesses and the support for high-mix low-volume shipments, the constant labor shortage is becoming an issue. In response to this issue, Hitachi is working on the utilization of logistics robots and the evolution of the operational control of the entire center as well as promoting automation and streamlining.

Hitachi recently focused on the picking work that has historically relied on manual labor and created a picking robot proof of concept (PoC) aimed at automating the work of feeding products into automatic sorting machines (sorters) and introduced the system to a logistics center in October 2022.

The features of this system are as follows.

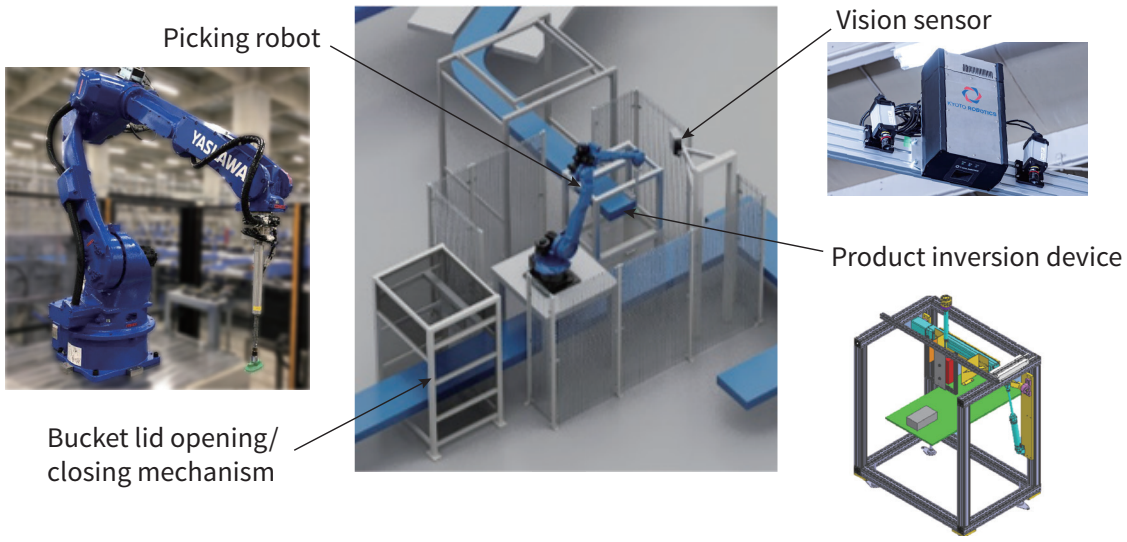
(1) Application of high-resolution three-dimensional recognition vision systems

Recognizes the products in the bucket with high resolution and at high speed and can handle various types of packages in various positions.

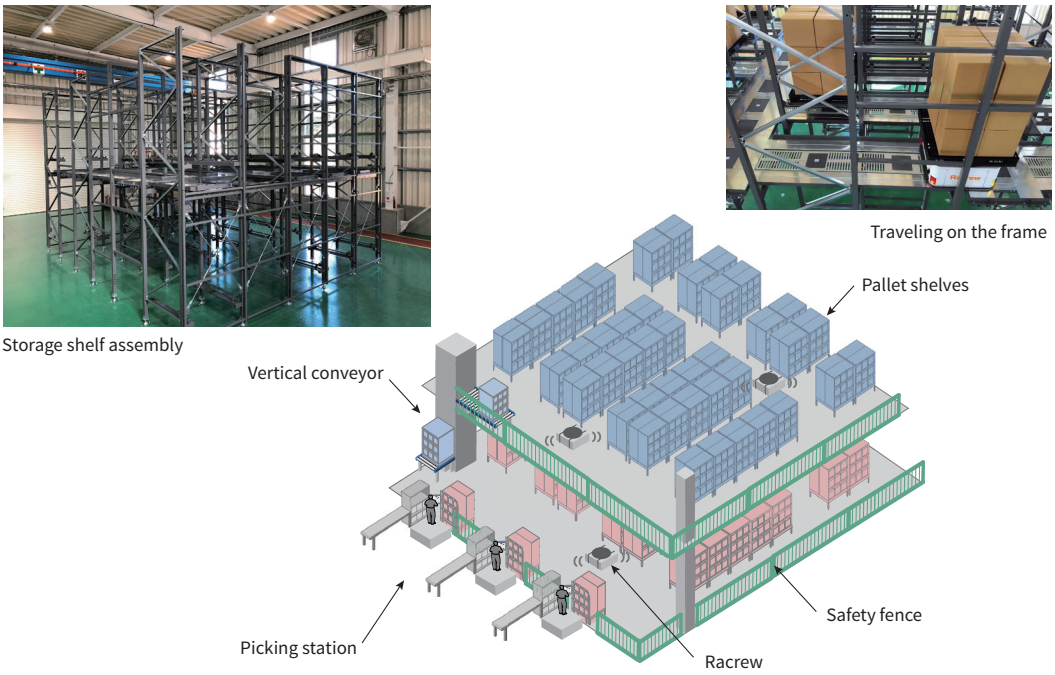
(2) Automation of the entire picking process

Embeds not only picking, but also features that are required for pre- and post-processes (opening and closing bucket lids, product inversion, etc.) into the system to achieve full automation of a sequence of actions.

Going forward, the company will continue to advance automation technologies while also working on further innovations at logistics sites through the utilization of digital data.



11 Construction of a picking robot system for logistics warehouses



12 Image of the hierarchical solution

12 Racrew Hierarchical Solution

In recent years, many goods-to-person (GTP) picking systems based on AGV have been introduced as solutions to support the streamlining of tasks inside warehouses, but typical warehouses have high ceilings, and making effective use of the space above these systems has been an issue.

To resolve this issue, Hitachi developed the Racrew Hierarchical Solution which divides the picking system storage area of the Hitachi Racrew shelf transport robot into two tiers.

The adopted frame design features frame columns with low loss to minimize the impact on storage capacity. Moreover, consideration was also given so that the traveling surface of the frame would not be included in the floor area stipulated by the Building Standards Act. The storage area was not simply separated into two tiers, but was also designed with flexibility in terms of operation, such as separating the product categories and management systems managed on the second tier as well as making it possible to load conveyors and other equipment.

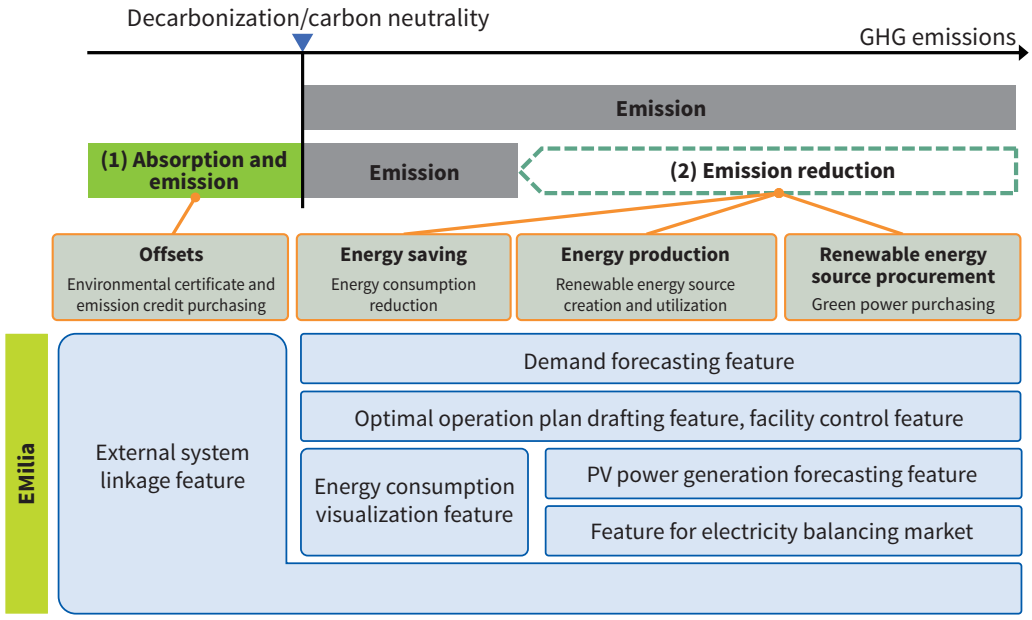
Going forward, the company will continue to develop and provide solutions to meet such customer needs.

13 EMilia—Integrated Management Service for Energy and Equipment

Achieving carbon neutrality requires four initiatives consisting of energy saving to reduce the amount of energy used, energy production to create and utilize our own carbon-free renewable energy sources, renewable energy source procurement to procure green energy, and offset for emitted carbon through the purchase of environmental certificates, etc.

The EMilia integrated management service for energy and equipment supports energy saving and energy production through demand forecasting using memory-based reasoning (MBR) and the drafting of optimal operation plans and equipment control which consider the operational restrictions and performance characteristics of equipment. Moreover, it also encourages renewable energy procurement by providing functions for the balancing market that assist in calculating the adjustment power that can be delivered and the correction of deviations from the target value. In addition, offset assistance by linking with external systems is also available.

By providing the EMilia service, Hitachi will continue to support resilient businesses and sustainable growth while responding to the various challenges faced by customers due to changes in the business environment.



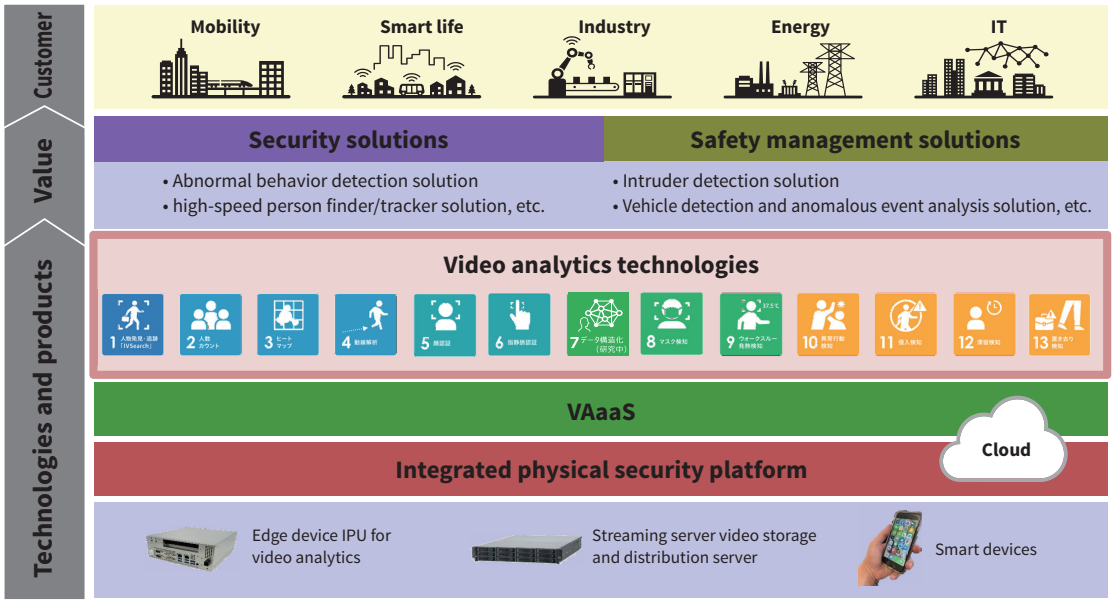
GHG: greenhouse gases PV: photovoltaics

13 Carbon-neutral implementation methods and features provided by EMilia

14 Video Analytics Solution

Hitachi provides video analytics technologies as a way to convert various people, events, and products into digital data through video analytics to solve problems with the goal of achieving DX in the social infrastructure field.

Recently, the company has been working on developing security solutions utilizing its proven integrated physical security platform and video analytics technologies, and expanding into safety management solutions. For example, at a manufacturing site, the company developed an intruder detection solution that detects workers' unintentional intrusions into hazardous areas and a



IPU: image processing unit

14 Solutions utilizing video analytics

vehicle detection and anomalous event analysis solution that detects falling objects on the road and the intrusion of two-wheeled vehicles and people onto highways.

Going forward, the company will provide video analytics as a service (VAaaS) to enable the utilization of video analytics as a cloud service to solve various customer issues, and will strive to develop and provide solutions that support the streamlining and improvement of operations at multiple sites across a wide area.
(Hitachi Industry & Control Solutions, Ltd.)

15 Service for Enhancing AI Value Promoting DX in Manufacturing and Logistics Peripheral Operations

In some cases, medium-sized manufacturing and logistics companies depend on manpower for coordination between systems and operations, and face a challenge in seamlessly linking information. To address this challenge, Hitachi is promoting a comprehensive proposal approach in which engineers who possess a variety of expertise work together with customers on digitization covering everything from organizing objects on the factory floor and operational flows to formulating a feasible improvement plan according to actual circumstances and constructing a system that is consistent across operations.

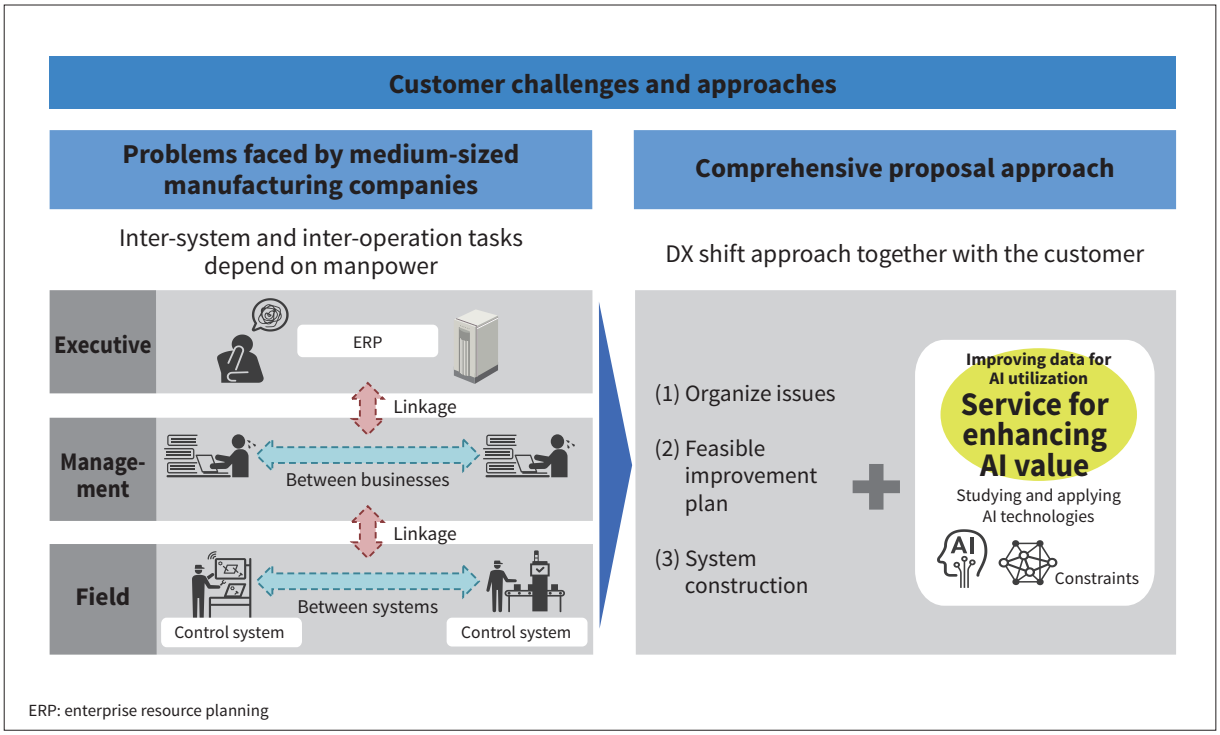
Hitachi's DX service, service for enhancing AI value, provides added value by utilizing AI technology to address the issues raised in these efforts. For example, by applying this service to planning operations that must consider experienced workers' knowhow and various constraints, it is possible to automatically draft an optimal plan that takes the constraints into account while eliminating task individualization, which leads to stability and efficiency in planning quality.

Going forward, the company will expand the scope of automation by adding a service for enhancing AI value to digitization and promote initiatives aimed at realizing customers' visions for the future.

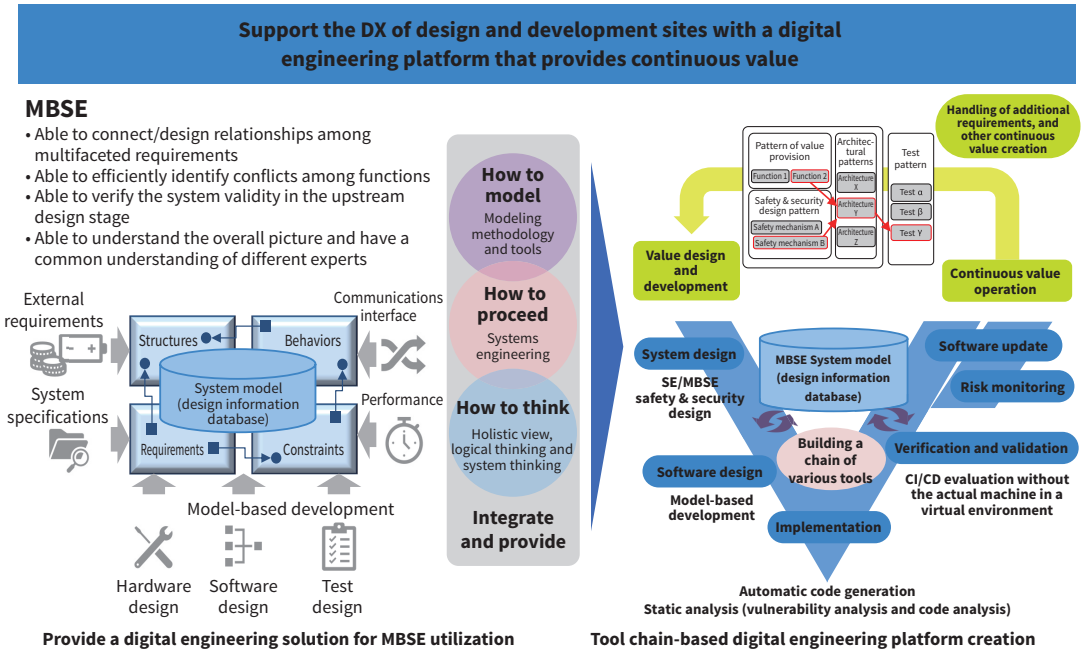
16 MBSE Utilization Solution to Support Design and Development in a Connected Era

In recent years, connected systems including mobility have been developed to connect with various external services and stakeholders. In an attempt to achieve precise control and automation that takes people and the environment into account, the requirements become more diverse, larger-scale, and more complex. In the design of connected systems, it is difficult to reconcile conflicts between requirements with conventional document-based design methods, and design rework is likely to occur.

Applying model-based systems engineering (MBSE), substantiating the relationships among multifaceted requirements in the form of a design information database, and visualizing the structure of complex requirements are



15 Customer challenges and approaches



16 MBSE utilization solution to support design and development in a connected era

effective for resolving such issues. The MBSE utilization solution provides a digital engineering solution that integrates (1) a modeling methodology that utilizes tools, (2) an approach to systems engineering that complies with international standards (ISO/IEC/IEEE 15288), and (3) holistic view thinking that focuses on the system objectives and values (logical thinking and system thinking). As a result, it is possible to efficiently extract the scope of impact and conflicts between features associated with feature modifications, which enables rational iterative design. In addition, it enables the realization of a digital engineering platform that provides continuous value, such as early handling of additional requirements, by constructing a tool chain that seamlessly achieves design, implementation, and evaluation.

Water & Environment

1 Kamitsubo Water Purification Plant panorama and central monitoring room

1 Renewal Construction of Hitachinaka City Waterworks Utility, Kamitsubo Water Purification Plant

The Kamitsubo Water Purification Plant is capable of supplying 38,100 m^3 of water per day and accounts for 70% of the demand for the entire city of Hitachinaka, Ibaraki Prefecture. The plant entered use in 1965, and a project was launched to build a new water purification plant due to deterioration and seismic resistance measures.

With this new construction, roughly 200 high-voltage panels, power control panels, auxiliary relay panels, local panels, controller panels, and remote-monitoring units were delivered for the central monitoring facility, receiving and transforming/non-utility generation facility, sedimentation basin facility, filtration facility, dosing facility, water distribution pump facility, wastewater treatment facility, instrumentation facility, and the remote monitoring facility, with operation started in February 2022. The key features are as follows.

(1) In order to directly distribute water within the city with the water distribution pump at the new water purification plant, a control circuit was built to be able to promptly restart during a momentary power failure, and the decrease in water distribution pressure was minimized.

(2) Reliability was increased by setting up redundancies for the controller and control local area network (LAN).

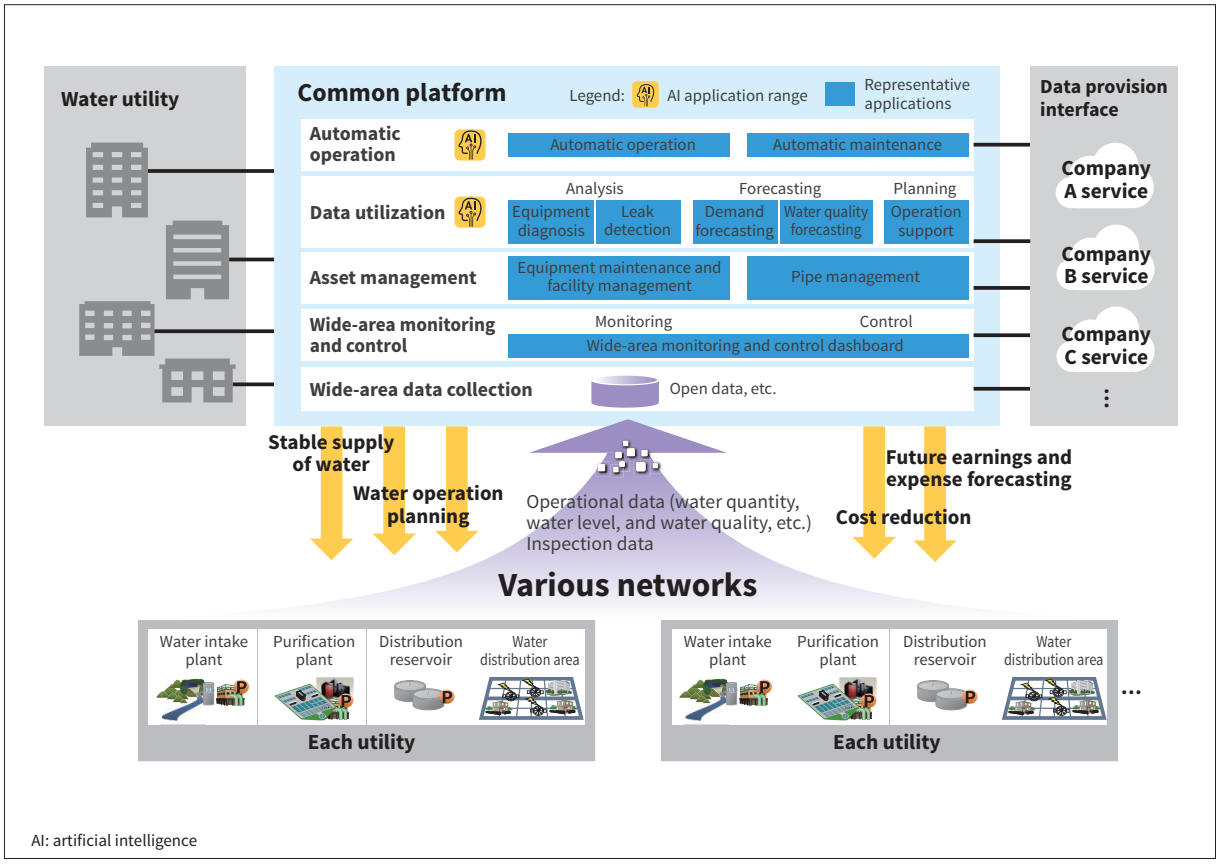
(3) The number of cables has been reduced by using FL-net* for signal transmission and reception with the machinery panels and implementing input-output devices in the auxiliary relay panels to conserve resources.

* See "Trademarks" on page 158.

2 Comprehensive DX Solution that Helps Streamline Wide Area Operation Monitoring and Control Systems for Waterworks

Water and sewage utilities in Japan are primarily operated by prefectural governments and local municipalities. Renewal costs for deteriorating facilities are expected to increase while the number of staffers working at such utilities is declining. In reality, the operation monitoring and maintenance tasks rely on the experience and know-how of these staffers, which has become a major issue. Promoting wide-area expansion that links the systems of each facility and carries out integrated utility operation streamlines utility operations and is expected to strengthen the management base.

Under these conditions, Hitachi developed a common platform as a comprehensive digital transformation (DX) solution that standardizes the interfaces between systems with different specifications and enables lateral data utilization by conforming with the water supply standard platform specifications. This platform uses a structure that enables it to be deployed to other fields such as industry, the environment, civil engineering, and disaster prevention.



AI: artificial intelligence

2 Wide-area expansion utilizing a common platform

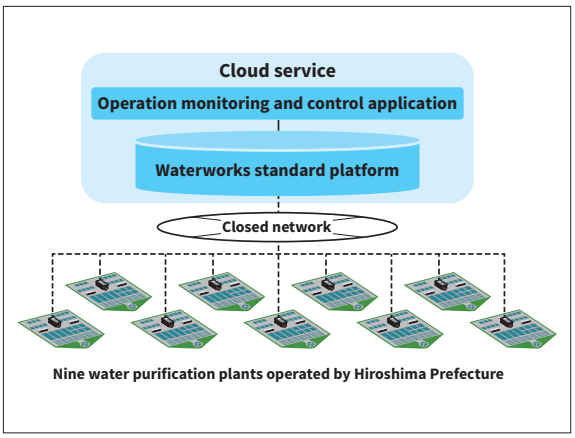
Hitachi will continue to contribute to the resolution of various issues, including wide-area expansion, and the realization of resilient social infrastructure through co-creation with customers and other companies.

3 Wide-area Operation Monitoring and Control System for Nine Water Purification Plants in Hiroshima Prefecture

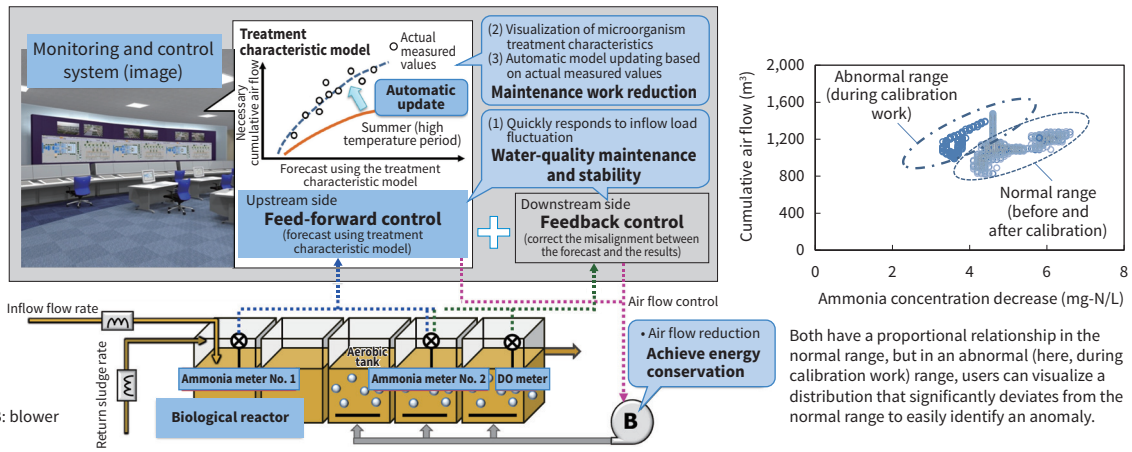
A joint enterprise consisting of Hitachi, Ltd. and Mizu Mirai Hiroshima Corporation received an order from Hiroshima Prefecture to construct a waterworks wide-area operation monitoring system. This work covers the nine water purification plants operated by Hiroshima Prefecture including the Senogawa water purification plant and involves the design and construction of a system that centrally monitors and controls the operating conditions of all facilities through a common platform in the cloud that can laterally utilize data even between systems with different vendors and specifications, and an application utilizing Hitachi's Lumada solutions.

This project combines Hitachi's products, operational technology (OT), and IT track record cultivated over many years as a comprehensive water provider, and the Lumada solutions with the technology and knowhow of Mizu Mirai Hiroshima, with its extensive track record of facility management and servicing/maintenance at water purification plants within Hiroshima Prefecture, to introduce advanced digital technologies in step with the pace of the promotion of waterworks utility DX by Hiroshima Prefecture.

This system will realize the wide-area expansion of waterworks utilities while also significantly improving efficiency and helping to save labor in the operation monitoring and maintenance that relies on the experience and knowhow of staffers.



3 Conceptual diagram of Hiroshima Prefectural Waterworks wide-area operation monitoring and control system



4 Nitrification control technologies contribute to nutrient salt control and decarbonizing

4 Sewage Treatment Control Technologies Contribute to Nutrient Salt Control and Decarbonization

With the accelerating transition to a decarbonized society in recent years, the importance of energy conservation in sewage systems is further increasing. Moreover, as a new role for sewage treatment plants, it is expected that they will contribute to the maintenance of beautiful and bountiful oceans by appropriately maintaining the cyclical balance of nitrogen, phosphorus, and other nutrient salts according to the region. At the same time, from the perspective of decarbonization, it is thought that this will also lead to the immobilization of carbon dioxide (CO_2) (blue carbon) through the ecosystems of coastal zones.

In response, Hitachi has modeled the operation of a sewage treatment plant to develop a simulator for advanced sewage treatment that can estimate nutrient salts and other treatment water quality and energy-conserving operation as well as a nitrification control technology that maintains the level of ammonia nitrogen at or below the target water quality and reduces blower power consumption. Moreover, based on these technologies, Hitachi is developing a hybrid operation support system that combines the sewage treatment knowledge possessed by people with AI.

The Hitachi Group will continue to support sewage works that contribute to building a society capable of sustainable development based on its long track record of products, systems, services, and other results over many years in the water infrastructure field.

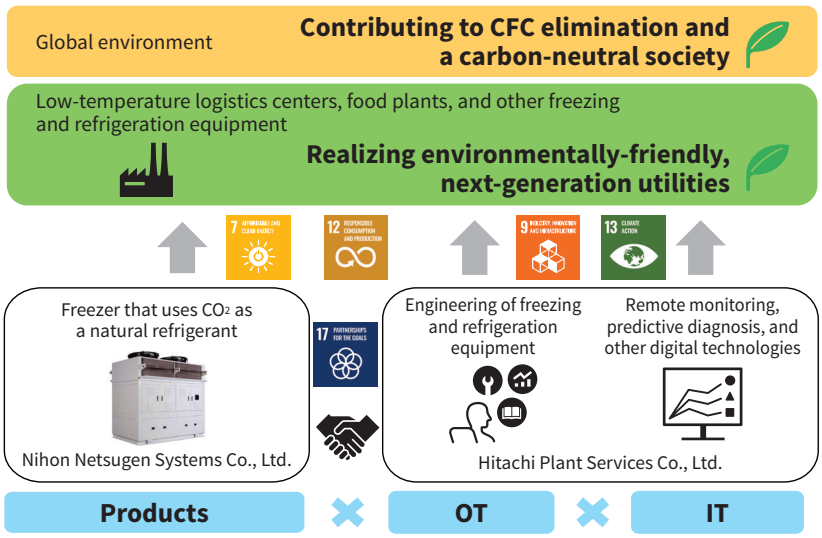
5 Decarbonization Solution Utilizing CO_2 Refrigerant Freezers

To achieve carbon neutrality by 2050, greenhouse gases must be reduced. The fluorocarbon refrigerant used in many freezers has a high greenhouse effect, and with some exceptions, the future reduction of its use is mandatory. Freezers that use CO_2 as a refrigerant have a lower greenhouse effect compared to fluorocarbon-refrigerated products, and they are attracting attention as environmentally-friendly products due to their energy-saving performance of 20% or more.

Hitachi Plant Services Co., Ltd. initiated a collaboration with Nihon Netsugen Systems Co., Ltd. regarding the large-sized freezing and refrigeration equipment business. By combining the engineering technologies as well as remote monitoring, predictive diagnosis, and other digital technologies of Hitachi Plant Services with the CO_2 refrigerant freezers of Nihon Netsugen Systems, Hitachi will provide environmentally-friendly bulk solutions.

Going forward, the company will continue to meet the broad needs of customers while also aiming to improve social, environmental, and economic value and to contribute to a carbon-neutral society.

(Hitachi Plant Services Co., Ltd.)



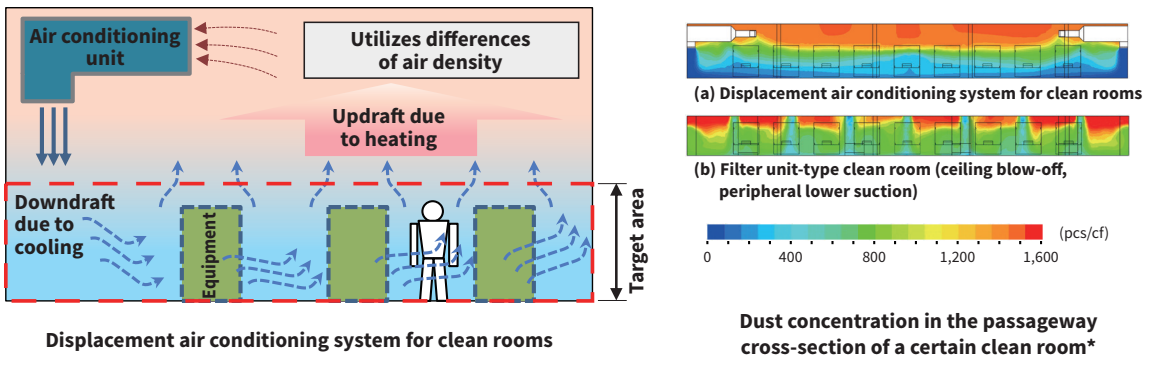
CFC: chlorofluorocarbon

5 Image depicting the realization of the decarbonizing solution

6 Displacement Air Conditioning System for Clean Rooms

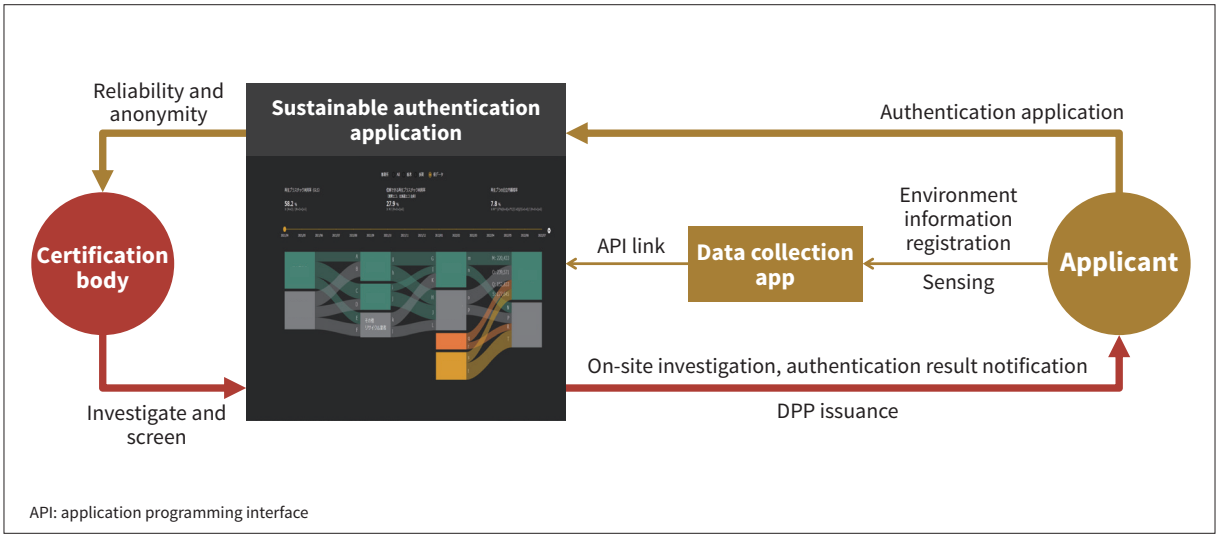
Because of the growing demand for semiconductors in recent years, there has also been an increase in requests for the construction and renovation of clean rooms. In this context, the accelerating trend toward improving the performance of manufacturing equipment, Sustainable Development Goals (SDGs), and a decarbonized society calls for proposals focusing on low costs and saving energy for clean rooms that do not require a high level of cleanliness.

Due to the energy that can be saved through localized cleaning of the clean room, Hitachi has focused on a displacement air conditioning system that target the working area in the lower part of the clean room for air conditioning. With the goal of increasing the footprint of the clean room floor, the company built a bottom-blow-out displacement air conditioning system that installs the air conditioner in the upper part of the clean room, supplies cool air to the lower working area, and air conditions/removes dust from the working area. Compared to the model case of a typical filter unit system, the displacement air conditioning system is estimated to reduce the initial cost by 50% and the running cost by 44% by reducing the circulating airflow rate. Currently, Hitachi is working on applying this system to actual projects.



*Theoretically, equivalent to room dust emission of 1,000 pcs/cf

6 Displacement air conditioning system for clean rooms



7 Sustainable authentication application

7 Developing a Platform to Realize the Transformation to a Sustainable Society

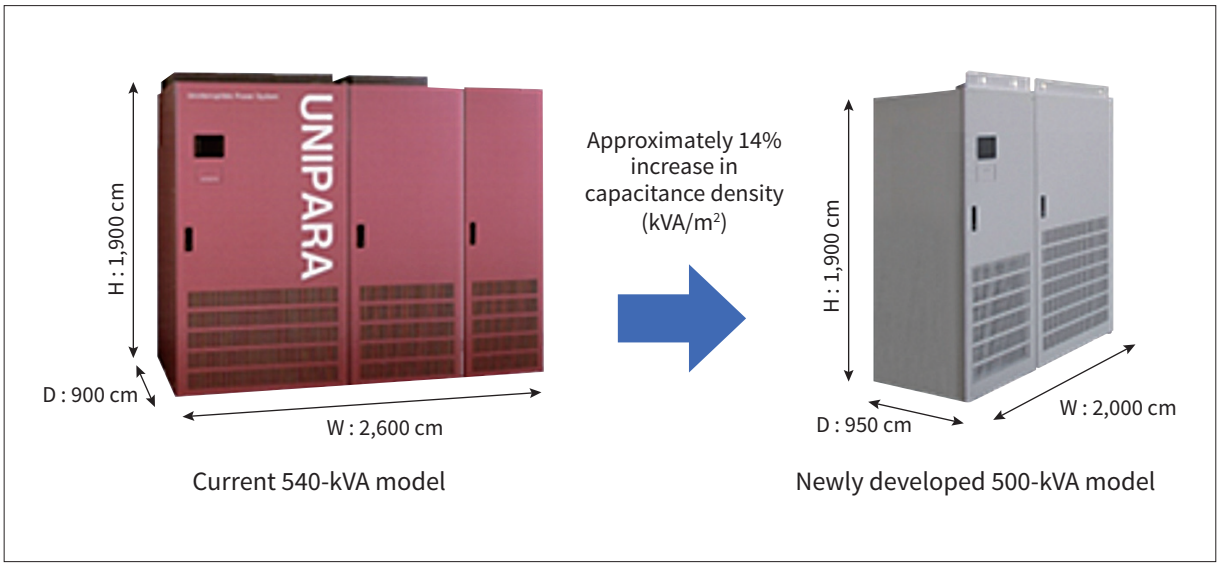
The transformation to a sustainable society, including support for decarbonization and resource recycling, requires cooperation and collaboration between stakeholders across industries. Accordingly, Hitachi conceived of a platform to connect these stakeholders and is working to realize it. This activity consists of three layers, a vision layer that forms an ecosystem and rules, a digital layer that distributes information and value, and a physical layer that provides physical equipment and solutions.

As one feature of the digital layer, the company developed a sustainable authentication application that visualizes resource recycling in supply chains and connects companies with certification bodies.

Companies register the resource transaction information and other environment-related information and apply for sustainable authentication of their business through this application. The reliability and anonymity of this information is guaranteed and delivered to the certification body. In addition to screening this information, the certification body registers the certification result in the application after performing an on-site and physical investigation as needed. A digital product passport (DPP) is issued, and the applicant is notified of the result.

Through this platform, companies can easily comply with the European Ecodesign for Sustainable Products Regulation (ESPR), which can be expected to promote the transformation to a sustainable society.

Industrial Products



1 Comparison of capacitance density between old and new UPS system series models

1 UPS System Series New 500-kVA Model

The uninterruptible power supply (UPS) system market is maturing, and almost all of the companies have achieved parity in terms of performance and features. Because 10 years have passed since the development of the product currently on the market, Hitachi developed a new 500-kVA UPS system with an emphasis on miniaturization, high density, and cost reduction.

The key features are as follows.

(1) Incorporates the peripheral equipment components inside the UPS system to achieve high density and cost reduction for the entire system.

(2) Successfully increases the capacitance density for a single UPS system by approximately 14% compared to the current 500-kVA model to achieve a compact size.

(3) Supports remote monitoring service.

(4) Minimized the copper bar through a thermo-fluid analysis of the board.

(5) Reduced the reactor that detects the direct current (DC) component included in the output voltage through control logic improvements.

(Hitachi Industrial Products, Ltd.)

2 Relocation of Zenigamecho Pumping Station Due to Tokyo Tokiwabashi Project

The Tokyo Metropolitan Government Bureau of Sewerage Zenigamecho Pumping Station was a deteriorating facility that had been in operation for about 50 years. Since the area where this pumping station is located was designated as a special urban renaissance district in 2016, the redevelopment project has been advanced as the Tokyo Tokiwabashi Project, and the project for the entire district is scheduled to be completed in FY2027. With the progress of the redevelopment project, the Zenigamecho Building (D Tower) was completed in March 2022, and the new relocation/shared use of the new pumping station started in April of the same year.

The features of this pumping station construction are as follows.

(1) In addition to being an underground station and a crowded commuter area in the northern part of Tokyo Station, it was a very difficult project due to the fact that the construction period coincided with the hosting of the Olympics. However, the construction was completed without any accidents or disasters, thanks to the meticulous daily process adjustments that were made with each of the relevant companies, such as the usage time for work cranes used to carry materials and equipment in and out.

2 Zenigamecho Pumping Station pump room

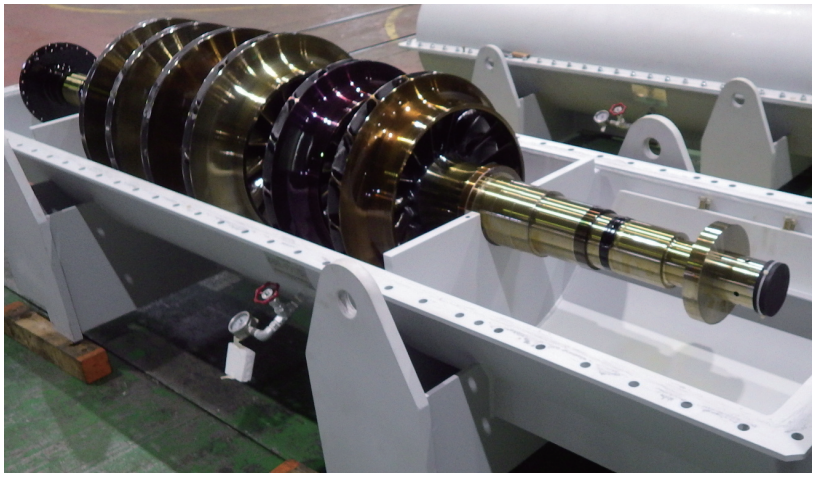
(2) To supply water over a long distance to a remote water reclamation center, a flywheel was installed as a water hammer countermeasure.
(3) Because the volume of wastewater flowing in fluctuates according to the time of day, two of the four pumps support rotational speed control with an inverter.
(Hitachi Industrial Products, Ltd.)

3 Performance Enhancement Case Study of Existing Centrifugal Compressor at an Ethylene Plant

Hitachi received and delivered an order from a major petrochemical company in Malaysia for a project to modify the spare rotor for an existing centrifugal compressor at an ethylene plant.

This project was implemented in response to a customer request to increase the flow rate of a propylene/ethylene compressor that had been in stable operation for about 30 years since Hitachi delivered it in 1992 with the goal of expanding the plant. The order for this project was received after proposing that the desired flow rate increase was feasible just by trimming the impeller flow channel of the spare rotor, which was ordered in advance without modifying or updating the existing equipment, and Hitachi was able to provide the solution to the customer with a short delivery time.

Hitachi considers the performance modification of the ethylene plant centrifugal compressor to be one solution that will directly lead to customer value creation, and will continue to promote this proposal going forward.
(Hitachi Industrial Products, Ltd.)



3 Spare rotor modified to increase flow rate by trimming impeller flow channel

4 IoT Support for Water Supply Pump Unit

Water supply pumps are used to supply and distribute water to buildings such as condominiums and factories, and cloud and communication features are increasingly being promoted in the market. Recently, Hitachi implemented Internet of Things (IoT) support for visualization of water supply pumps.

It enables monitoring of water supply pump operating conditions in real time, and the visualization of operational frequency, output current, and discharge pressure with trend graphs. In the unlikely event of an alarm or failure in the equipment, emails are automatically sent not only to the customer, but also to official distributors, vendors, and Hitachi Industrial Equipment Systems Co., Ltd. This makes it possible to contact the customer as needed and provides a reliable support system.

Moreover, the operating time, number of starts, maximum current value, and failure status can be checked as part of maintenance management. It has a feature that automatically notifies the user when the recommended maintenance period has been reached based on the operating time of each component. Displaying the current operation time with respect to the recommended time for parts replacement makes it easier to recognize when it is time for replacement and enables systematic maintenance. (Hitachi Industrial Equipment Systems Co., Ltd.)

4 Water supply pump unit with IoT support

5 Oil-flooded Rotary Screw Air Compressor G-Series 11/15 kW

With various measures being implemented to achieve carbon neutrality on a global scale due to the growing severity of climate change, Hitachi launched a new oil-flooded rotary screw air compressor G-Series 11/15 kW model positioned as a product that can contribute to the environment and society through energy conservation.

The key features of this model are as follows.

(1) In addition to developing an airend equipped with a new tooth profile, Hitachi has achieved a compact, high-performance compressor unit and a low-torque motor, combining high performance and environmental friendliness by reducing permanent magnet usage. As a result, the discharge air volume was increased by approximately 9.3% compared to existing models.

(2) Standard support for an IoT-based cloud monitoring service for air compressors, enables shorter downtime during use and improved operational efficiency.

(3) A peak cut-off feature, which can temporarily reduce power consumption, and a heat safety mode, which can supply air in a stable manner under high ambient temperatures, were added to improve usability.

(4) The brushless direct current (DCBL) controller, DCBL motor, fan motor, fan inverter, and communications equipment all use Hitachi products. The DCBL controller was designed to share parts with higher-output class controllers.

Going forward, the company will continue to expand the product series with other models.

(Hitachi Industrial Equipment Systems Co., Ltd.)

5 New oil-flooded rotary screw air compressor 11/15 kW air cooler

Healthcare & Analytical Systems

1 Contributing to Healthcare through a Medical Solution Services Platform

In clinical testing that supports healthcare, there is a need to improve the quality of test data and the efficiency of lab operations. Hitachi High-Tech Corporation has developed a medical solution services platform (SSP) to provide services aimed at optimizing clinical lab operations.

SSP collects the operation information of clinical labs in the cloud server to provide valuable services for stakeholders related to clinical labs. First, Hitachi will start a service to help streamline clinical lab operations and equipment maintenance. Each stakeholder can utilize applications developed through co-creation with customers to resolve problems in clinical lab operations and equipment maintenance.

In the future, Hitachi will contribute to improving the quality of healthcare and reducing medical costs by achieving higher quality and efficiency in clinical testing such as quality assurance for test data and the predictive diagnosis of equipment failures, etc.

(Hitachi High-Tech Corporation)

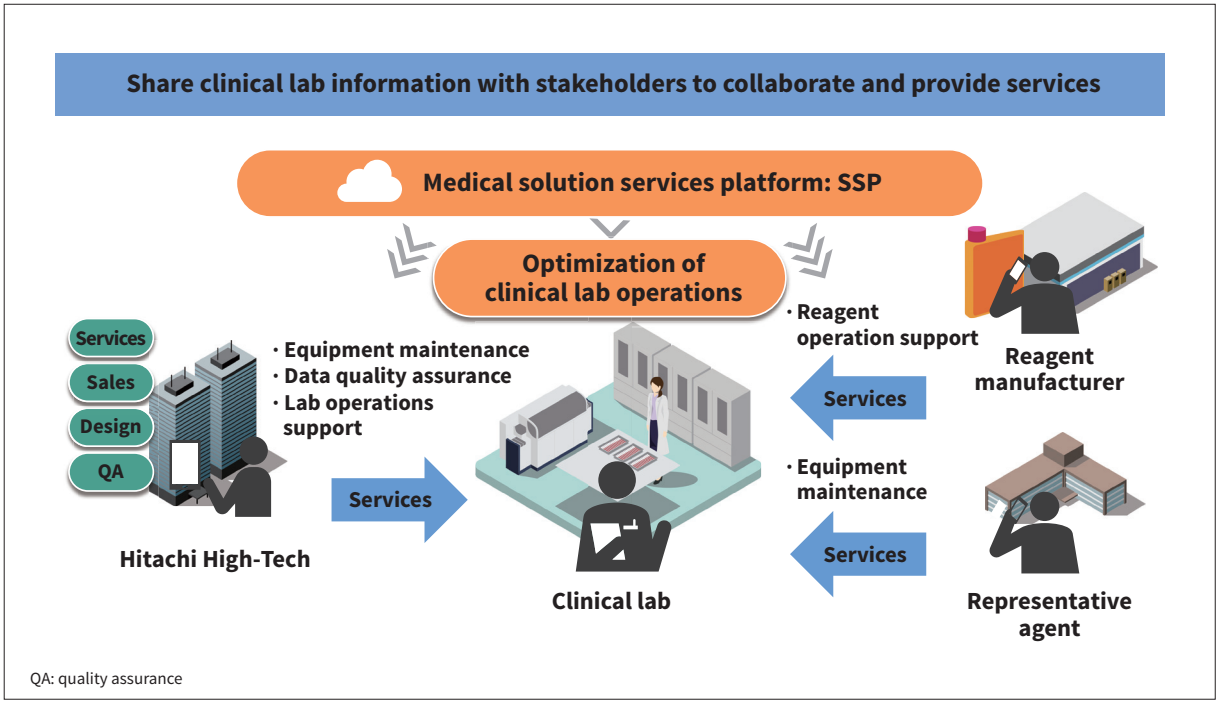
2 Medium-sized Capillary DNA Sequencer Successor Model SeqStudio Flex

Capillary electrophoresis deoxyribonucleic acid (DNA) sequencers analyze the base sequences in DNA and the length of DNA fragments, the blueprint of life. Such sequencers have come to be used by a variety of users not only for research purposes, but also for personal identification in criminal investigations, the medical and health fields, and other application markets, and there is a growing need for new applications.

To respond to this, Hitachi High-Tech has commercialized SeqStudio* Flex in collaboration with the US company, Thermo Fisher Scientific Inc. While maintaining the analysis performance of the previous 3500 Genetic Analyzer model, this product possesses the following four features as a more user-friendly instrument.

(1) Priority support for urgent samples

Supports feeding of urgent samples even during measurement, allowing users to feed in samples whenever they want, at any time.



1 Medical solution services platform concept

2 SeqStudio Flex 24-ch medium-sized capillary DNA sequencer main unit (left), capillary array (24 channels) (upper right), and capillary array (8 channels) (lower right)

(2) Increased number of installed samples

The new model can accommodate twice the number of samples as before (maximum of 1,536 samples).

(3) Easy operation

The improved capillary array, a consumable that requires careful handling, can be replaced easily and safely.

(4) Space-saving

Incorporates a touch panel to integrate the operation PC with the instrument. The install footprint is approximately half that of the previous model.

With this sequencer, the company aims to expand its business by promoting the replacement of previous models while also attracting new customers in application markets.

(Hitachi High-Tech Corporation)

*See "Trademarks" on page 158.

3 Lumione BL3000 Rapid Microbial Testing System

The Lumione BL3000 rapid microbial testing system from Hitachi High-Tech Science Corporation can detect microbes in a short period of time without cultivation using a bioluminescent technique based on firefly luminescence as its detection principle. For example, while the testing of water used in the manufacture of pharmaceutical products can take 3 to 14 days with conventional cultivation methods, the Lumione BL3000 can detect microbes in one hour, and it is expected to be widely used in industries that require microbial control such as pharmaceuticals, beverages, foodstuffs, and hygiene materials, etc.

With the goal of further market expansion, the Lumione BL3000 offers higher throughput and a more compact size as well as superior cost performance that is roughly half that of the previous model. The key features are as follows.

(1) By shortening the luminescent measurement time per sample, it realizes a throughput of 24 samples per hour (double the throughput of the previous model).

(2) The dynamic range was expanded to 0 to 500,000 amol to support high-concentration samples (a two-digit increase compared to the previous model).

(3) Capable of measuring various sample solutions by retaining 10 types of calibration curves (10 times that of the previous model).

(4) Improved the calibration precision through the optimal concentration range with multipoint calibration curves (12 times the concentration number of the previous model). Going forward, the company aims to expand into regenerative medicine and other new fields where future growth is expected.

(Hitachi High-Tech Science Corporation)

3 Lumione BL3000 rapid microbial testing system

4 UH5200/UH5210 Spectrophotometers

Spectrophotometers are used in research and development and testing in a wide range of fields from optical components and construction materials to chemistry, pharmaceuticals, foodstuffs, and the environment. Hitachi productized the UH5200 spectrophotometer as an instrument which is easy even for beginners to understand and use to provide a smooth measurement environment for applications for which optical characteristics are measured in the ultraviolet-visible (UV-VIS) range.

This product is equipped with a measurement condition shortcut feature and a sample name barcode reader input feature. In addition, it incorporates new design graphics with superior visibility to realize a comfortable operating environment. Moreover, it supports many accessories[*1] such as an autosampler, autosipper, and micro-cells, which can be applied to measurement automation and a wide range of applications. The key features are as follows.

(1) A standalone model (UH5200) and a PC-controlled model (UH5210) are provided according to the intended application.

(2) Incorporates a 10.4 inch large-sized/high-resolution liquid crystal display not found on competing products.

(3) Supports commercially-available thermal paper printer and USB printers[*2].

(Hitachi High-Tech Science Corporation)

*1 Product sold separately

*2 Supported models are limited.

UH5200

UH5210

4 UH5200/UH5210 spectrophotometers

5 FT230 high-volume X-ray fluorescence coatings and materials analyzer

5 Smarter X-ray Fluorescence for Coating Thickness and Composition Measurement

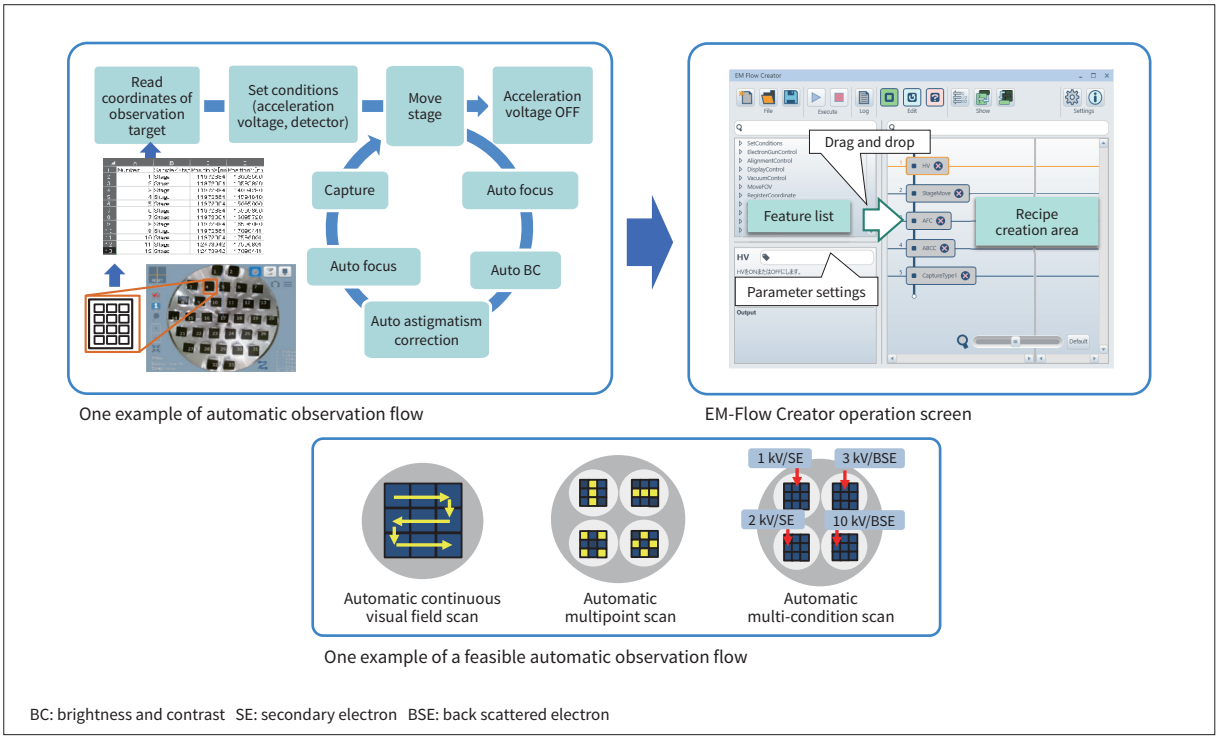
Coatings analysis with X-ray fluorescence (XRF) is a long-established practice for verifying the thickness and composition of coatings applied to critical electronic and mechanical components. This testing is essential for ensuring the components reliably perform as specified as well as for cost and resource control in production, as frequent testing can quickly identify defects and help reduce excessive use of common expensive coating materials such as gold or platinum.

There is growing demand in the automotive, aerospace, medical, communications, and other industries to perform 100% inspection at the component level, which adds more load on XRF analyzers and operators in production control and quality control. With XRF coatings analysis, the measurement step that takes the longest is typically not the analysis, but sample presentation—locating areas to be measured, aligning (focusing) the part, and selecting analytical parameters. Hitachi High-Tech Analytical Science Ltd. has combined advanced features including an operational support function and new machine vision technology called Find My Part to simplify measurement setup and significantly reduce the amount of time spent by operators making decisions. This enables the production facility to test many more parts in less time, avoid mistakes, reduce scrap, and reduce energy and material consumption.

(Hitachi High-Tech Analytical Science Ltd.)

6 EM Flow Creator SEM Automatic Data Acquisition Support Feature

With advances in information processing technologies, data-driven research and development, which requires



6 Overview of EM Flow Creator

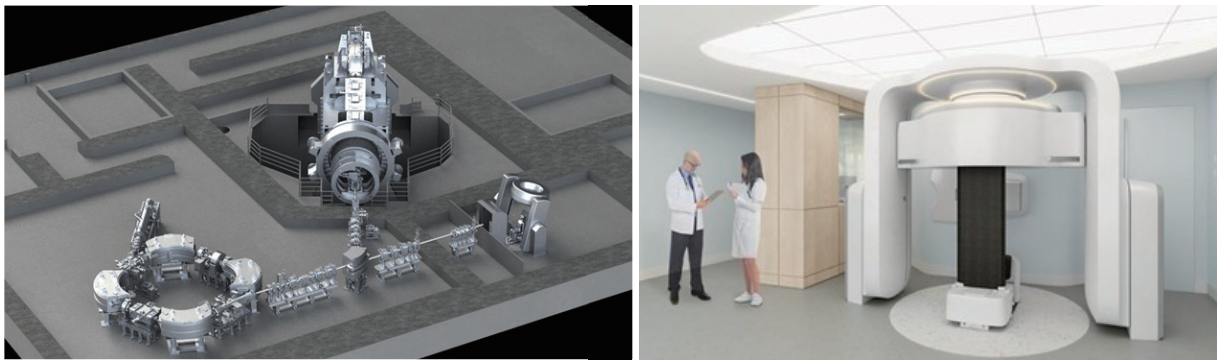
the acquisition of large amounts of data, is being promoted in various fields such as semiconductors, materials, and life sciences. In the field emission-scanning electron microscopes (FE-SEM) that are widely utilized for the purpose of observing and analyzing the microstructure of samples as well, there is a need to acquire large amounts of data in a short period of time and to reduce the operational burden on the user.

The recently developed EM Flow Creator is software for creating and executing scanning electron microscope (SEM) observation recipes that incorporates visual programming technologies. For SEM observation recipes, a series of automatic observation recipes can be easily created by selecting the necessary features from a feature list, arranging them by dragging and dropping them into the recipe creation area, and setting the SEM parameters.

The easy-to-operate user interface enables the rapid creation of diverse observation flows and enables the acquisition of a large volume of data with stable and continuous operation. This software is expected to reduce the operational burden on users and promote further data acquisition and analysis. EM Flow Creator can be installed on two FE-SEM models, SU8600 and SU8700. (Hitachi High-Tech Corporation)

7 Development of Advanced Proton Beam Therapy System

In addition to proton beams, the utilization of carbon ion beams is advancing in particle therapy systems, and diverse needs are emerging. Thus far, Hitachi has globally



7 Image of the proton beam therapy system (left figure) equipped with a rotating gantry (center) and the UPPS (right) and the UPPS from Leo Cancer Care (right figure)

deployed an extensive range of proton beam and carbon ion beam therapy system solutions.

The company is developing an advanced proton beam therapy system that combines Hitachi's proton beam therapy system with an upright patient positioning system (UPPS) from UK company, Leo Cancer Care Ltd. In existing particle therapy, patients are typically required to lie down on the patient couch. However, enabling treatment in an upright orientation on a patient positioning chair, which is a more natural way, can be expected to improve the workflow and reduce the treatment time while also alleviating the burden on the patient. Moreover, because the system uses a smaller installation footprint for the therapeutic device than that of the facilities with multiple rotating gantry treatment rooms, it reduces the building volume while also leading to a reduction in implementation costs.

Automotive Systems

Automotive Systems

1 360° Stereo Vision

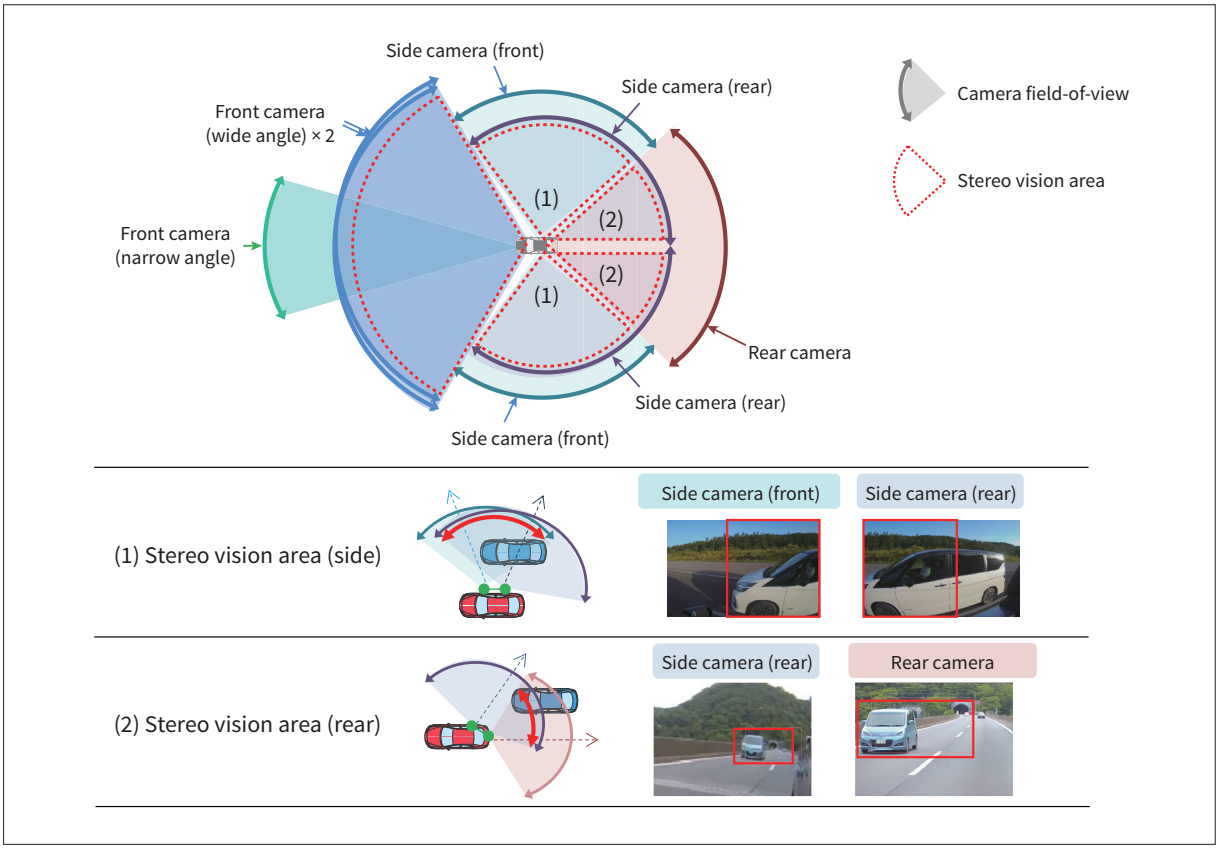
To realize autonomous driving on city roads, Hitachi Astemo developed a 360° stereo vision prototype with multiple cameras that can sense the entire area around a vehicle in three dimensions (3D).

Conventional stereo vision uses an integrated structure composed of two cameras in parallel with the same field-of-view. The newly developed stereo vision technology combines different field-of-view and non-parallel monocular camera pairs. It uses multiple cameras placed around the vehicle to enable 3D sensing along the entire periphery. Allowing for freedom in camera placement makes it possible to use existing cameras, which keeps system costs down and realizes stereo vision with high precision and high-resolution 3D sensing. The goal is to realize autonomous driving on city roads by accurately measuring the distance to objects such as a vehicle traveling side-by-side in the lane adjacent to the vehicle, a two-wheeled vehicle pulling out of a line of cars to the rear during a traffic jam, and pedestrians or bicycles when turning right or left at an intersection, and applying it to applications for avoiding a collision, for example.

(Hitachi Astemo, Ltd.)

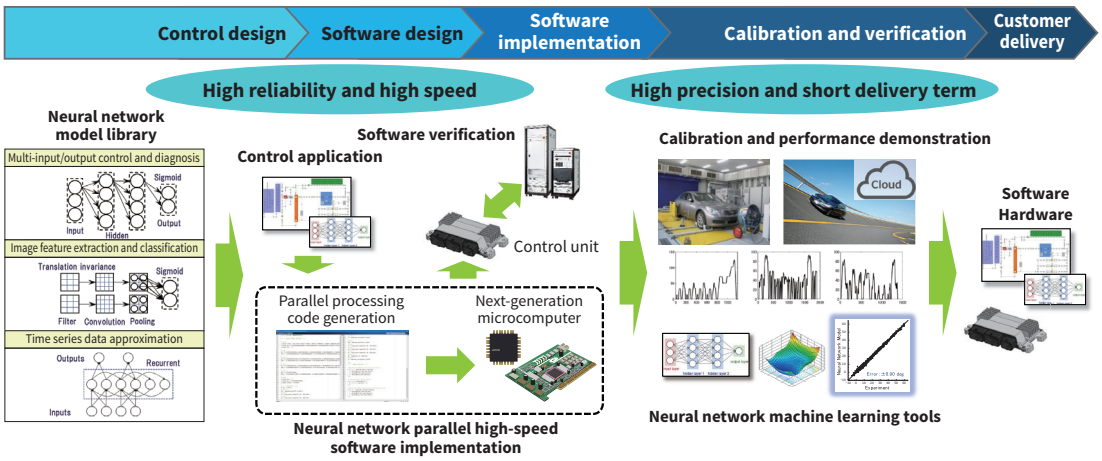
2 Neural Network Control Technology for Automobile Powertrain Systems

With the strengthening of environmental regulations on automobiles, powertrain control systems are becoming more complex, and the calibration (control parameter tuning) workload is increasing in size. Although model-based methods and automation of experimental measurements are advancing toward calibration efficiency, it is effective to adopt control algorithms with few calibration



1 360° stereo vision

Automotive Systems



2 Neural network control implementation technology realizing calibration efficiency and high-speed arithmetic operations

elements in the control software itself or that can be automated for calibration.

Therefore, Hitachi developed a powertrain control and software implementation technology that utilizes a neural network (NN), which is one type of mathematical model. This technology is composed of various NN control libraries and learning tools according to the target such as steady state, transient, and multi-inputs and outputs, etc. Using experimental data acquired under various conditions such as acceleration and deceleration as supervised data, the NN parameters are optimized through machine learning. Utilizing the parallel processing features of next-generation microcomputers, high-speed arithmetic operation is realized through implementation software optimized according to the NN structure.

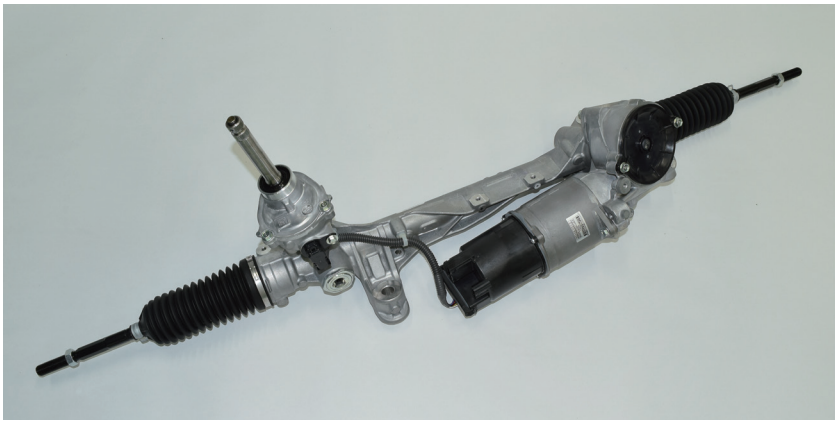
Going forward, the company will utilize this technology to apply NN control applications to the reduction of engine exhaust gas and the thermal management of electric powertrains.

(Hitachi Astemo, Ltd.)

3 Development of Bioplastic Material Applied to Resin Gear of Deceleration Mechanism for Electric Power Steering

Hitachi has developed a resin gear that uses bioplastic aimed at achieving carbon neutrality throughout the entire value chain, and it was incorporated into the worm wheel for dual-pinion electric power steering for the first time in the world*.

By adopting the biomass material polyamide 410, which comes from plant-derived raw materials, in place of the conventional polyamide 66 material, which is based on raw materials derived from 100% fossil fuels, the company reduced the carbon footprint [greenhouse gas emissions emitted throughout the entire lifecycle converted to carbon dioxide (CO_2)] by 71% and the CO_2 per kilogram of resin by 4.6 kg. Moreover it satisfies the durability, oil resistance, and other component requirement characteristics and increases the resin gear strength by 30% with a product design that applies the high toughness characteristics of this material. As a result, Hitachi achieved a



3 Dual-pinion electric power steering

size and weight reduction of the deceleration mechanism including the worm wheel.

Going forward, the company will contribute to the realization of a carbon-neutral society in 2050 by providing a variety of sustainable products.
(Hitachi Astemo, Ltd.)

* According to a survey by Hitachi Astemo, Ltd.

4 Compact, High Output Inverter with Direct Water-cooled Double-sided Cooling Power Module for EVs/PHEVs

The miniaturization and weight reduction of drive systems continues to be pursued in the rapidly advancing electrification of automobiles aimed at decarbonization. Under such circumstances, in order to reduce the thermal resistance of power modules (PMs) which integrate power semiconductor elements that generate a lot of heat, Hitachi eliminated heat-dissipating grease and developed a double-sided direct cooling PM for electric vehicles (EVs) and plug-in hybrid EVs (PHEVs) with a structure that cools both sides of the semiconductor instead of just one side, and commercialized the third-generation inverter in 2013.

In addition to reducing the size by 15% and adding 400 V support to the fourth-generation PMs, 800 V support PMs were added to the lineup, and an 800-V fourth-generation inverter was commercialized in 2019. For the 800-V fourth-generation inverter, PM parallel drive technology was developed, the insulation design was revised, and the components were adapted for higher voltages to achieve a smaller size and a higher output with a power density of 94 kVA/L (maximum rated/capacity) that is 2.7 times greater than conventional products.

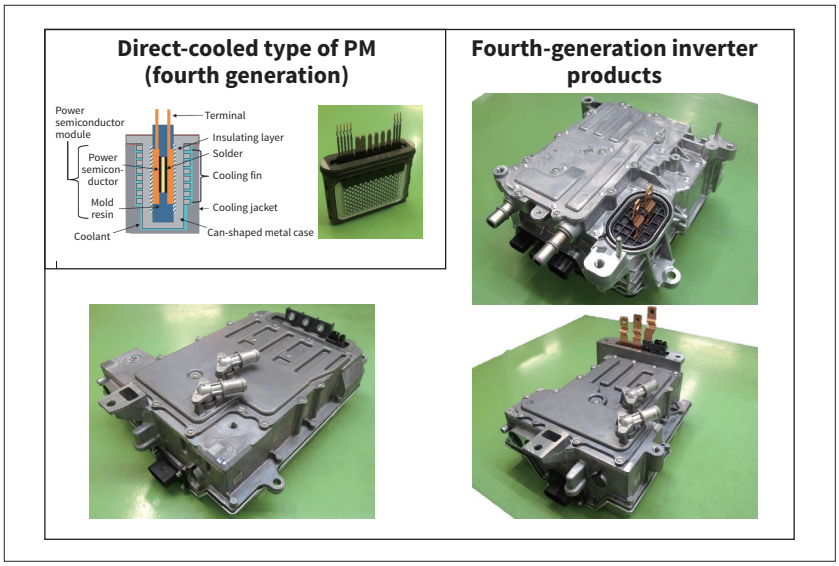
These inverters have been well received and were awarded the 68th Okochi Memorial Prize in FY2022. Going forward, Hitachi will contribute to the evolution of EVs and the realization of a carbon-neutral society.
(Hitachi Astemo, Ltd.)

5 High-performance Dual-pinion Assist EPS Utilizing High-precision MBD Technology

As a supplier of electric power steering (EPS), Hitachi has improved development efficiency by improving the precision of initial design studies. In addition, it has completed high-precision model-based development (MBD) technology with the goal of contributing to the realization of efficient customer vehicle development. The features of this technology are as follows.
(1) Achieves computer-aided engineering (CAE) analysis on a full EPS system with a one-dimensional (1D) control model + 3D mechanical component model

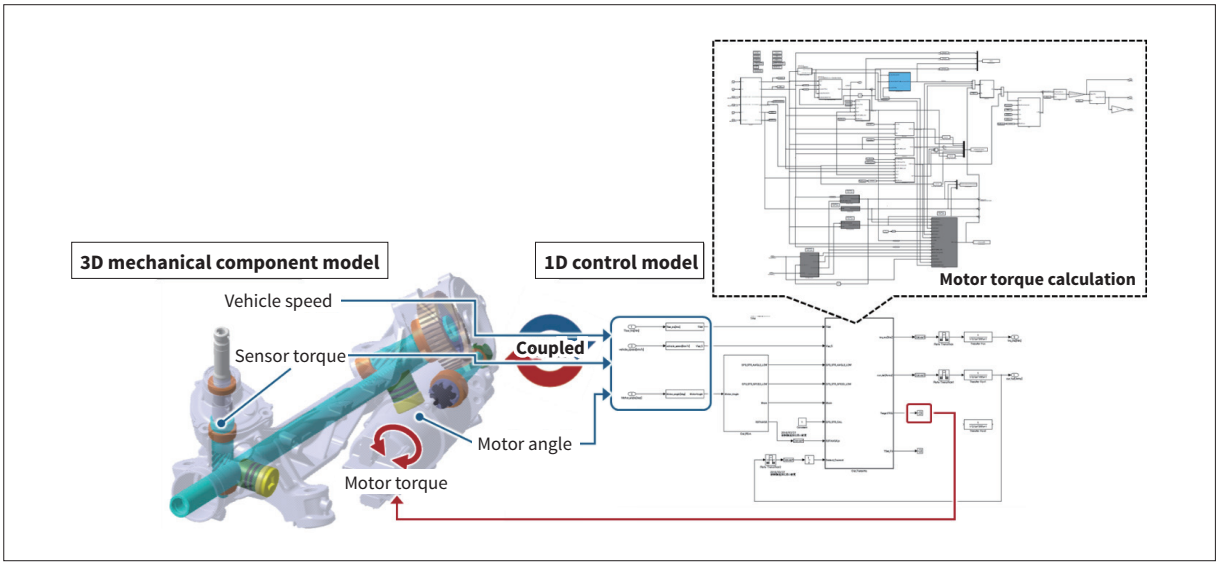
An environment that enables optimal design without performing actual sample verification, making it possible to verify system performance evaluations and abnormal noise evaluations with CAE.
(2) Realizes auto-tuning through a 1D control model + 1D mechanical component model and automatic optimal parameter tuning logic construction

By automating the current control map setting process, which determines the steering feel, Hitachi has reduced the work time by approximately 80% and, together with improved accuracy of initial map settings, has significantly



4 Fourth-generation inverter

Automotive Systems



5 Electric power steering mechanical component model + control model

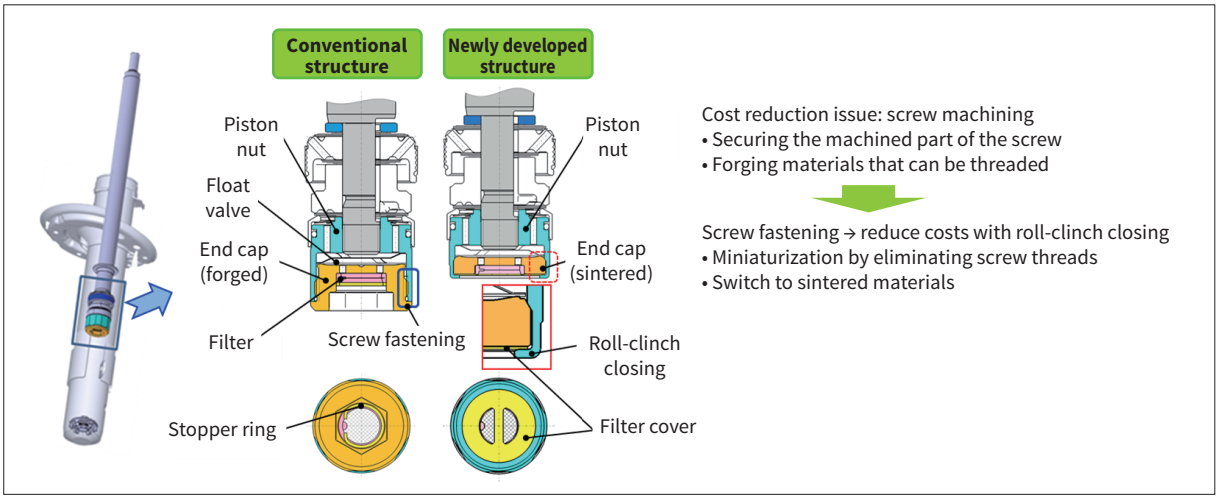
shortened the delivery time. The company started gradually applying these technologies to EPS products being mass-produced from 2021.

Going forward, Hitachi will steadily expand the applicable areas of CAE to shorten the prototype evaluation period and contribute to the effective utilization of resources. (Hitachi Astemo, Ltd.)

6 Sensitive Frequency Response Damper (Generation 2.5)

The sensitive frequency response damper (SFRD) improves ride comfort without sacrificing handling stability by changing the oil flow channel according to road conditions and mechanically adjusting the damping force. In recent years, the rapid expansion of electrification and automation in vehicles has increased the demand for ride comfort and quietness, while cost reductions are being sought for existing products, including suspension products, as vehicle development costs increase in the automotive industry. Amid such circumstances, Hitachi developed a high value-added product featuring excellent cost competitiveness and performance with a mechanical variable damping force piston structure that is positioned between semi-active and conventional control.

In this development, the company changed the fixing method of components from the conventional screw fastening to roll-clinch closing, eliminating screw machining, and changed the component material to achieve a more compact size and lighter weight in addition to significant cost reduction. Moreover, the product maintains the same level of performance as the current product without loss, resulting in a highly competitive, high-value-added product that achieves both performance and cost at a high level. (Hitachi Astemo, Ltd.)



6 SFRD (Generation 2.5)

7 Kawasaki Ninja ZX-25R

7 Electronically Controlled Throttle Body for 250-cc Parallel Four-cylinder Engines

Electronically controlled throttle bodies (drive-by-wire), which separate the accelerator from the throttle controlling the engine output and increase the degree of control freedom are becoming more prevalent.

Under such circumstances, Hitachi started mass production of the world's first* electronically controlled throttle body for 250-cc parallel four-cylinder engines.

It has been adopted for use in the Kawasaki Ninja ZX-25R super sports model where it helps improve riding enjoyment by making it possible to switch the throttle control mode.

Target vehicles are equipped with a mechanism that mechanically maintains the throttle at a constant opening even when the throttle drive motor of the electronically controlled throttle body experiences an electrical fault, which enables the vehicle to limp home at a constant speed even during a breakdown. It adopts a structure that places the drive motor and opening retention mechanism in the center of the throttle body to consolidate the features of the opening retention mechanism composed of multiple components, achieving a more compact layout through a reduction in the number of components.

The downsizing of the entire throttle body contributes to a slimmer frame.

(Hitachi Astemo, Ltd.)

*According to a survey by Hitachi Astemo, Ltd.

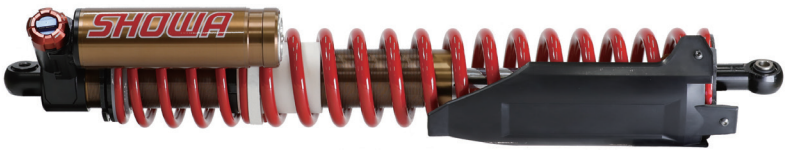
8 Development and Mass Production of Suspension for Side-by-Side Vehicles

Hitachi has developed a side-by-side vehicle (multi-purpose offroad vehicle) suspension and started production in the USA.

The market for this category is expanding in North America for outdoor leisure use due to the impact of COVID-19, and original equipment manufacturers (OEMs) have begun full-scale entry into the market, with all of them announcing new models in recent years.

In response, Hitachi has applied its motocross suspension technology, which is specialized for off-road driving with features such as anti-dust performance, and has optimized the piston size. Moreover, the company has achieved a balance between road handling, toughness, and durability in a wide range of driving zones from race use to leisure use by applying a position-dependent mechanism for greater wear and dust resistance with the goal of improved bottom toughness. As a result, Hitachi has won orders for many models that have been well-received by customers.

(Hitachi Astemo, Ltd.)



8 Rear cushion for side-by-side vehicles

Research & Development

Innovation for Advancing with Customers: Digital Systems & Services

Innovation for Advancing with Customers: Green Energy & Mobility

Innovation for Advancing with Customers: Connective Industries

Innovation for Addressing Future Challenges

Research & Development Group

As we work to realize a sustainable society, there are growing expectations for the value that new digital technologies such as Web 3.0 and metaverse can provide in a world transitioning towards carbon neutrality and a circular economy, and value chains are being reconfigured in response to the pandemics and geopolitical risks. It is against this background that Hitachi has embarked upon its Mid-term Management Plan 2024 in which “Green, Digital, and Innovation” feature as key elements in the ongoing evolution of its Social Innovation Business to realize a sustainable society and support people’s well-being with data and technology.

The Research & Development Group is focusing its efforts on the creation of new value through GX and DX to support the continuing growth of Hitachi’s customers’ businesses, and on innovation to resolve future societal challenges. These efforts have evolved from establishing collaborative creation (co-creation) centers at sites in each region under the Mid-term Management Plan 2018 to other initiatives such as expanding co-creation activities leveraging the Kyōsō-no-Mori facility set up the Kokubunji site, in Tokyo to promote innovation and the establishment of the Corporate Venturing Office to invest in and work with startups for new business models, under the Mid-term Management Plan 2021. Such efforts are now being further accelerated under the Mid-term Management Plan 2024, which came into force from FY2022, with steps being taken to develop Lumada-based digital service businesses and to strengthen radical innovation to resolve societal challenges.

The creation of digital service businesses starts with an understanding of the challenges faced by customers, and through “IT, OT, and products” the Hitachi Group works as “One Hitachi” to create new value for customers. To realize this, Hitachi is accelerating innovation through dialogue with customers to gain a deeper appreciation of the challenges they will face in the future and by working with them to deliver value through data-driven co-creation. The section on “Innovation for Advancing with Customers” describes how Hitachi is working toward this goal in different areas.

For radical innovation to resolve societal challenges, Hitachi is backcasting from the anticipated challenges facing customers and wider society in 2050 to identify what needs to be done today. In addition to driving innovation to deliver breakthroughs, Hitachi is working with various stakeholders through ecosystems aiming to overcome the current challenges. The section on “Innovation for Addressing Future Challenges” describes the progress of this research and development work as well as the activities of laboratories that Hitachi has set up in partnership with universities and other research institutions.

By pursuing such initiatives, Hitachi is investing in leading-edge technologies and creating innovations leading to the future. Reports from the front line of research and development are accompanied by coverage of technologies and solutions intended to resolve societal challenges and deliver value to customers.

Innovation for Advancing with Customers

The Research & Development Group works to deliver innovation on the basis of the Lumada growth cycle for growing in partnership with customers, leveraging GX and DX to resolve the challenges facing customers and wider society. The NEXPERIENCE methodology for co-creation with customers deploys digital technology in work with customers to identify new ways in which they can grow, going on to deliver the innovations needed to put these ideas into practice. As well as classifying ideas based on the characteristics of their business segments and the operations they entail, the Lumada growth cycle also involves the use of co-creation for implementation and scaling.

Activities in the Digital Systems & Services sector include improvements to the transparency of environmental management through the digital transformation of customer operations and social infrastructure. Along with the reform of infrastructure management and security enhancement, this also encompasses measures for automating and optimizing business processes while reducing workforce requirements. The subsequent section on the Green Energy & Mobility and Automotive sectors includes reports on the smoothing of energy supply and demand to help achieve carbon neutrality by enabling greater use of renewable energy, innovation and operational efficiency improvements for rolling stock, and technology for highly efficient EV charging infrastructure. The final section covers the Connective Industries sector and presents ways of optimizing and improving the efficiency of manufacturing plants, innovation in the development of medical products, solutions for smart cities and home appliances, innovative products, and work on a materials platform.

Digital Systems & Services >>> Page 105
Green Energy & Mobility >>> Page 122
Connective Industries >>> Page 131

Innovation for Addressing Future Challenges >>> Page 143

In the process of formulating the Mid-term Management Plan 2024, the Research & Development Group talked to international institutions, universities, customers, and startups to help identify the societal challenges of the future. Looking ahead to the society of 2050, these consultations were then used as a basis for drawing up a map of areas that combine a high technological impact with a high weighting among customers and wider society. Reviewing this map, the society of 2050 was defined as one that is environmentally-neutral, supports an active 100-year lifespan for its citizens, and features the co-evolution of digital technologies, people, and society. Innovations were then identified that will help to realize this society.

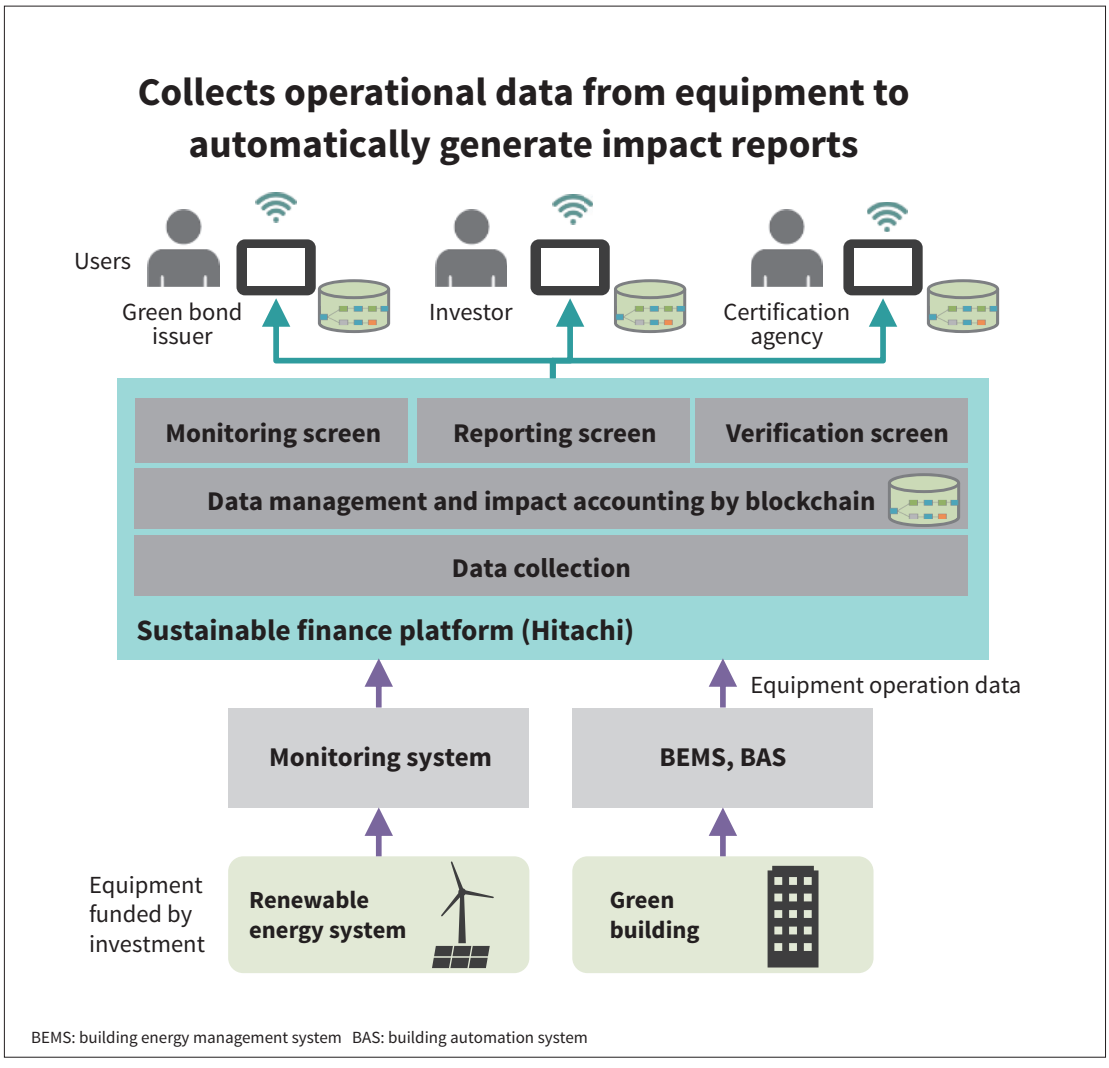
For example, direct air capture and energy storage and supply were identified as helping to achieve an environmentally-neutral society. Similarly, minimally invasive cancer therapies and cell design were seen as ways of overcoming cancer and other difficult-to-treat conditions, important requirements for a society that supports an active 100-year lifespan for its citizens. Similarly, research and development work at Hitachi targeting the co-evolution of digital technologies, people, and society includes the establishment of open innovation ecosystems with universities and startups, one example being in the field of silicon quantum computing aimed at boosting the data economy and computing innovation. Through this research, Hitachi is taking up the challenge of radical innovation as it seeks to resolve the societal challenges of the future by backcasting from 2050. This section presents important examples of this work.

1 Sustainable Finance Platform

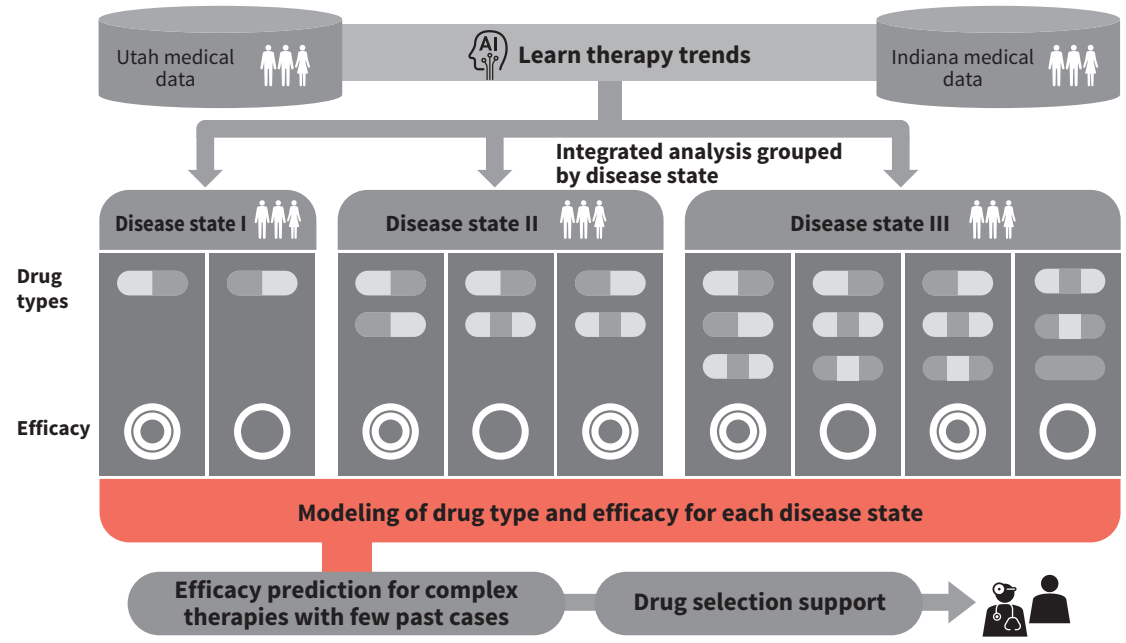
The sustainable finance market has expanded over recent years in an effort to address societal challenges such as climate change. However, reporting on the environmental and social impacts of their projects imposes a considerable workload on the companies that issue securities. Investors, for their part, are calling for impact indicators to have a high degree of transparency to facilitate accurate comparisons between potential investments.

The sustainable finance platform extracts data from the green design of investments and uses blockchain technology to calculate a variety of impacts in a way that cannot be forged. The platform was chosen for Japan's first Digitally Tracked Green Bond issued by Japan Exchange Group, Inc. in June 2022 and is currently being trialed as a means both of improving the efficiency of impact reporting and of providing investors with a transparent way to assess impacts whenever they need.

In the future, Hitachi intends to help resolve the challenges of the sustainable finance market by expanding the functionality of the platform, including broadening the types of equipment covered and adding support for third-party verification.



1 Sustainable finance platform



2 Efficacy prediction model with integrated analysis of medical data from two different regions grouped by patient condition

2 Drug Selection Support AI for Diabetes Patients Requiring Combination Therapy

Diabetes is a chronic condition that manifests in about one of every 10 people worldwide. While the control of blood sugar level is vital to slowing the progression of the disease, combination therapy involving two or more drugs has only been used in a limited number of cases and it is difficult for anyone other than an experienced specialist to select an appropriate mix of drugs.

In response, Hitachi has partnered with the University of Utah Health and the Regenstrief Institute, Inc. to develop a technique that supports drug selection for type 2 diabetes patients requiring combination therapy based on medical data.

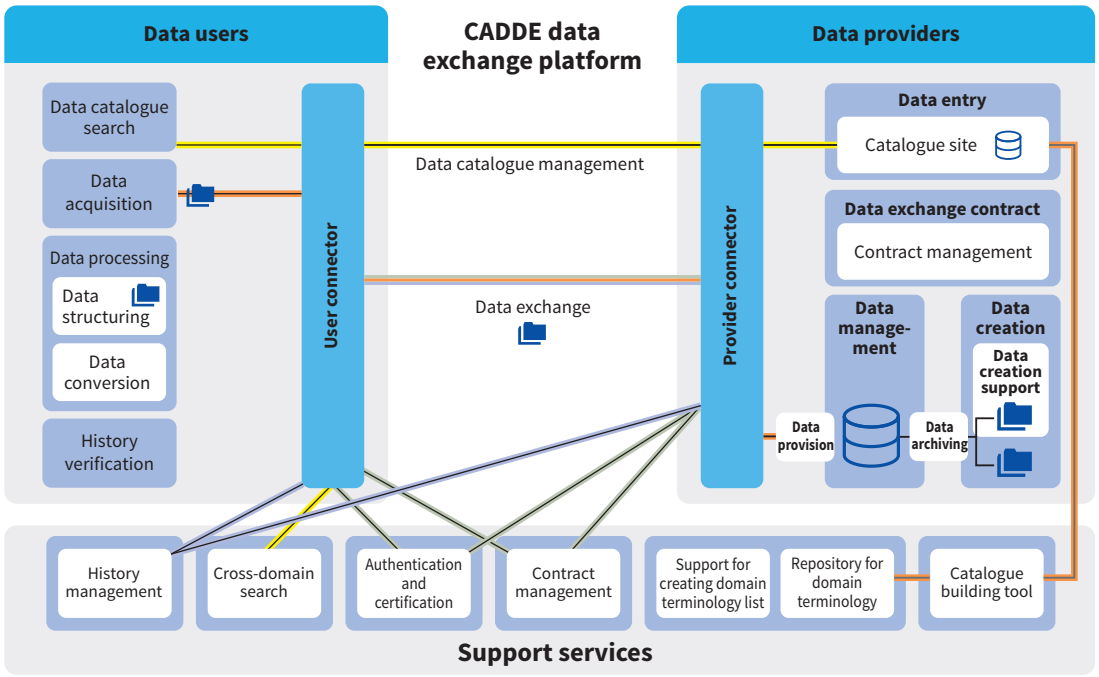
The technique works by modeling the relationship between drugs and their efficacy for groups of patients with similar disease states. It takes data from a number of different locations and facilities covering a wide range of patient characteristics and drug choices and then integrates it on the basis of disease state. By doing so, it is able to assist approximately 83% of patients by providing efficacy predictions, even for combination therapies that have only been used in a small number of cases. The value of the technique for optimizing the treatment of diabetes is currently being assessed at two hospital groups in Utah and Indiana.

In the future, Hitachi intends to utilize the technique to continue creating healthcare services that improve patient quality of life (QoL).

3 Cross-domain Data Exchange Platform: CADDE

Anticipating that the transition to Society 5.0 will involve the creation of new businesses that utilize a variety of different data, domain-specific data platforms have been established in fields like civil defense and transportation. However, little progress has been made in the use of data across different fields.

Through an eight-company partnership, Hitachi has been involved in the development of the platform for cross-domain interoperability of data Connector Architecture for Decentralized Data Exchange (CADDE*), and has released it as open source software (OSS). The platform works by means of software modules called connectors that perform the various operations, including data discovery, contracting, exchange, and history tracking. These modules interconnect with external services that support tasks such as data search, authentication and certification, and history tracking. The plan for the future is for the platform to be further developed as part of DATA-EX, a scheme for creating a nationwide data space in Japan.



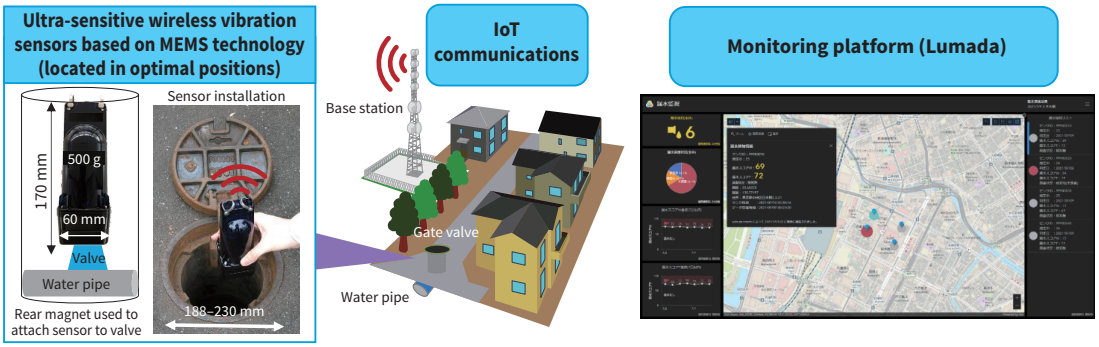
3 Block diagram of CADDE cross-domain data exchange platform

This work was supported by the Council for Science, Technology and Innovation, "Cross-ministerial Strategic Innovation Promotion Program (SIP), Big-data and AI-enabled Cyberspace Technologies." (funding agency: NEDO)

* See "Trademarks" on page 158.

4 Water Leakage Detection Service for Innovation in Social Infrastructure Maintenance

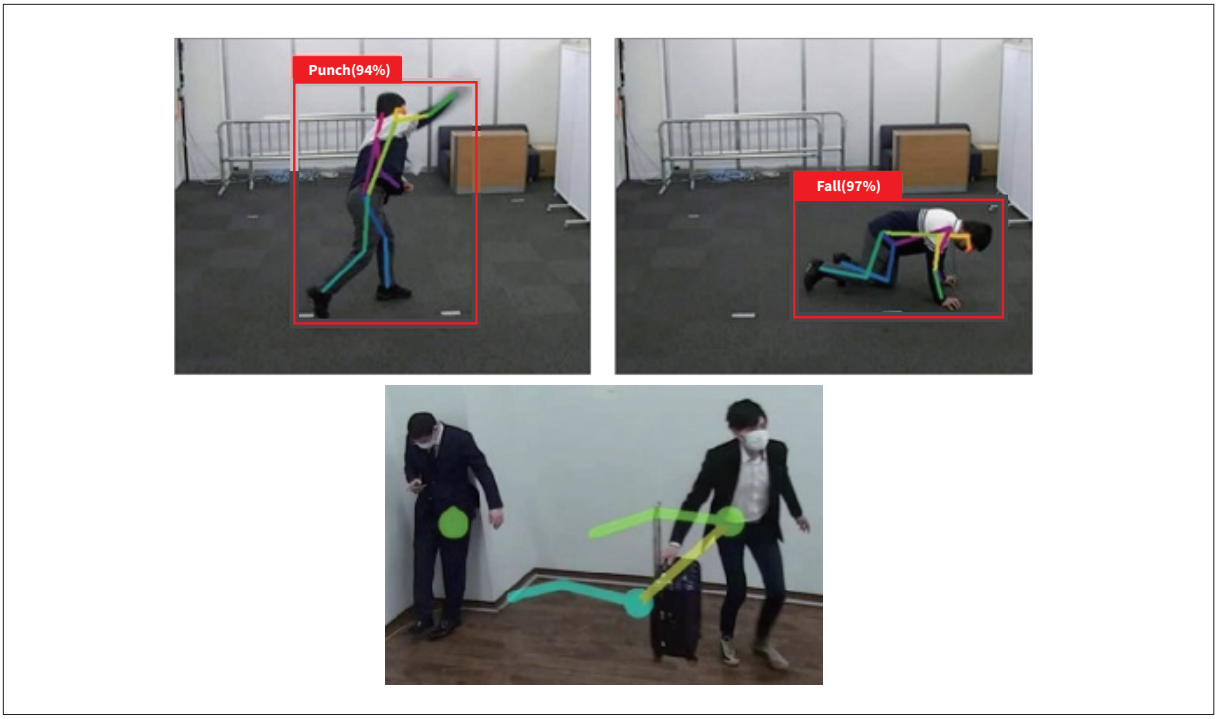
While social infrastructure built during the era of rapid economic growth is increasingly showing its age, societies around the world are having to deal with a falling off in the quality of social infrastructure maintenance due to an aging and shrinking maintenance workforce. This is also



Parameter	Conventional leak inspection	Water leakage detection system
Inspection frequency	Once every three to five years	Continuous monitoring for water leaks by permanent sensor and IoT communication link
Detection accuracy	10–40%	80–90%

IoT: Internet of Things

4 Overview of water leakage detection service



5 Performance of new image recognition algorithms added to MVS 1.4

true for water pipes, where regular manual inspection is a feature of maintenance work. As delays in the identification of leaks can lead to sink holes and other similar incidents, the sooner such leaks can be detected, the better.

Hitachi has commercialized a water leakage detection service that can remotely assess leakage in pipes using ultra-sensitive wireless vibration sensors with a seven-year battery life that were developed by Hitachi using micro-electro-mechanical system (MEMS) technology. The sensors incorporate a detection algorithm developed using more than 400,000 water leak data points. Even minor underground leaks can be detected and notification passed on to the cloud. The service achieves early detection of leaks by providing continuous monitoring over a wide area. The service officially commenced operation in FY2021 and has been adopted by a growing number of utilities, including the Kumamoto City Waterworks and Sewerage Bureau.

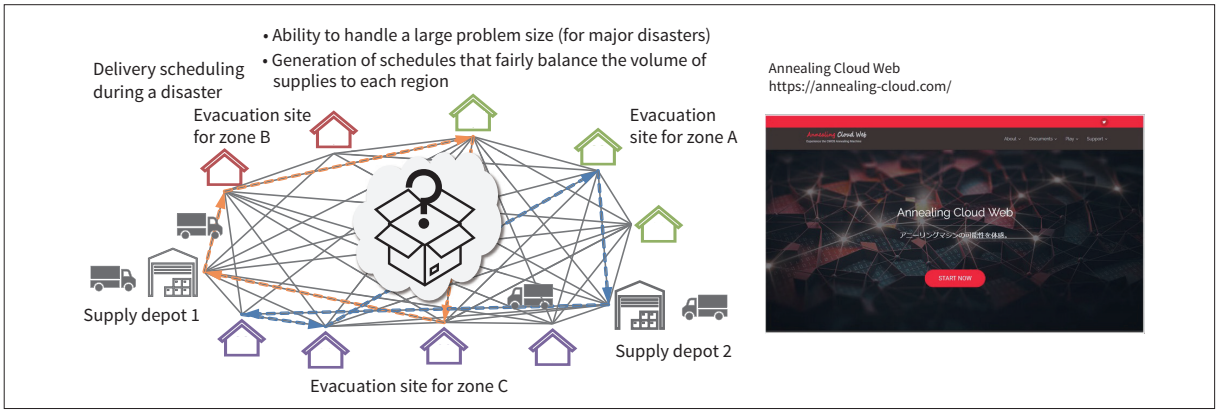
By continuing to develop and deploy the technology, Hitachi intends to continue contributing to innovation in water supply management with consideration for the future maintenance of social infrastructure.

5 MVS v1.4 Solution for Enhanced Security and Surveillance

Multifeature video search (MVS) is a solution for the rapid identification of specific individuals in surveillance camera video based on their whole-body characteristics. It can run searches on the basis of more than 100 different personal attributes, with speed of search being a key feature. Rising concern about maintaining public order over recent years has brought demand from business operators wanting to prevent incidents in public places before they happen. In response, Hitachi has released MVS v1.4 featuring two new functions based on technology that has been recognized at international conferences for its world-leading accuracy[*1]: (1) A wide-area monitoring function for detecting behaviors indicative of an incident about to happen[*2], and (2) A lost property and suspicious object function that can detect items that have been abandoned or taken.

These functions provide earlier warning of potential incidents in public places. With studies already underway looking at commercial deployment of the solution at airports or in industries such as electric power, Hitachi plans to proceed with more detailed trials in readiness for product launch.

*1 The associated technology has been adopted at leading industry conferences on image analysis, including the Computer Vision and Pattern Recognition Conference (CVPR) 2021 and International Conference on Image Processing (ICIP) 2022.
*2 The function is able to identify nine different actions, such as looking around, and can be trained to recognize additional actions.



6 Co-creation with MPAT (left) and Annealing Cloud Web (right)

6 Collaborative Creation Using CMOS Annealing

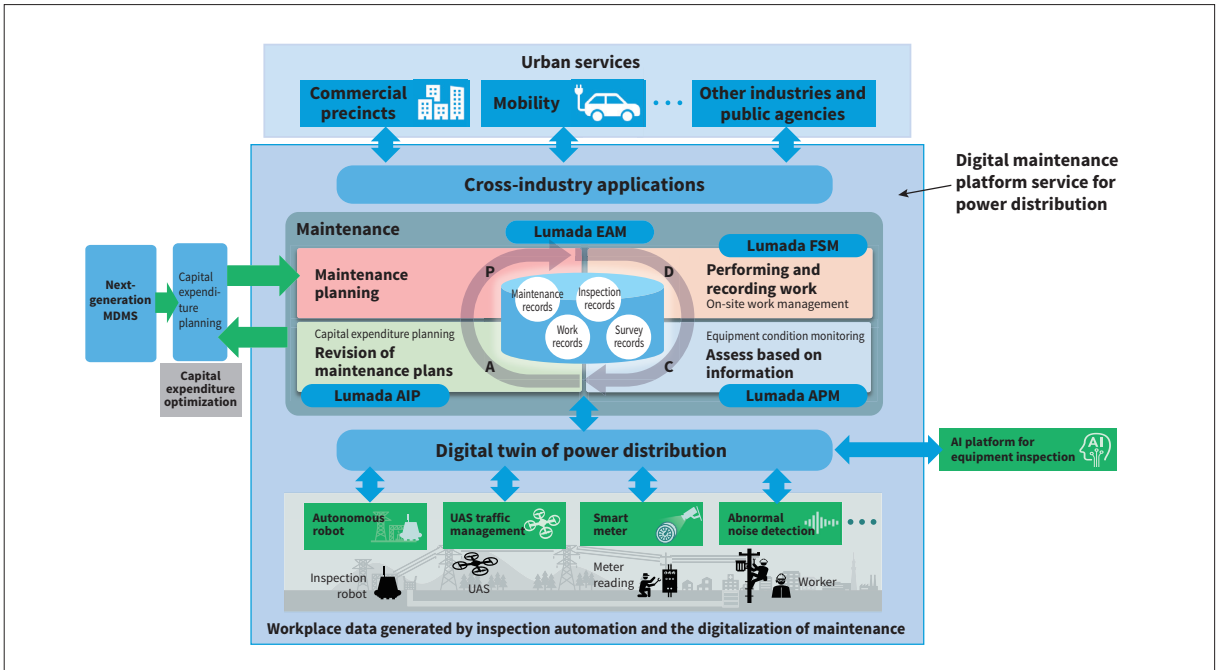
Around the world, people's lives are being disrupted by the pandemic and by abnormal weather events and other natural disasters. Situations like these call for timely action to ensure the efficient operation and rescheduling of social infrastructure and systems.

Having developed complementary metal-oxide semiconductor (CMOS) annealing technology that can obtain practical solutions to combinational optimization problems at high speed, Hitachi is now engaging in collaborative creation (co-creation) with a variety of partners aimed at putting the technology to use to address societal challenges.

One example is the work Hitachi is doing with the National Institute of Maritime, Port and Aviation Technology (MPAT) to optimize the planning of relief supply delivery during disasters. This involves the efficient delivery of a large volume of goods to multiple evacuation sites without favoring one site over another. Trials have been conducted to verify that rapid calculations using CMOS annealing can produce delivery schedules that fulfill these requirements, and that the solutions it comes up with are realistic.

To make the technology more widely available for co-creation, Hitachi has been progressively upgrading the Annealing Cloud Web content that provides web access to CMOS annealing. By doing so, it is accelerating its use for the resolution of societal challenges.

Part of this work is based on results obtained from a project, JPNP16007, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).



MDMS: meter data management system FSM: field service management AIP: asset investment planning APM: asset performance management
PDCA: plan, do, check, act

7 Block diagram of digital maintenance platform service for power distribution

7 Digital Maintenance Platform Service for Power Distribution Using Digital Twins

Power distribution faces the challenges of maintaining security of supply while also reducing maintenance costs and coping with workforce shortages. To overcome these, the industry is pursuing digital transformation (DX), making use of AI to improve work efficiency and utilizing unmanned aircraft systems (UASs) to automate inspection work. In turn, making a success of DX calls for integration of the enterprise asset management (EAM) systems that manage the capital equipment being maintained, with a wide variety of different systems including newly adopted technologies like AI platforms, IoT sensors, robots, and three-dimensional (3D) city models.

To enable this, Hitachi builds digital twins for electrical distribution systems that serve as a central repository for a wide variety of operational information. By replicating the current and past state of the distribution system in digital space, these digital twins facilitate the seamless integration of EAM with these diverse systems. With the digital twin of the city playing a core role, this digital maintenance platform service for electricity distribution interoperates with operational systems from other industries that are involved in the functioning of the city, such as commercial precincts and mobility. In doing so, it contributes to the economic development of the city and the resolution of societal challenges.

8 Technology for Zero-emission Data Centers

Amid an acceleration in decarbonization efforts aimed at addressing global climate change, achieving zero emissions has become a requirement for data centers also as the digitalization of society results in their consuming more power than ever. These background factors have prompted research and development aimed at realizing zero-emission data centers based on the idea of using information and operational technologies (IT and OT) to reduce costs through sophisticated prediction and control techniques for data center power consumption and by optimizing supply and demand for renewable energy. Specifically, the following technologies are being developed in recognition of the particular challenges posed by the monitoring of power use at data centers and the use of electric power derived from intermittent renewable energy sources.

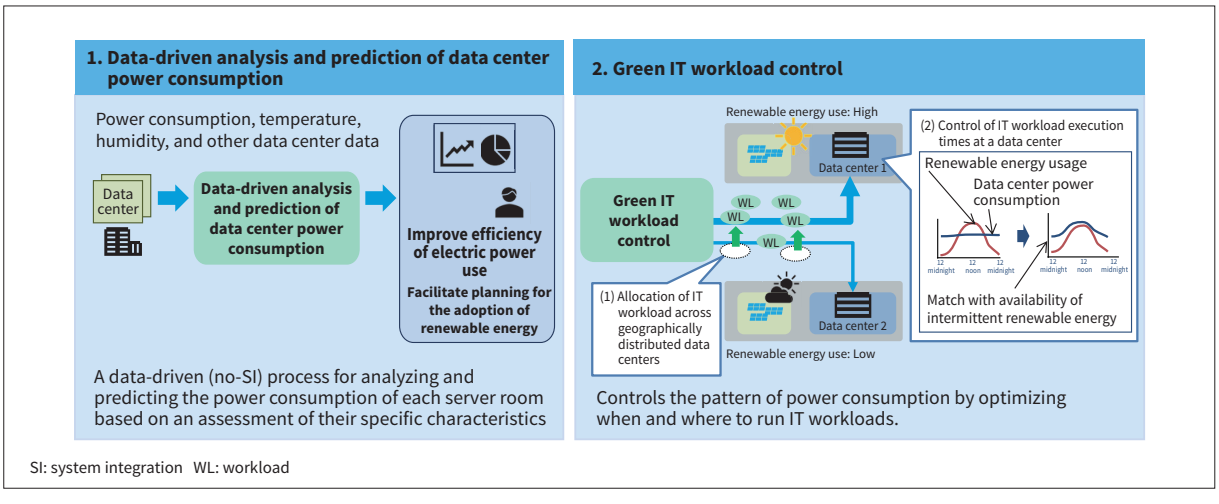
(1) Data-driven analysis and prediction of data center power consumption

By automatically determining the characteristics of each server room using only easily obtained data, this analyzes and predicts their power consumption. Doing so facilitates improvements in the efficiency of electric power use and planning for the adoption of renewable energy.

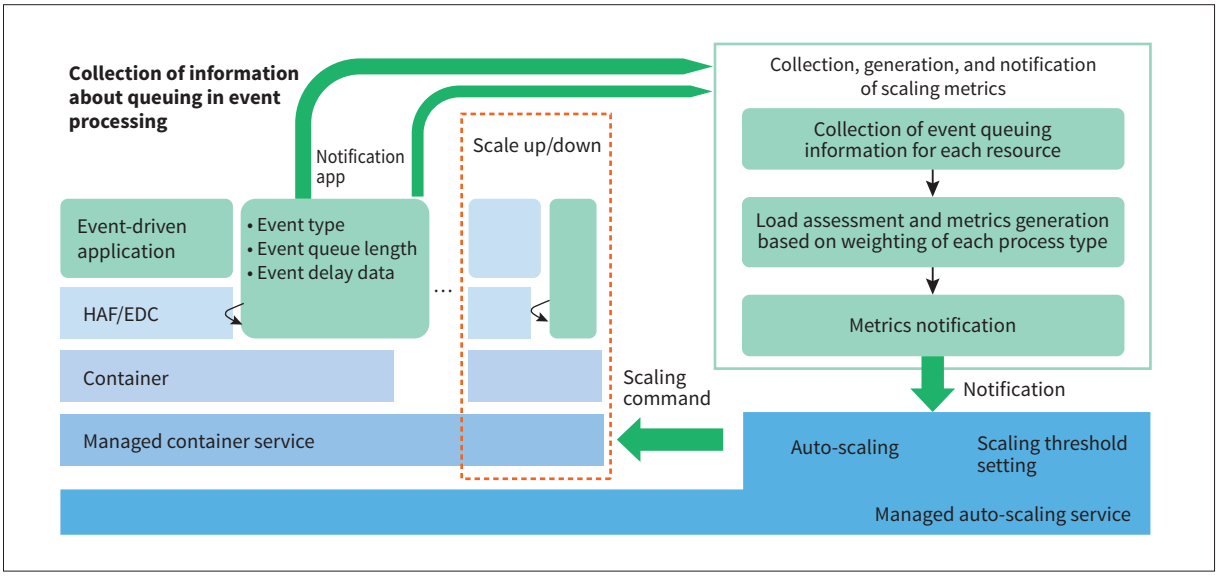
(2) Green IT workload control

This optimizes when and where IT workloads are run across a number of geographically distributed data centers to control the pattern of electric power consumption in a way that utilizes green energy.

In the future, Hitachi plans to contribute to the decarbonization of digital society through the commercial deployment of these technologies.



8 Technology for zero-emission data centers



9 Block diagram of auto-scaling for event-driven distributed applications

9 Auto-scaling for Event-driven Distributed Applications

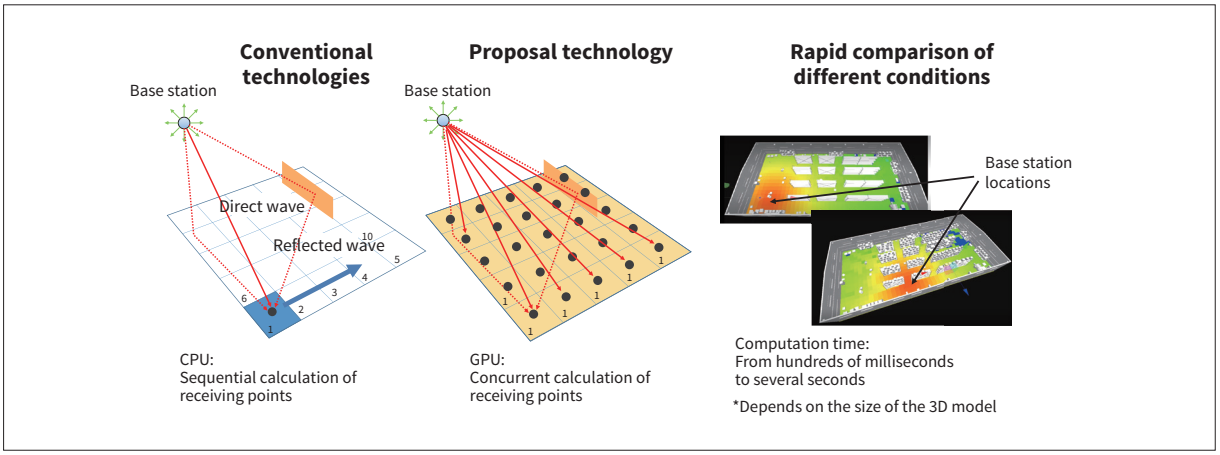
Driven by the need to satisfy service level agreements (SLAs) while also delivering reduced operating costs and interoperation with other systems, the SI market for social infrastructure systems, such as those for communications and electric power, is seeing rising demand for migration to the cloud. Unfortunately, the use of cloud services such as managed containers can bring high costs due to the need to maintain a safety margin of additional resources over long periods of time. To address this issue, Hitachi has developed an auto-scaling mechanism that monitors application workloads (events) and passes this information on to an orchestration service.

This auto-scaling works for container applications running on Hitachi Application Framework/Event Driven Computing (HAF/EDC), a platform for event-driven distributed applications that handles the control, notification, and distribution of events across multiple resources. It determines processing workloads by collecting data at regular intervals on how many and what type (processing time) of events are queued awaiting action by HAF/EDC container applications and passes this information on to an orchestration service to scale-up or scale-down resource availability. This keeps the cost of container resources to a minimum while still satisfying the SLA.

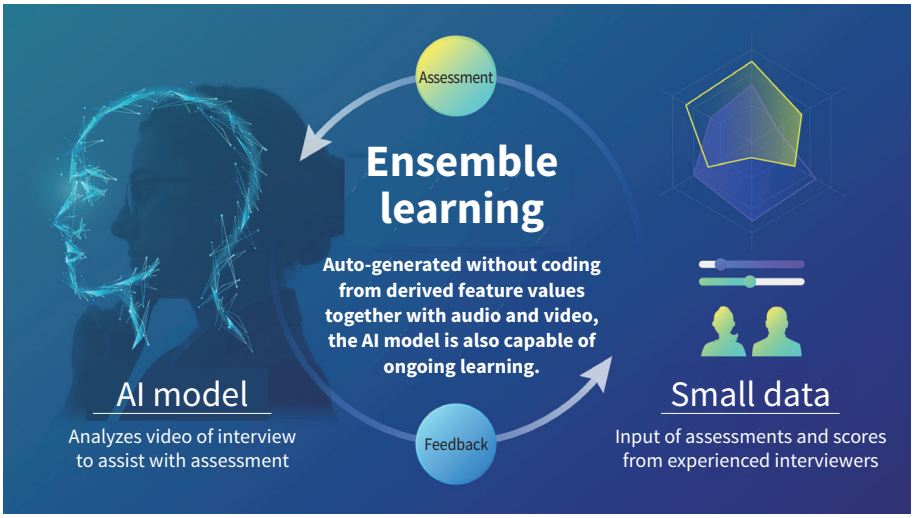
By further developing this technology into a technique for reducing bills in cloud environments, Hitachi intends to help minimize resource use as systems migrate to the cloud.

10 Wireless Digital Twin Utilizing Ultra-high-speed Radio Transmission Simulator

When installing and operating wireless systems such as fifth-generation (5G) mobile networks and wireless



10 Use of ultra-high-speed radio transmission simulator to build wireless digital twin



11 Code-free generation of AI model replicating expertise of experienced interviewers

local-area networks (LANs), the performance of radio communications can be degraded by changes in conditions on the ground, such as the rearrangement of the site layout or the movement of people and goods.

To address these changes in environment that disrupt communications, Hitachi has developed an ultra-high-speed radio transmission simulator that can be used to evaluate a site prior to installation, quickly assessing a wide range of conditions for its 3D digital space.

In the past, assessing radio signal quality for the digital space at a site required an analysis that considered hundreds or thousands of receiving points and took hours to perform. In contrast, the new simulator is able to complete an analysis in just a few seconds (around 10,000 times faster than before) thanks to the development of a radio environment analysis algorithm optimized for execution on a graphics processing unit (GPU) that can run analyses for multiple receiving points in parallel. By providing the ability to perform rapid pre-installation site evaluations that consider a wide variety of potential changes, this enables wireless systems to be installed and operated reliably.

11 AI Interview Service for Assessing Skills of Diverse Human Capital

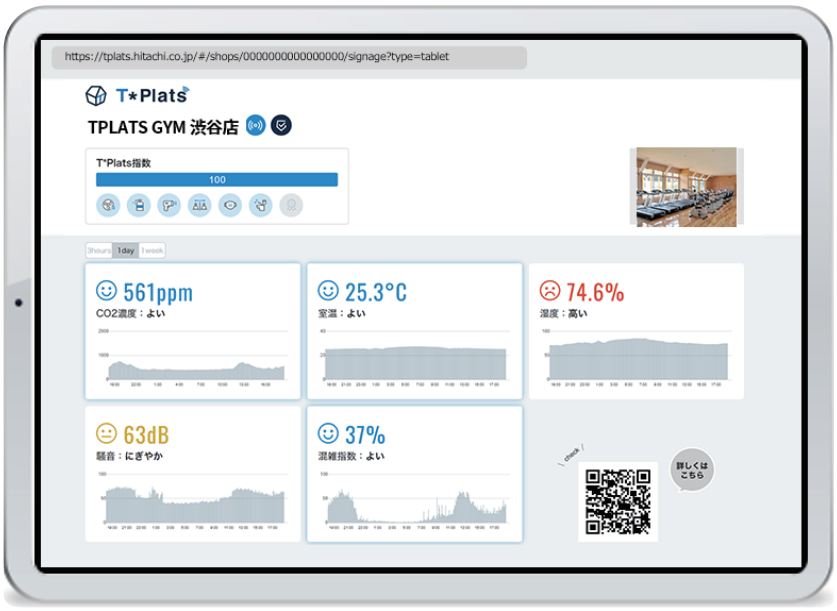
An increasing number of companies have, over recent years, adopted the practice of conducting interviews with employees aimed at facilitating their career advancement. Unfortunately, a reliance on subjective assessment by interviewers has made it difficult to achieve fairness and consistency in the outcomes of these interviews. Furthermore, because the interview candidates heavily outnumber the small pool of available interviewers, the actual number of interviews that can be completed is small.

In response, Hitachi has used code-free techniques to generate an AI model that replicates the expertise of experienced interviewers and, when applied to videos of interviews, is able predict their conclusions with a high degree of accuracy. This can be used to minimize the variability between the conclusions of different interviewers. Moreover, the development of a self-interviewing function using an avatar in place of a live interviewer means that the interviews no longer need to take place in-person and can be completed at any time.

Hitachi Solutions, Ltd. has launched the AI Interview Service, which utilizes this technology. As the service is able to support a wide range of online activities, it is hoped that it will contribute to overcoming the challenges of online communication in such diverse industries as temporary staffing, education, and healthcare.

12 Compliance Verification Using VCP Model

While the post-COVID-19 new normal comes with expectations that retail and other facilities will take the initiative in providing information about their hygiene management, the inadequate provision of such information in the past has compromised the safety and security of facility users. In response, a compliance verification technique was developed as part of Cyber Physical Security for IoT Society of the SIP program Phase 2. The technique can determine whether conditions at such sites have deviated from the rules and regulations covering people, systems, components, data, and processes. It uses a value creation process (VCP) model that is able to express these hygiene requirements in machine-readable format and



12 Compliance verification using VCP model

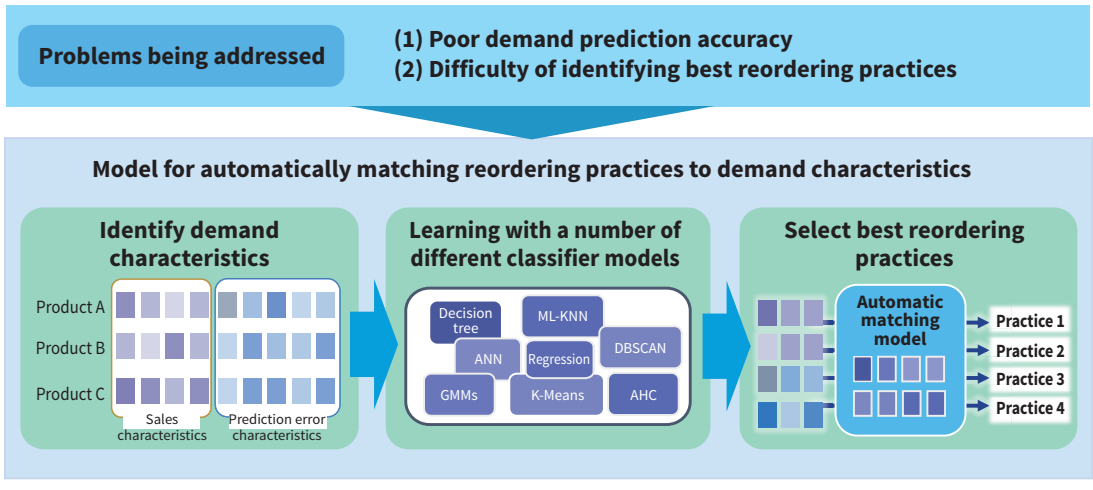
works by collecting hygiene management data from onsite sensors (including CO_2 concentration, noise level, temperature, humidity, and so on) and then checking these against the VCP model to verify compliance. It helps retail and other facilities to attract customers and ensure their safety and security by presenting real-time information on hygiene management conditions at the site.

The intention for the future is to deploy the technology at sites such as shopping centers, office buildings, and public facilities, extending its use to a wide range of applications such as at restaurant chains, real estate companies, local government, and educational institutions.

Part of the work described in this article was undertaken by the Cyber Physical Security for IoT Society project run by NEDO under the Cabinet Office's SIP program.

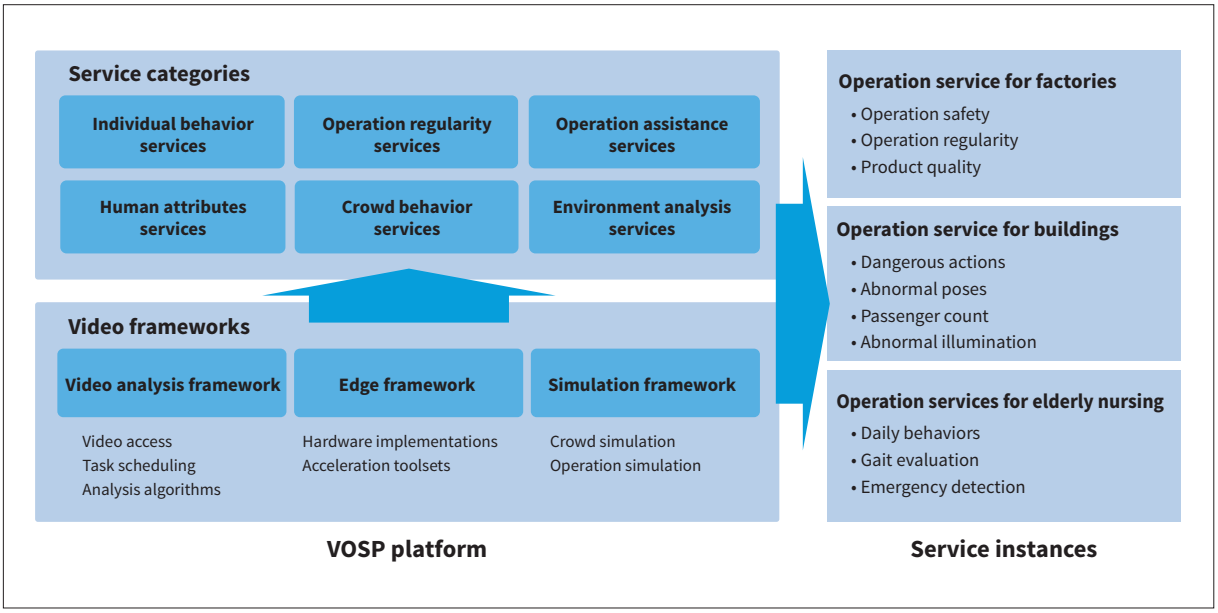
13 Solution for Demand Prediction and Automatic Reordering Based on Demand Characteristics

Supply and demand have become even more erratic amid the rapid changes in the post-COVID era, resulting in frequent instances of overstocking and sudden changes in production levels. Unfortunately, the requirement for more fine-grained corporate management cannot be satisfied when tasks such as decision making and the



ML-KNN: machine learning – k-nearest neighbor ANN: artificial neural network DBSCAN: density-based spatial clustering of applications with noise
GMMs: Gaussian mixture models AHC: agglomerative hierarchical clustering

13 Model for automatically matching reordering practices to demand characteristics



14 Structure and advantages of VOSP platform

revision of inventory and procurement planning are dependent on the empirical knowledge of individuals. This means that utilizing technologies like big data and AI to expedite DX in supply chains has a major impact on corporate competitiveness.

This solution focuses on inventory and procurement planning and is intended to make procurement management more efficient and to reduce stocking levels while still satisfying demand. Numerous solutions already exist in this space that use demand prediction as a basis for inventory optimization. However, when the product range is very large, AI demand prediction may work well for some items while being less reliable for others. This means that adequate performance cannot be achieved by relying on a single methodology to reorder goods based on demand prediction.

In response, the solution achieves its targets by performing a multi-dimensional analysis of the characteristics of demand for goods and materials and then using this to automatically determine the prediction method and reordering practices that best suit these characteristics. The system has been supplied to a large brewing company in China where it has reduced inventory by 16% by value.

[Hitachi (China) Ltd.]

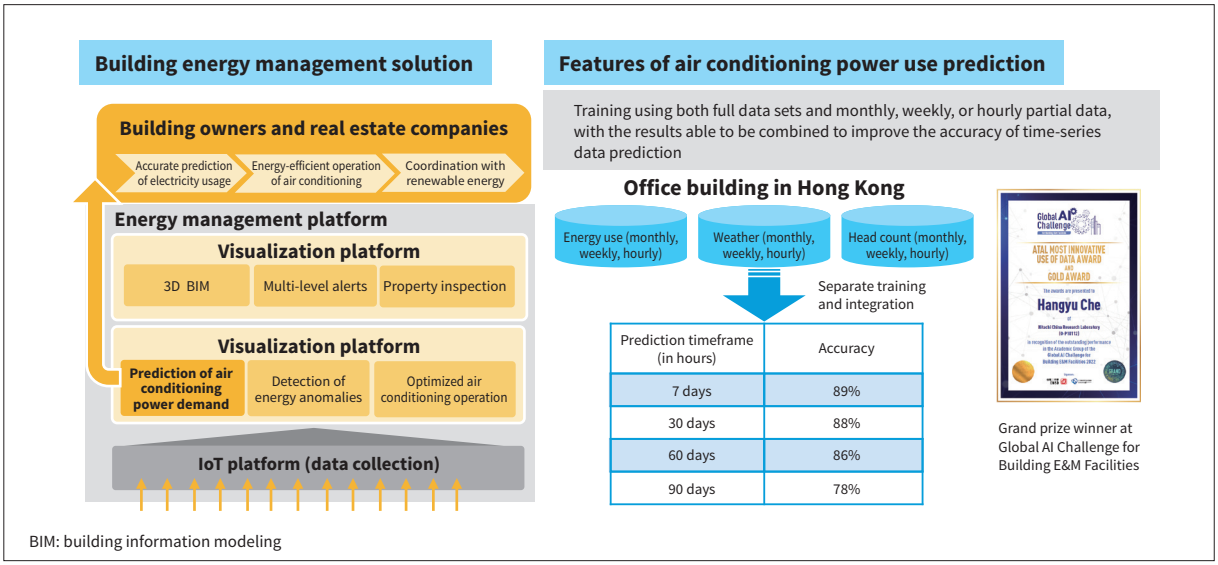
14 VOSP Development and Business Collaboration Approaches

The acceleration of DX in China has led to the need for visual analysis of onsite situations and optimization of business operations for purposes such as safety, efficiency, and regularity. However, the conventional case-by-case approach taken to address various customization requirements faces difficulty in solving various customer issues in the early stages at a fast pace. Under these circumstances, Hitachi developed an integrated common platform, the video operation service platform (VOSP), to promptly provide systems that meet various customer needs. VOSP contains frameworks with modular blocks holding common functions abstracted from customer cases. It also contains data interfaces and tuning methods as tools to quickly adjust common functions in various customer scenarios. State of the art technologies including video analysis, machine learning, and data simulation have achieved recognition at conferences and in journals. With advanced technologies, VOSP is successfully applied in manufacturing safety video solution development to reduce the solution construction time by two-thirds. Through these applications, VOSP has helped to create a win-win relationship with local customers and effectively scaled local DX business in China.

[Hitachi (China), Ltd.]

15 Building Energy Management Solution for China

Prompted by environmental regulations such as the Chinese government's National Standard for Building Carbon Emission Calculation, building owners and real estate companies are wanting to manage their properties in ways that combine regulatory compliance with



15 Building energy management solution

economic activity. Achieving this requires the accurate prediction of electricity usage and the fine-grained control of things like air conditioning parameter settings (chillers, fan coil units, etc.), photovoltaic power usage, and purchases of renewable energy.

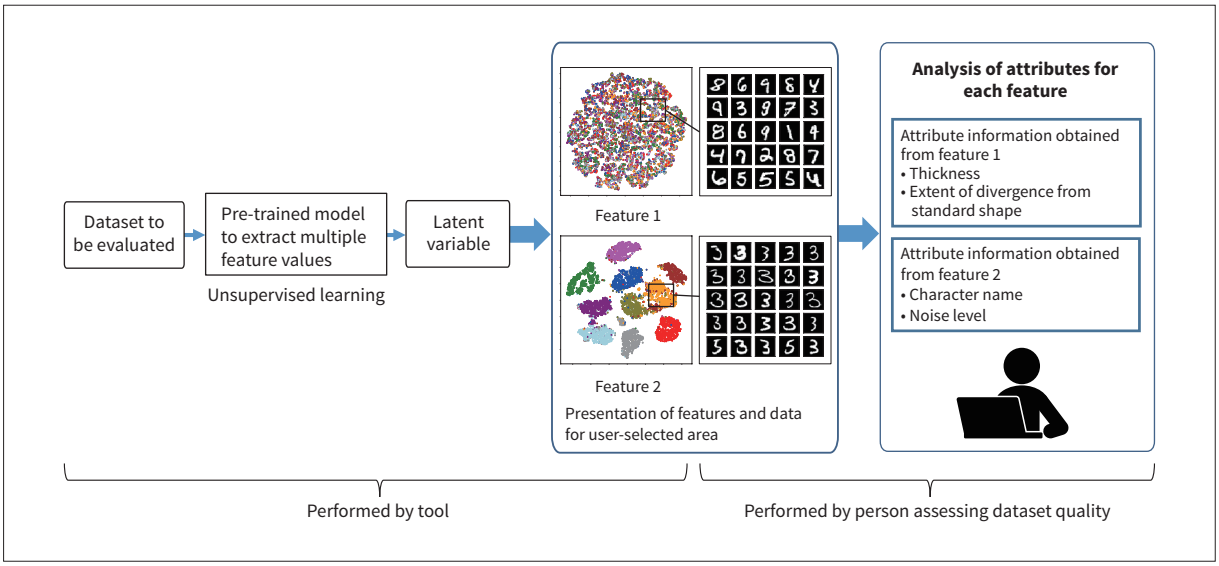
The research and development (R&D) division of Hitachi (China) Ltd. has drawn on its expertise in the highly accurate prediction of air conditioning power demand to develop a building energy management solution. The solution can be trained using both full data sets and partial data that contains monthly, weekly, and hourly characteristics, and the results can be combined to further improve prediction accuracy.

At the Global AI Challenge for Building E&M Facilities, where teams from more than 90 countries or regions participated in the world's largest AI competition for smart buildings and cities, the solution was one of five grand prize winners in the open group, achieving an accuracy of 75% in its prediction of hourly cooling load demand three months ahead while keeping the various error rates low.

[Hitachi (China) Ltd.]

16 Dataset Quality Assessment for AI Software

AI software differs from conventional software in that it is developed recursively from training data. In other words, obtaining high-quality datasets is a prerequisite for the development of high-quality AI software. For a detailed assessment of the quality of a dataset, it is important to look not only at single attributes such as the tagging of objects that appear in video data, for example,



16 Evaluation of dataset quality by multiple attribute analyses

but also at multiple attributes such as object shape or background color, and to determine whether the data for these are adequate.

Accordingly, Hitachi has extended the technology of a variational autoencoder to develop a way to extract and analyze multiple feature values from a single set of data, implementing it in the form of a tool. The tool was tested by applying it to a dataset containing forms with handwritten text. The results demonstrated that it was able to identify groups of data with similar characteristics to those identified by the person who evaluated the quality of the dataset, which included not only the characters in the text but also multiple attributes such as thickness, extent of divergence from the standard shape, and the level of noise.

In the future, Hitachi intends to use this technique to assess adequacy and other quality considerations for a wide variety of datasets, including using it as a basis for quantifying the adequacy of a dataset.

17 Security Digital Twin to Assure Business Continuity when Implementing Security Measures

The rise in cyberattacks targeting OT systems over recent years means that security measures are urgently required at a level similar to those found in IT systems. Unfortunately, it is often more difficult to halt the OT systems in comparison to IT systems, and likewise difficult to determine whether to install software patches or make changes to firewall rules given the risk that those changes may cause unintended system outages. As a result, vulnerabilities end up being left unresolved for long periods.

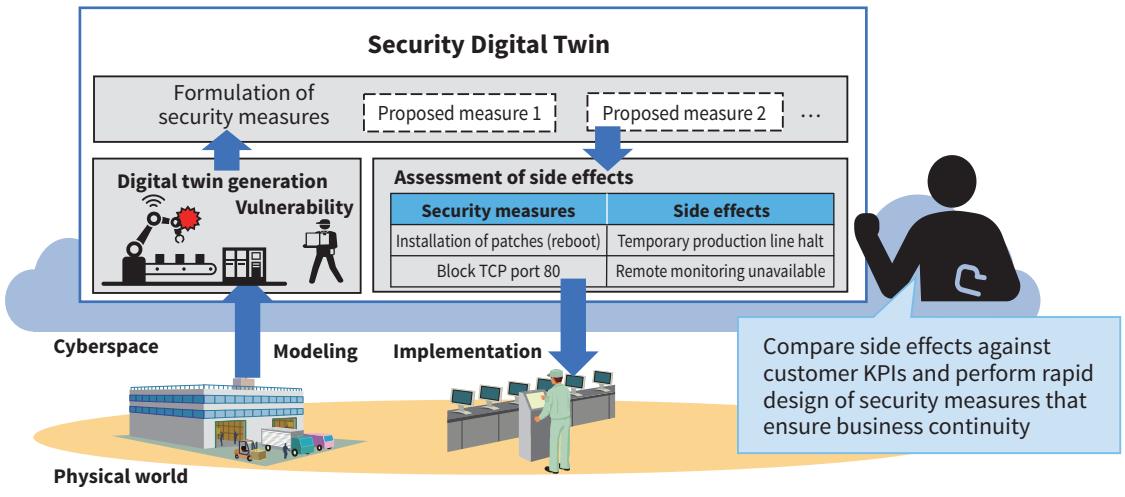
In response, Hitachi has developed a way of using digital twins for security, utilizing them to formulate security measures for reducing the damage caused by cyberattacks that exploit these vulnerabilities. This Security Digital Twin is able to assess each security measure in cyberspace prior to actual deployment, to determine the impact of system outages or other side effects on business continuity.

In the future, Hitachi intends to use this to help ensure the correct and efficient implementation of security measures at customers' plants, electric utilities, and other social infrastructure as well as in connected cars and medical devices and systems.

18 High-speed Data Retrieval to Improve Product Safety and Reliability

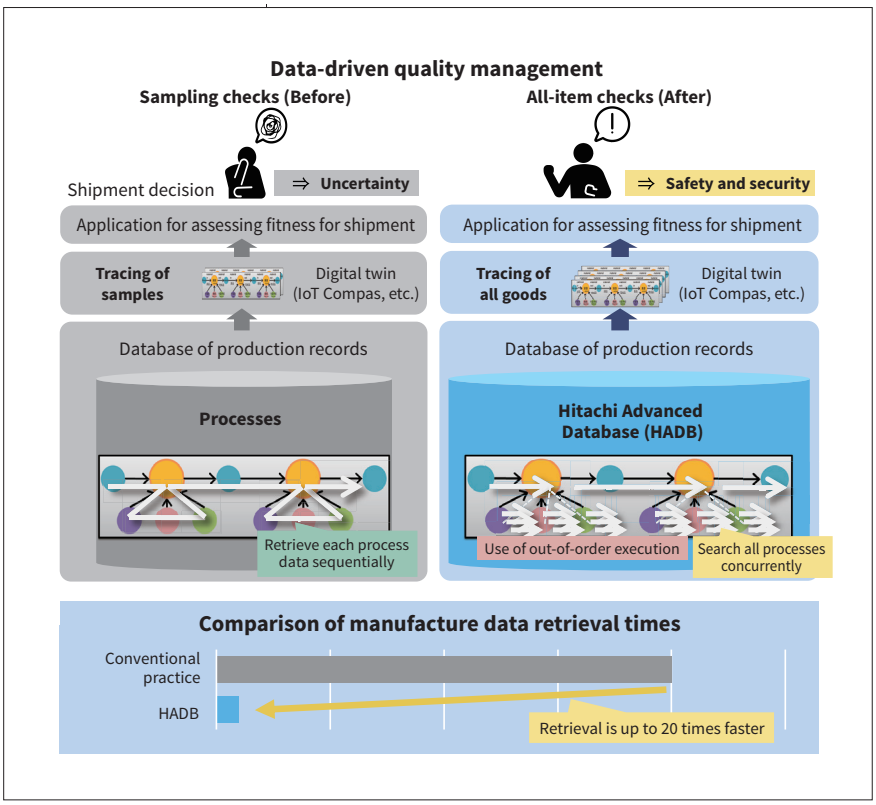
Data-driven quality management is becoming increasingly crucial as safety awareness grows; inspecting all products before shipment requires high-speed retrieval of production data in manufacturing. High-speed retrieval requires a complete set of production data covering every process, from raw materials and parts to finished items associated with each product at shipment determination.

Hitachi Advanced Database (HADB)[*1] achieves inspection of all products by retrieving all processes concurrently by using the principle of out-of-order execution[*2]. HADB reduces data retrieval time by a factor of 20[*3] and enables all products to be checked.



TCP: Transmission Control Protocol KPI: key performance indicator

17 Technology for using digital twins in security



18 Data-driven quality management

As a result, HADB significantly improves product (inspection) quality and reliability in many manufacturing industries such as automotive, pharmacy, materials, and foods by executing quality inspections on all processes.

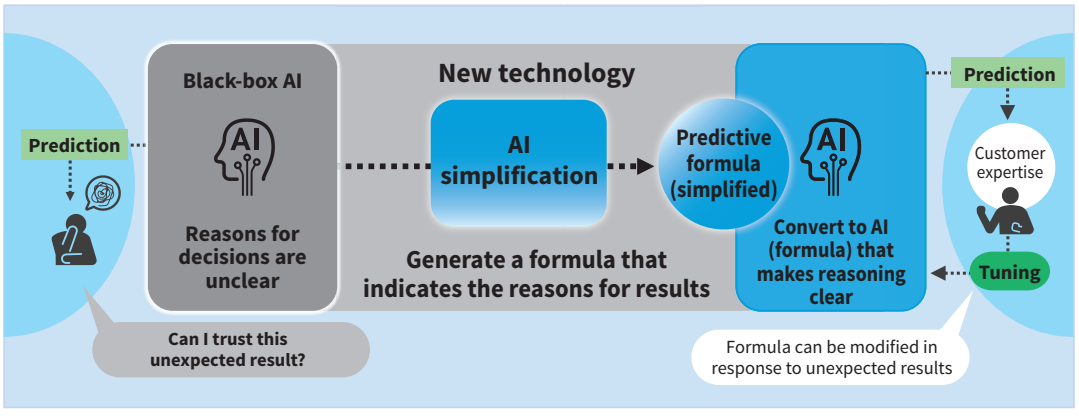
*1 Using results from the study "Development of the Fastest Database Engine for the Era of Very Large Database and Experiment and Evaluation of Strategic Social Services Enabled by the Database Engine" (Core researcher: Masaru Kitsuregawa, University Professor at the University of Tokyo and Director-General of the National Institute of Informatics), which was supported by the Funding Program for World-Leading Innovative R&D on Science and Technology (Cabinet Office, Japan).

*2 An execution principle devised by Professor Kitsuregawa (the University of Tokyo and Director General of the National Institute of Informatics) and Associate Professor Goda (the University of Tokyo)

*3 Based on comparative testing by Hitachi, Ltd.

19 Simplification Technology for Accelerating AI Deployment in Mission-critical Applications

Hitachi has developed an AI simplification technology that can convert a black-box AI into a predictive formula that provides clear reasons for why it generates specific results. An issue with conventional black-box AIs is a lack of clarity regarding the basis of their decisions, a consequence of their use of complex formulas to improve prediction accuracy. This brings a risk of their producing unexpected predictions when supplied with unknown



19 Block diagram of AI simplification technology

data. To address the issue, this technology creates an AI (predictive formula) that is simple enough for people to understand, meaning that the reasons why it generates the results it does to any given input are readily apparent. As the technology also allows for the modification of formulas to reflect customer experience or expertise, its accuracy can be maintained and improved without loss of confidence.

The technology has been partially adopted within Hitachi on an automated line for inspecting products prior to delivery. While use of conventional AI has been impeded by a lack of confidence in its results, the simplification provided by this technology has enabled its use in this case by making its results more convincing, without compromising accuracy. Deployed in practice, the resulting benefits of the technology included higher inspection accuracy as well as helping to alleviate the shortage of skilled staff. In the future, Hitachi will continue to accelerate DX across all areas of society and deploy AIs that can be trusted in applications such as manufacturing, finance, and infrastructure control.

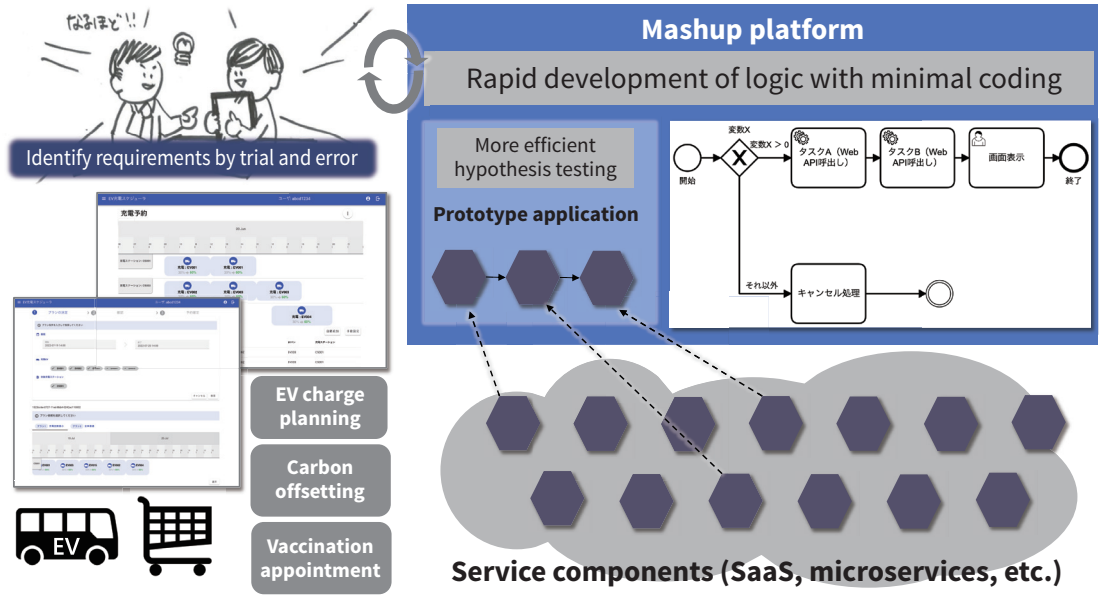
20 Service Mashup Platform for Rapid Application Development

The increasingly uncertain and complex business environment calls for companies to be agile and flexible. When building a digital solution, it is rare to have an overall picture of the service and its requirements from the very beginning. What is needed, rather, is to adopt an approach based on co-creation in which this is worked out in consultation with customers.

As a solution to this issue, Hitachi has developed a service mashup platform that enables the rapid development of prototype applications. The platform incorporates methods for service chaining in which the logic is assembled by combining software-as-a-service (SaaS), microservices, and other loosely coupled service components in a composable architecture. This allows prototype development to proceed quickly with a minimum of coding, providing an environment in which an overall picture of the service and its requirements can be established quickly through a process of hypothesis testing and trial and error.

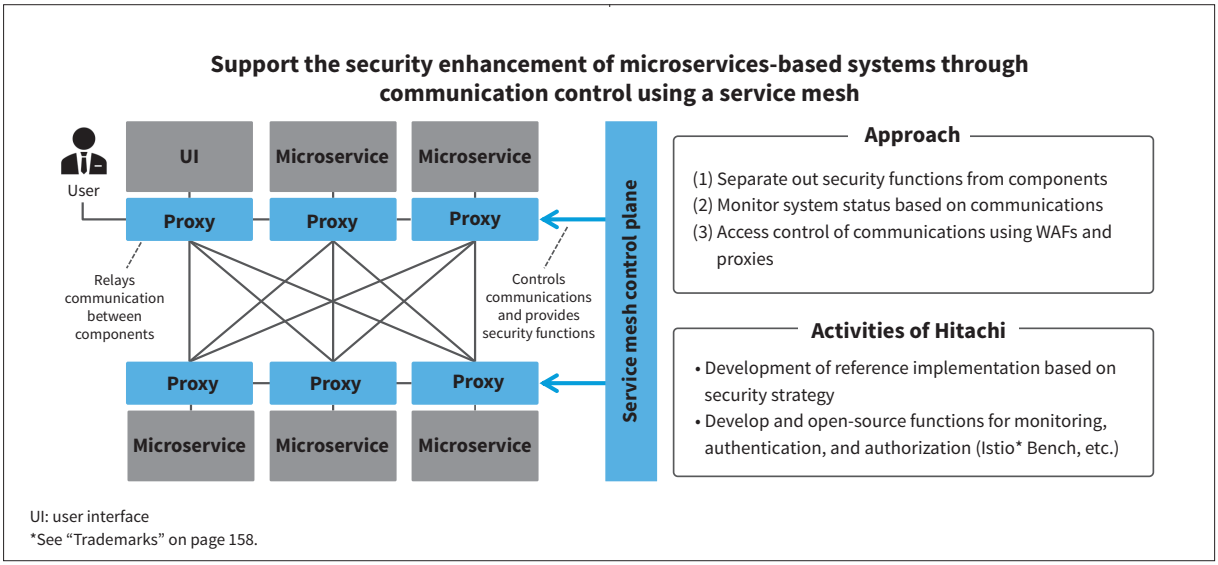
21 Enhancing Security of Microservices-based Systems with Service Mesh

Due to the increasing emphasis on improving business agility and securing competitive resources, there has been a growing interest in microservices-based systems. These systems interconnect multiple small-scale systems to enhance scalability and reusability. However, such systems have a high number of access points, and ensuring security is a significant challenge. In response, Hitachi is utilizing service mesh technology to apply a consistent security policy to entire systems via communication control using a proxy. The following approaches are



EV: electric vehicle

20 Identification of requirements through rapid application development and hypothesis testing



21 Security enhancement for microservice systems

being taken to enhance the security of microservices-based systems:

(1) Separation of security responsibilities

Achieving separation of communication security responsibilities from each system component, and centralized management on the infrastructure side with service mesh.

(2) System status awareness

Achieving observability by visualizing communication status and abnormal access based on communication metrics and logs between components.

(3) Access control

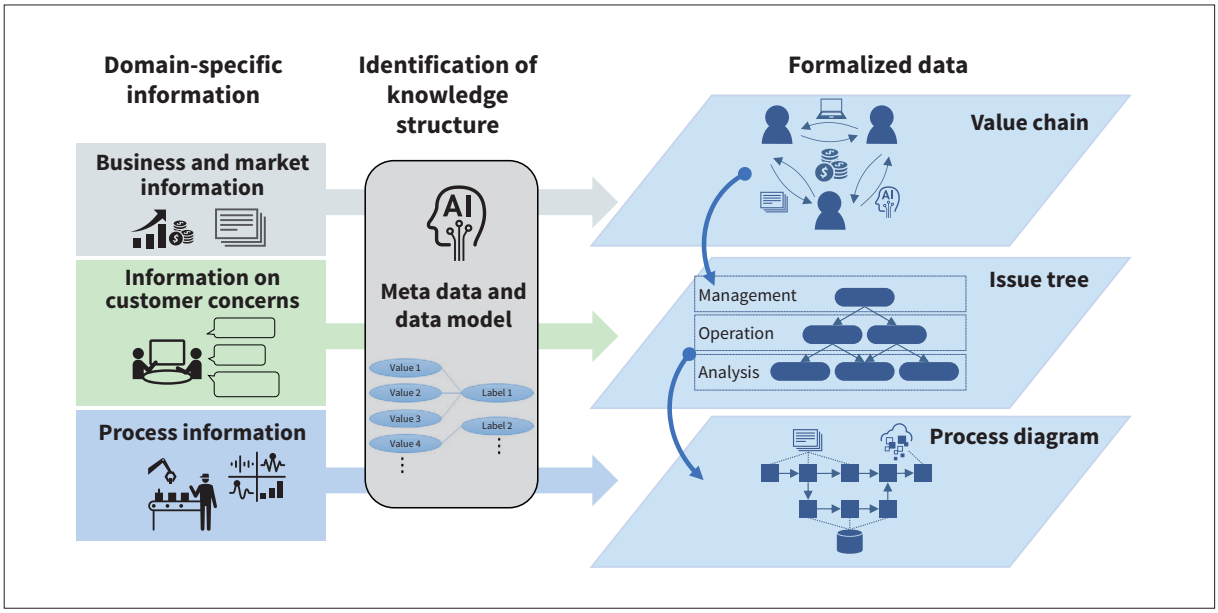
Achieving comprehensive authentication and authorization using web application firewall (WAF) and service mesh to block unauthorized access.

To date, Hitachi has constructed a reference implementation based on its security strategy and developed functions for monitoring, authentication, and authorization and has open-sourced* it. By expanding the scope of security to also include code and infrastructure, Hitachi intends to contribute to both agility and security in microservices-based systems.

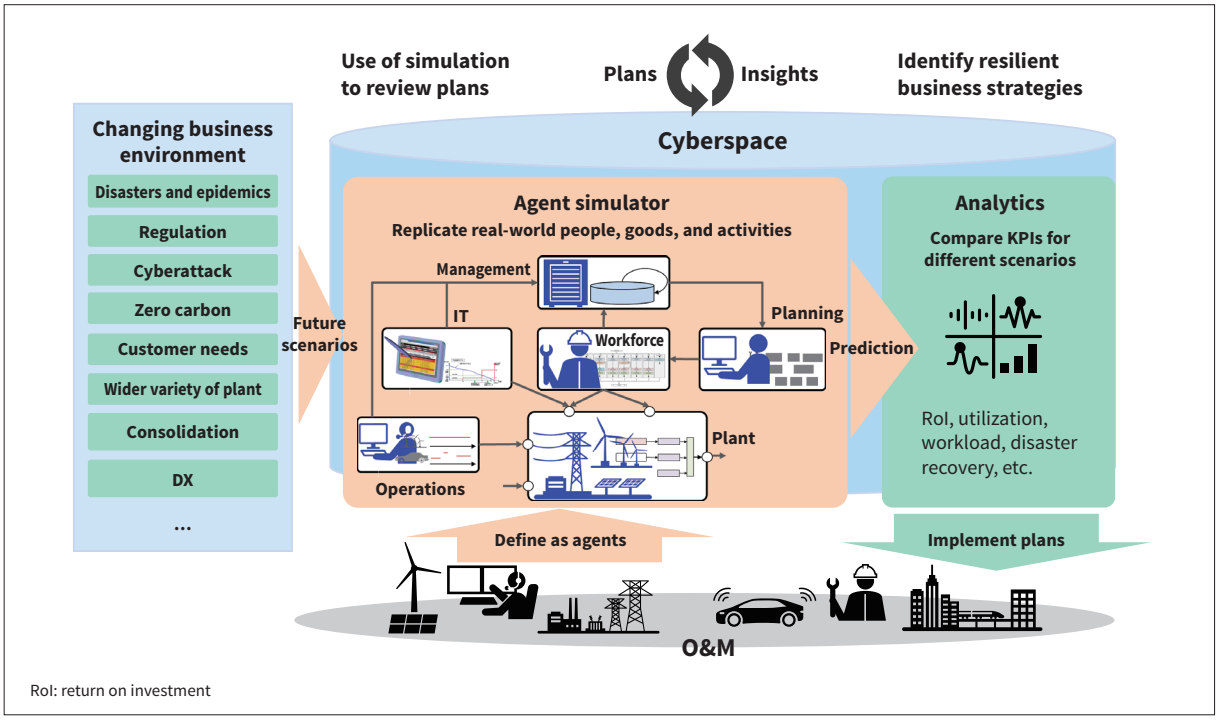
*Istio Bench: https://github.com/Hitachi/istio-bench

22 DX Consulting Technology for Accumulating and Using Domain Knowledge

The Lumada Data Science Laboratory (LDSL) was established in 2020 to bring together researchers and engineers with a depth of knowledge in techniques from the fields of AI and data science as well as the



22 Overview of framework for accumulating domain knowledge



RoI: return on investment

23 Use of O&M simulator to review plans and create value

OT essential for real-world deployment. By putting this knowledge and skill to work in co-creation projects with customers, the laboratory is expanding Hitachi's Lumada business through the rapid implementation of data-driven and value-creating solutions.

While the need for DX has been rising in recent years, it is important to adopt it in a staged manner by identifying the challenges in the customer phase and choosing the best techniques from AI and data analytics, thereby ensuring that it satisfies the needs of practical deployment. Hitachi has built up a portfolio of knowledge, skills, and use cases by understanding the issues facing its diverse customers who operate a wide range of businesses and coming up with specific measures for achieving their goals. This has involved developing a framework and data platform for formalizing this domain knowledge in graph data structures and managing it as a digital asset that can be put to use across different industries. The aim is to use this technology to speed up the work of devising scenarios for customer business growth and solutions for supporting that growth.

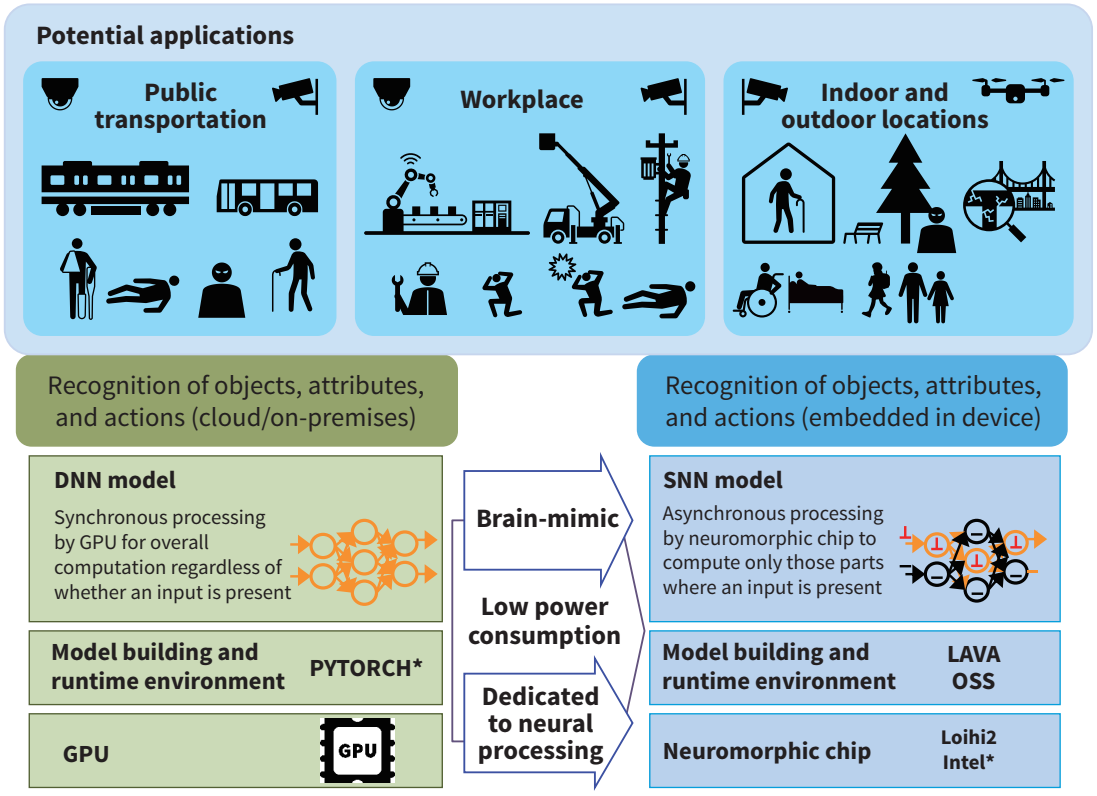
23 O&M Simulation to Help Manage for Resilience

Business planning for operation and maintenance (O&M) needs to factor in a range of value considerations, including safety, reliability, the environment, resilience, and work practices. This new technique supports rapid decision making in areas like organizational change and investment by giving business planners the ability to assess the risks and benefits of a variety of different strategies quantitatively. This is done using agent simulation. Simulation agents are provided to represent factors such as plant, workforce, and IT, and reliability analysis is used as a basis for the plant agents so that they are able to replicate equipment with complex configurations and characteristics. The simulations can be used to investigate performance targets as well as in the selection of maintenance practices and planning for the installation of condition monitoring, fault diagnosis, and other IT solutions.

The simulations are applicable to a wide range of fields, from the supply of workers for O&M at wind farms or retail outlets, to large facilities such as factories or power plants. By combining agents in ways that replicate actual management scenarios, the simulations provide an objective and quantitative means of reviewing plans without the need for additional work such as building mathematical models.

24 Neuromorphic Computing that Expands the Scope of Edge AI with Ultra-low Power Consumption

AI techniques such as image recognition are now finding applications in edge devices. However, if AI is to be widely adopted in the diverse environments at the network edge, power consumption needs to be as low as possible.



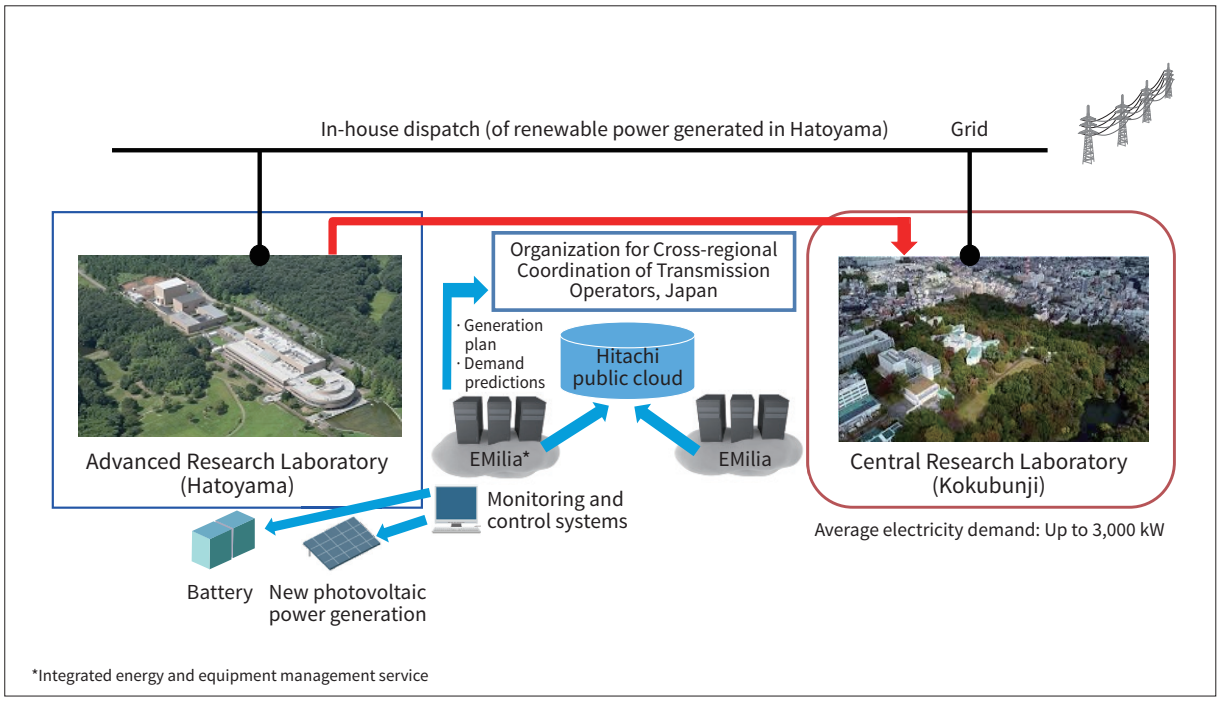
DNN: deep neural network SNN: spiking neural network
*See "Trademarks" on page 158.

24 Comparison of computing environments for deep learning and potential applications

The human brain is known to consume a mere 20 W of power. By using neuromorphic algorithms and innovative devices to mimic its operation, the energy required to perform image recognition by techniques such as deep learning can be reduced more than 100-fold compared to a GPU. Hitachi has developed recognition algorithms suitable for use in video surveillance. Because this allows advanced recognition tasks such as identifying the attributes or actions of people to run on less than 1 W of power, it can be incorporated into security cameras, drones, or other edge devices to perform real-time, on-the-spot incident detection without having to send back video for processing on a server or the cloud.

In the future, Hitachi intends to help make people safer and more secure by investigating the use of this technology in real-time monitoring and surveillance solutions for public transportation and workplaces as well as other indoor and outdoor locations.

Innovation for Advancing with Customers
Green Energy & Mobility



1 Demonstration system for dispatching of power between Hatoyama and Kokubunji

1 System for In-house Dispatching of PV Power across Multiple Sites

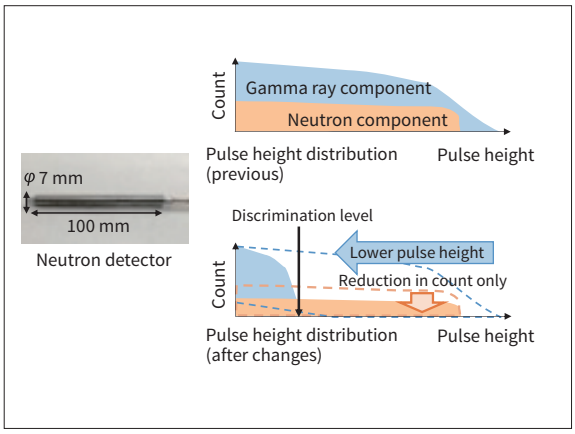
Hitachi has developed a technique for estimating electricity generation in real time using a mathematical model of photovoltaic (PV) generation that is intended to encourage wider adoption of in-house electric power dispatching systems for the low-cost and reliable procurement of green electricity. Factors such as the weather make the output of PV generation highly variable, meaning that the contracted level of power supply usually needs to be set lower than the actual generation capacity. It is estimated that the new technique will be able to increase contracted power by 30% compared to past practice by estimating actual PV generation (available power) in one-minute intervals and coordinating operation with battery control.

To demonstrate the operation of the system, PV generation has been installed at the Advanced Research Laboratory in Hatoyama-machi, Saitama Prefecture and work started on implementing a system for the in-house dispatch of this electric power to the Central Research Laboratory in Kokubunji City, Tokyo. Along with using this demonstration to trial the reliable and highly efficient dispatch of PV electric power in the MW range, there are also plans to expand the system into one for the in-house dispatch of PV power across multiple sites. By doing so, it will deliver both economic and environmental value by minimizing volatility and making full use of PV generation across many sites where the process of electrification is ongoing.

2 Sensing Technique for High-radiation Environments

This article describes two techniques for sensing in high-radiation environments, a requirement in the nuclear power industry.

Hitachi has developed a neutron detector that can function in the high-radiation environment at Fukushima Daiichi Nuclear Power Station. Previous neutron detectors have been unable to distinguish between gamma rays and neutrons because the simultaneous detection of multiple gamma rays in contaminated water results in a pulse height similar to that for neutrons. Noting that



2 Neutron detector for conducting surveys of Fukushima Daiichi Nuclear Power Station

sensitivity and pulse height are correlated for gamma rays but not for neutrons, Hitachi has addressed this problem by shrinking the metal electrode that influences sensitivity, thereby eliminating the gamma rays that interfere with neutron detection. Surveys conducted using a submersible remotely operated vehicle (ROV) equipped with this new detector were able to detect neutrons for the first time since the earthquake*.

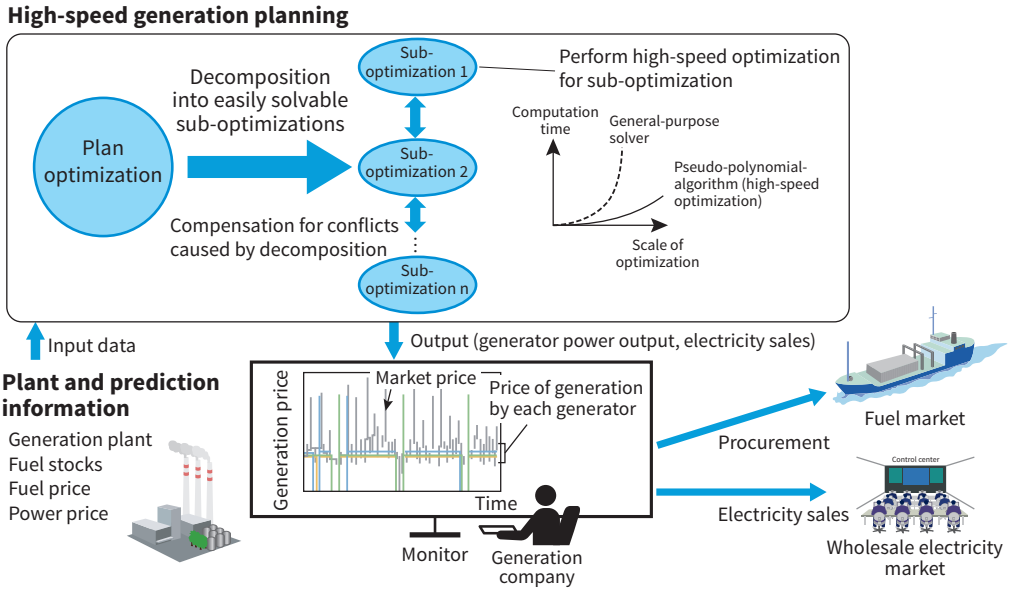
Hitachi has also developed an amplifier that uses silicon carbide (SiC) material in order to make the instrumentation at nuclear power plants more tolerant of radiation. As SiC is a wide-band-gap semiconductor, devices that use it are less prone to gamma-ray-induced defects than conventional silicon devices. By using complementary metal-oxide semiconductor (CMOS) components that take advantage of this superior property of SiC, the radiation tolerance of the new amplifier has been improved by a factor of 6,000 compared to previous amplifiers.

* The work described here was undertaken by Hitachi-GE Nuclear Energy, Ltd. in its role as a member of the project entitled, "Development of Technology for Detailed Investigation inside Primary Containment Vessel (On-site Demonstration of Technology for Detailed Investigation Considering Deposit Measures)" run by the International Research Institute for Nuclear Decommissioning.

3 Optimization Solution to Support Economical Electricity Supply and Demand Operation in Increasingly Volatile Electricity Markets

Generation companies predict future conditions such as volatile fuel and electricity market prices and optimize their operation plan for their plants in a way that makes economic sense. To maintain the economic sustainability of their operations in the face of changes in these future conditions, Hitachi is developing a solution for optimizing the supply and demand operations based on prediction techniques that compensate for prediction errors dynamically and planning techniques that can rapidly evaluate the impact of future changes and provide advance assessments of the consequences of specific actions to mitigate the impact.

In the operation planning, future changes such as fuel and electricity market prices during operation are simulated by several dozen scenarios and operation plans are



3 Diagram of high-speed planning technique

created to consider these scenarios and reduce risk of losses and constraint violations by taking countermeasures in advance. However, it can take several hours of computing to optimize the plan for just one of these scenarios. Accordingly, Hitachi has developed a high-speed planning technique that is able to complete even large-scale plan optimization in around half an hour by decomposing the plan optimization process and using parallel processing to concurrently execute high-speed pseudo-polynomial algorithms for each of these decomposed optimization processes.

This enables economic operation by increasing the number of scenarios that can be considered and by more accurately estimating the effects of potential actions or the changes in future conditions.

4 Use of Reinforcement Learning to Prevent Power Outages Based on Anticipation of Risks

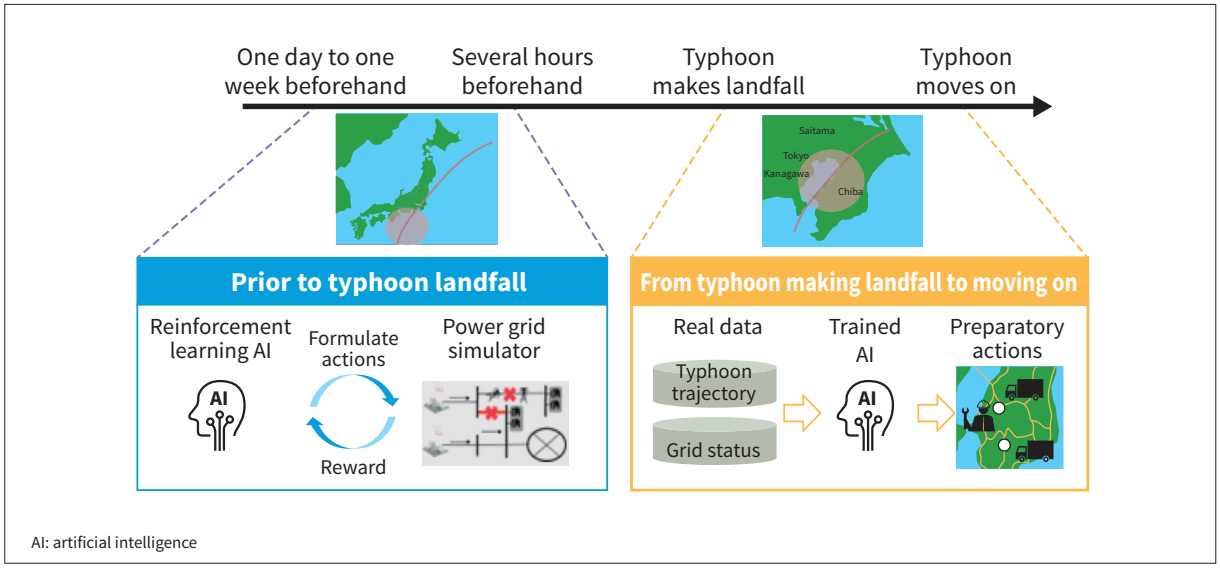
More attention is being paid to disaster preparedness measures that minimize the time and geographical spread of power outages caused by typhoons or other low-frequency/high-impact natural disasters. Conventional operational planning methods based on mathematical optimization have found it difficult to calculate timely operational plans for typhoons due to the way their path continuously changes over time, resulting in a massive increase in the number of fault scenarios that need to be considered. Hitachi has developed a technique for preventing power outages based on the anticipation of risks utilizing reinforcement learning.

This involves using a large number of transmission-line-fault scenarios generated from the typhoon predictions to train a machine learning model in advance on what actions are appropriate, taking account of the tradeoffs between the extent of outages and the costs of action. When a typhoon approaches, the trained model is then used to rapidly identify a set of actions that will be efficient given the actual damage. Simulations have verified that the technique can reduce power outages, taking less than an hour to produce plans for power plant output and the pre-deployment of mobile generators.

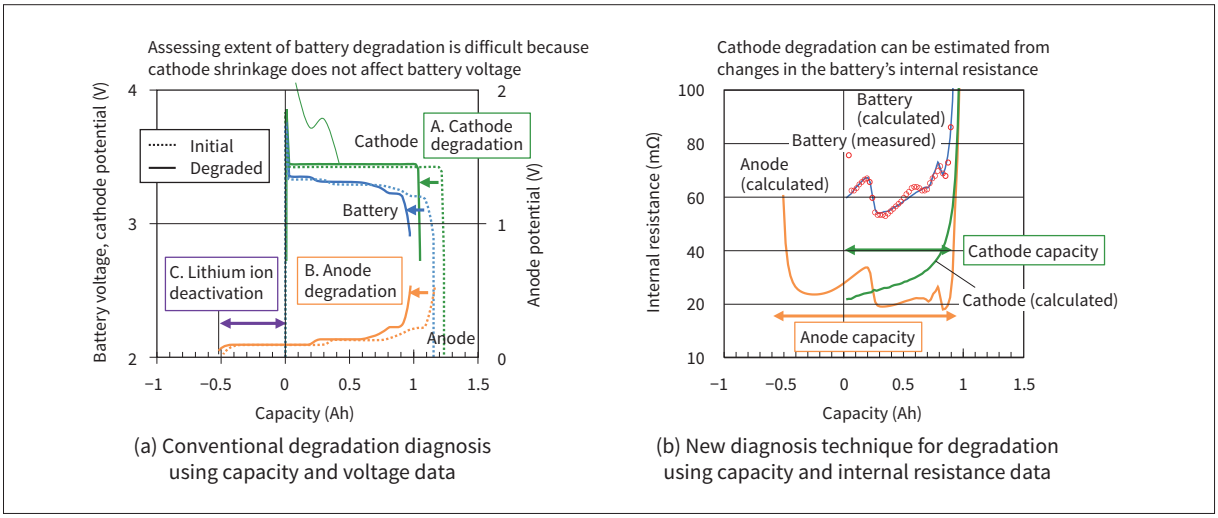
In the future, Hitachi intends to contribute to making the electricity system more resilient by continually testing the technique in practical use.

5 Accurate Diagnosis of Lithium-ion Battery Degradation through Discharge Curve Analysis

Lithium-ion batteries are experiencing rising demand for use as a power source in stationary electric power systems and electric vehicles. Ensuring high reliability in the control of these battery systems calls for accurate and non-destructive means of assessing battery degradation. For highly reliable control of the lithium nickel manganese cobalt oxide batteries that currently predominate, past practice at Hitachi has been to assess degradation using the relationship between battery voltage and capacity (discharge curve analysis). Recent years have seen growing use of lithium iron phosphate batteries, however, and this method does not work well on these batteries due to their characteristic of maintaining a constant voltage. In response, Hitachi



4 Flowchart for use of reinforcement learning to formulate actions in advance



(a) Conventional degradation diagnosis using capacity and voltage data

(b) New diagnosis technique for degradation using capacity and internal resistance data

5 Non-destructive diagnosis of causes of degradation in lithium iron phosphate batteries

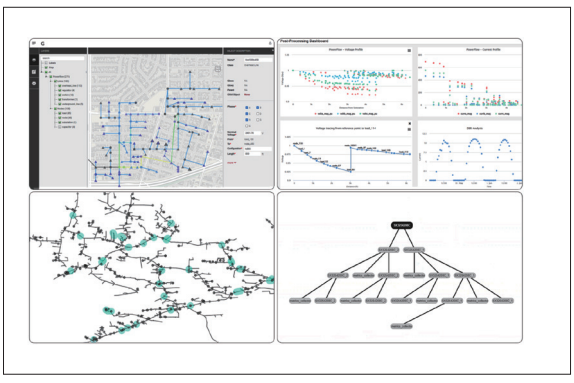
has developed a new diagnostic technique for degradation using data on capacity and internal resistance that has demonstrated high reliability on all types of lithium-ion battery, including lithium iron phosphate.

To commercialize this kind of battery diagnostic technique, Hitachi has developed a service for remotely diagnosing degradation in on-board automotive lithium-ion batteries in partnership with Hitachi High-Tech Corporation (detailed in a Hitachi High-Tech news release dated July 25, 2022). The service provides highly accurate remote diagnosis by combining the use of discharge curve analysis to collect basic battery data with a technique for assessing the extent of battery degradation from both this basic battery data and operational information from the vehicle.

6 Distribution Planning Method and Modeling Platform for DER Integration

The rise of self-generating communities is requiring advanced control of the grid and creating opportunities for innovation. Hitachi has developed an open-source power distribution planning method and modeling platform, G Platform, to bridge the gap and enable intuitive resource planning, which lowers the barriers for engineers to analyze the grid to manage and mitigate the impacts of distributed energy resources (DER).

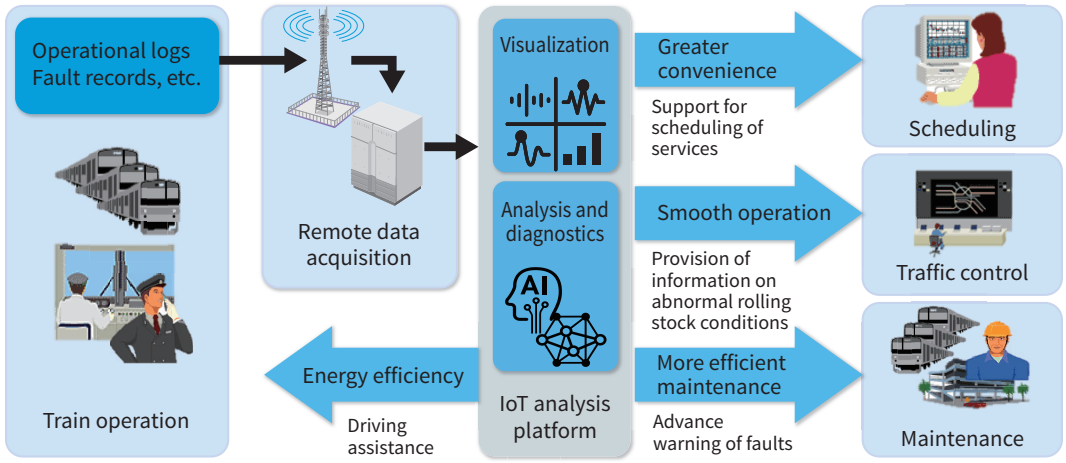
G Platform allows integration of third-party solvers for complex distribution grid modeling scenarios. Use cases include hosting capacity analysis, grid resilience, and electrification evaluation for buildings and electric vehicles. G Platform visualizes complex information, supports flexible architecture, and provides scalability for big data simulation. Additionally, a post-processing tool is integrated in the platform to facilitate data analysis and result realization. Deployment on both workstations and cloud computing are supported. G Platform promotes the adoption of green energy by reducing both the time and cost of the DER integration process. G Platform is supported with funding from the California Energy Commission under grant EPC-17-043.



6 G Platform

7 Added Value from Use of IoT for Rolling Stock Data

The comprehensive and quantitative monitoring of operations is essential to improving convenience and reducing operating costs for rolling stock. In response, Hitachi supplies solutions for resolving wide-ranging operational challenges such as energy and maintenance efficiency through the remote acquisition and analysis of rolling stock data. Underpinning these solutions, development is also progressing on techniques for the reliable and remote collection of data from rolling stock and on an analysis platform that utilizes the Internet of Things (IoT) for the visualization and analysis of big data archives.



7 Flowchart of how value is added through visualization and analysis of rolling stock data

One example of a solution that Hitachi has implemented to use these technologies is a driver support system that facilitates energy-efficient operation by showing the variability in train driving practices and identifying which practices use less energy.

In the future, Hitachi intends to extend this work to include support for driving practices that save energy and the scheduling of services to help improve convenience for passengers, the provision of information on abnormal rolling stock conditions to help ensure that those services run smoothly, and diagnostics for advance warning of faults to help make maintenance more efficient.

8 Development of Rolling Stock with Low Environmental Impact for HS2 in UK

The new High Speed 2 (HS2*) railway line in the UK is scheduled to enter service in 2029. Hitachi is currently developing a new generation of quiet and energy-efficient rolling stock for use on the line that feature low environmental impact and a top speed of 360 km/h. As aerodynamic drag accounts for the bulk of energy used by a high-speed train, streamlining the design plays a crucial role in energy efficiency. By leveraging expertise in the use of computational flow dynamics for large-scale simulations acquired from the past development of rolling stock for Europe, Hitachi is able to work rapidly through a large number of design iterations. By doing so, it has succeeded in creating a low-drag design.

Likewise for quiet operation, Hitachi has used operational trials on existing rolling stock to highlight and quantify the sources of noise in parts such as the pantograph and bogies, augmenting this with simulations to allow for actual conditions on the new line, including the infrastructure of the track and sound-insulating walls. Together, these practices have enabled the design of rolling stock that is quiet enough to satisfy the regulations and specifications.

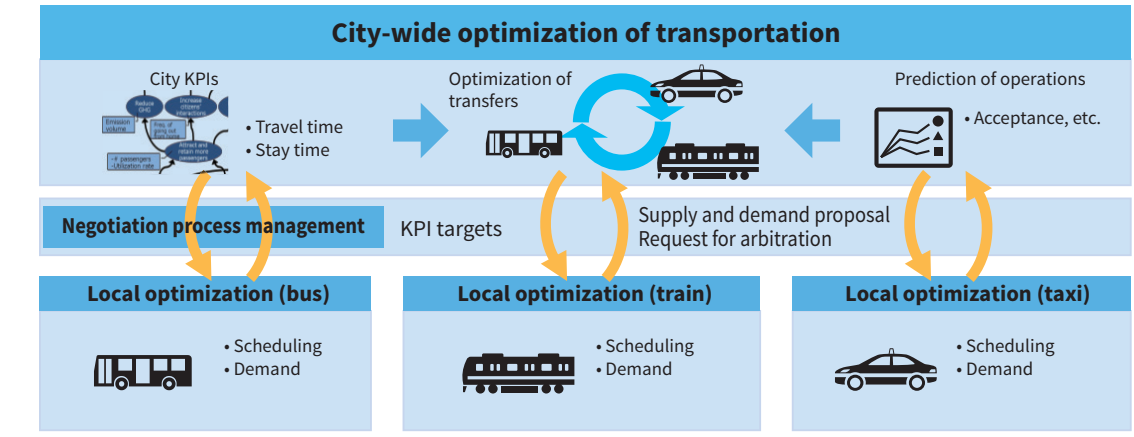
8 Artist's impression of HS rolling stock (top) and visualization of noise (bottom)

In the future, Hitachi intends to continue using simulation and measurement techniques to develop sustainable rolling stock with a low impact on the environment.

* See "Trademarks" on page 158.

9 Coordination of Mobility Providers to Improve Operations

COVID-19 has significantly impacted people's movement in terms of quality and quantity, raising expectations



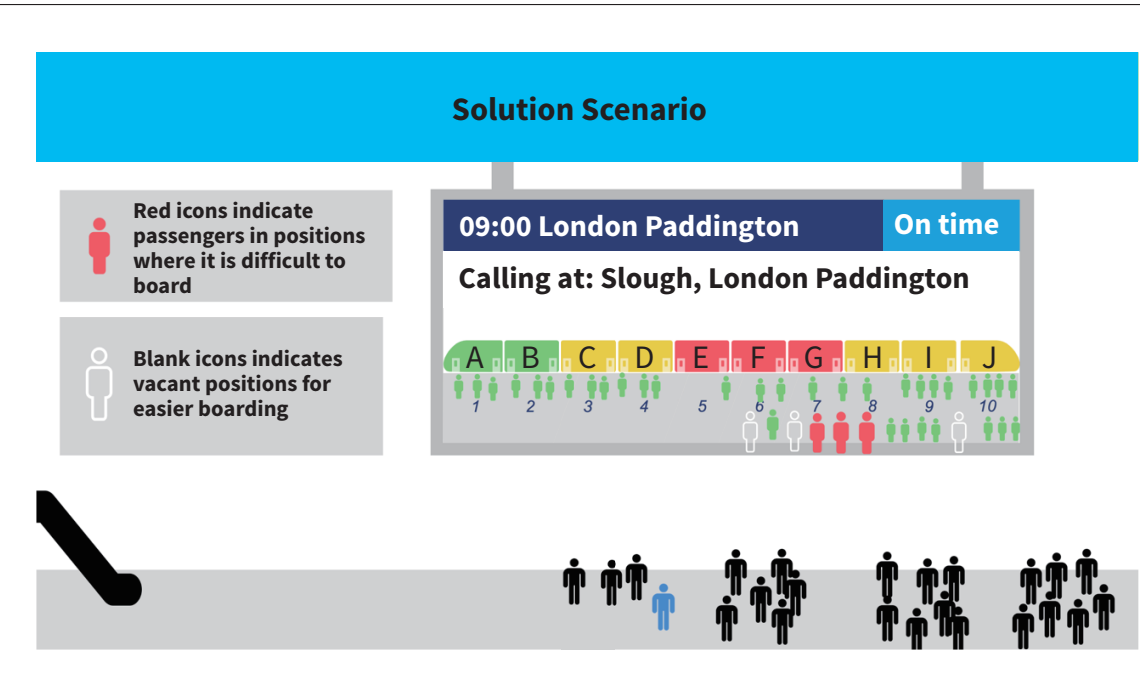
9 Coordination of mobility operations

for safety and comfort. The need for carbon neutrality also drives a modal shift toward public transportation, such as trains and buses with low carbon dioxide (CO_2) emissions. However, the different modes of urban mobility, including trains, buses, and taxis, are operated by various providers. Hitachi has developed a technology to facilitate operational improvements of mobility services provided by multiple entities and modes by coordinating these different mobility providers.

This technology looks at how each provider operates their services regarding their circumstance and then seeks to coordinate the public transportation and related services from the perspective of the city-wide transportation network by optimizing transfers between the various services. Hitachi aims to improve the convenience and sustainability of mobility services across entire cities by reducing overcrowdedness and ensuring seamless operation between different providers.

10 Easy Boarding—Optimising Passenger Boarding

The "Easy Boarding" solution reduces boarding times at busy stations by taking passenger boarding and disembarking data in real-time and visualising the optimal



10 Easy Boarding solution scenario

waiting positions for passengers on the platform. The goal is to reduce delays, improve passenger experience, and avoid accidents. Value was proven with Network Rail in the "First-of-a-Kind 2021" project funded by UK Research and Innovation.

Through collaboration with transport operators, the solution used historical passenger flow data from station sensors to simulate optimal passenger positioning with the potential to reduce boarding times by up to 50%. The solution was enhanced to comply with data protection regulations using the "privacy first" camera-as-a-sensor prototype; replacing real faces with synthetic faces using generative adversarial network technology.

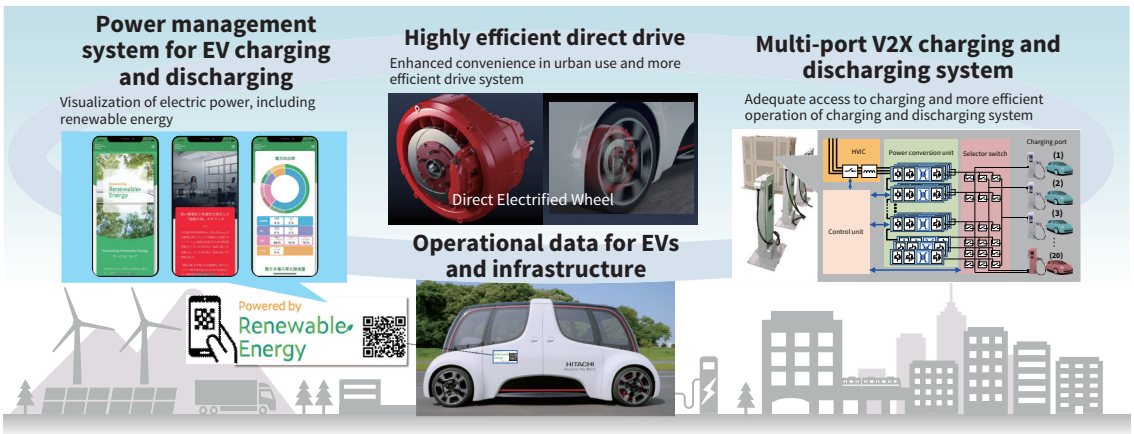
Passengers were interviewed to understand their motivations behind where they choose to wait along the platform, reflecting their needs into several interface designs, and usability testing each to identify the best option.

Hitachi Europe exhibited the solution at Innotrans 2022, alongside Hitachi Rail, leading to discussions and workshops with multiple transport operators across Europe.

11 Technology for Electric Mobility Infrastructure for Electrification of Society

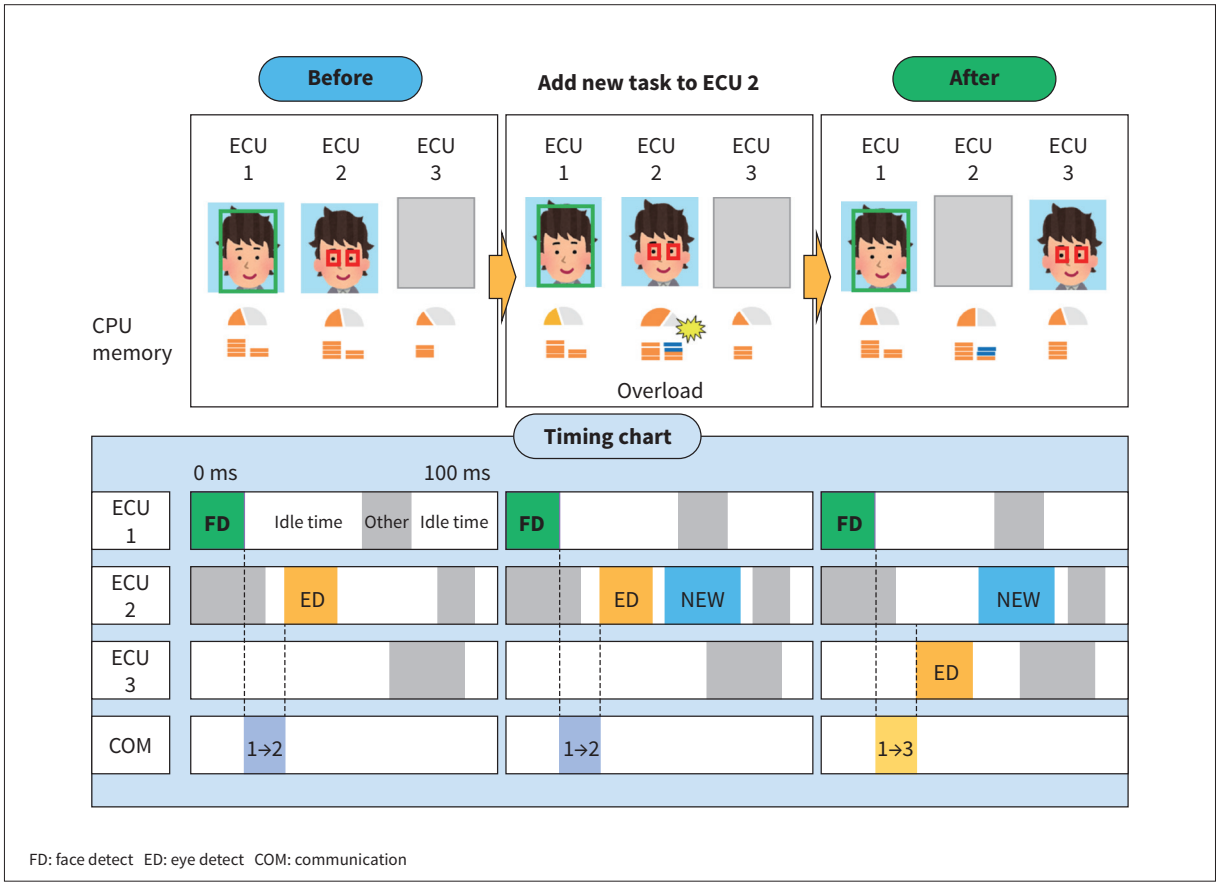
In response to the growing adoption of electric vehicles (EVs), Hitachi has developed a solution for EV charging and discharging to help establish infrastructure for electric mobility that operates efficiently not only for drivers and EV owners, but also for the infrastructure of the cities and other areas served by EVs. Overcoming the issues facing drivers and EV owners will require the delivery of renewable and other forms of energy while also ensuring sufficient access to vehicle charging to assuage concerns about its availability and making the EVs themselves more efficient to improve range. With existing charging systems, however, each charging port is tied to a specific parking space, meaning that the next vehicle cannot start charging until the previous one moves away. The result is less efficient use of the chargers and considerably fewer charging opportunities.

The new system ensures adequate access to charging by using a split configuration in which the output from multiple charging and discharging systems can be connected in parallel and switched on the basis of the number of EVs to be charged and when they will complete charging. This allows it to charge all of the EVs connected to the multiple charging ports provided, and to do so in an efficient manner without any gaps between one vehicle and the next. The system also uses digital grid technology to manage electric power for charging that is derived from renewable sources, thereby ensuring that this power is put to good use. This includes the analysis of operational data for drivers and EV owners and the areas where charging and discharging systems are located. Making vehicles more efficient and spacious is another important factor when they are used for transportation and delivery in urban areas. Hitachi has made improvements in these areas compared to previous EVs through the supply of direct-drive systems that provide higher efficiency and carrying capacity.
(Hitachi Industrial Products, Ltd. and Hitachi Astemo, Ltd.)



V2X: vehicle to x HVIC: high-voltage input circuit

11 Electric mobility infrastructure for electrification of society



12 Looking for idle time to spread processing workload

12 Software Design for Advanced Automobiles

Hitachi has developed software design techniques for creating the advanced cars of the future in which "connected, autonomous, shared and services, and electric" (CASE) are key features.

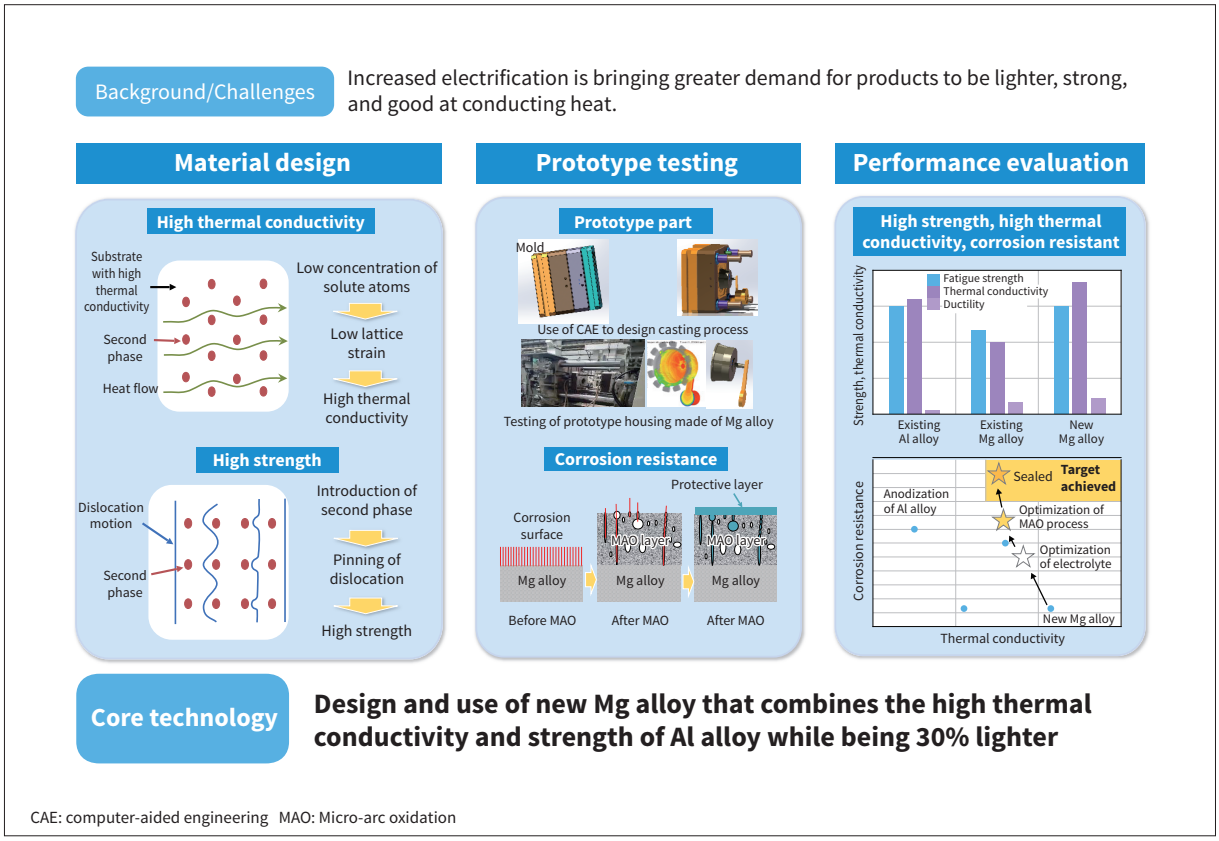
When using over-the-air (OTA) updating of software, it is necessary to ensure not only that the software being updated will operate as intended, but also that it will not interfere in unexpected ways with the output of the other existing control software. This new technique works by fixing the execution timing of each task (unit of software processing) and each communication between electronic control units (ECU) and then determining what idle times occur under these constraints. The task allocation and other configuration details are then adjusted to make room for the additional tasks and balance the processing workload for the new functions being added. This makes design and verification more efficient by keeping the same task execution sequencing, enabling software updates to be completed quickly and at low cost.

In the future, Hitachi intends to fulfill the expectations of its customers by supplying next-generation ECUs that combine performance and low cost, utilizing this new technique for autonomous driving and advanced driver assistance system (ADAS) ECUs that are updated by OTA as well as for the consolidation of multiple existing ECUs into a single device.

13 Light, High-strength, and High-thermal-conductivity Mg Alloy for Electric Mobility

The use of EVs has grown rapidly over recent years as part of efforts to make mobility greener. As reducing the amount of energy consumed by these vehicles requires that they be made significantly lighter and more efficient in their use of energy, this has also been accompanied by rising demand for automotive parts to be lighter, strong, and good at conducting heat. There is currently intense competition among automotive manufacturers to make their vehicles lighter and more energy efficient with longer range.

In pursuit of these goals of lighter weight, higher strength, and higher thermal conductivity in parts, development efforts in the field have focused on optimizing the design of material composition and microstructure. By using a base material with a low density of solute



13 Development of Mg alloy for electric mobility

atoms together with introduction of a second phase that is effective at pinning dislocations, Hitachi has successfully developed a new magnesium (Mg) alloy that combines the high thermal conductivity and strength of existing aluminum (Al) alloys while being 30% lighter. The ability of parts made from this Mg alloy to satisfy performance requirements has also been verified using a prototype housing. This prototype made from the new Mg alloy is intended to provide a high level of functionality, including improved corrosion resistance. Future plans include investigations into the use of the technology by Hitachi's business units.

Innovation for Advancing with Customers
Connective Industries

1 Online CPS for Dynamic Modification of Production Lines

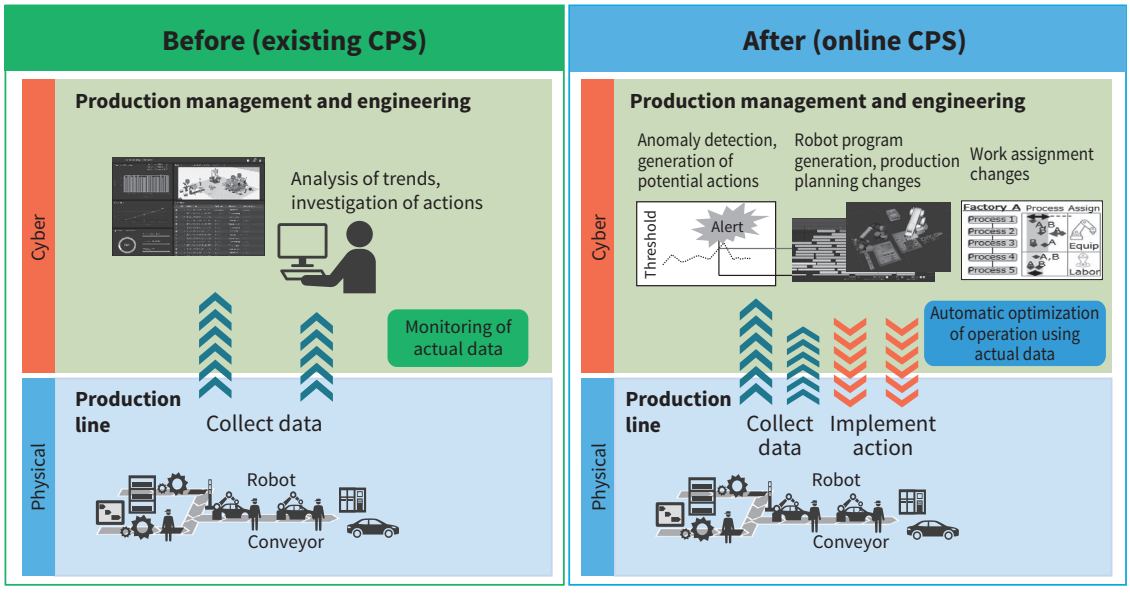
The challenges of recent years have included growing geopolitical risk, increasingly diverse customer requirements, shorter cycle times, and a shrinking workforce. In response, it is becoming more important than ever for manufacturing plants to be faster and more efficient in how they commission, operate, modify, and repair production lines. To address this challenge, Hitachi has developed practices for online cyber-physical systems (CPSs) that can dynamically modify the planning and control of production lines in response to demand fluctuations and changes in the plant itself.

While past practice with CPSs has required supervisors to monitor the actual data collected from the production line and consider what actions to take based on the analysis of trends, the problems with this are that analysis requires considerable expertise and it takes a lot of work to formulate a plan of action, during which time the line may be halted. With an online CPS, it is possible to automatically optimize the tasks of detecting anomalies, generating actions, and modifying plans. The result is a faster transition to the new plan, allowing the line to remain in production without shutdowns.

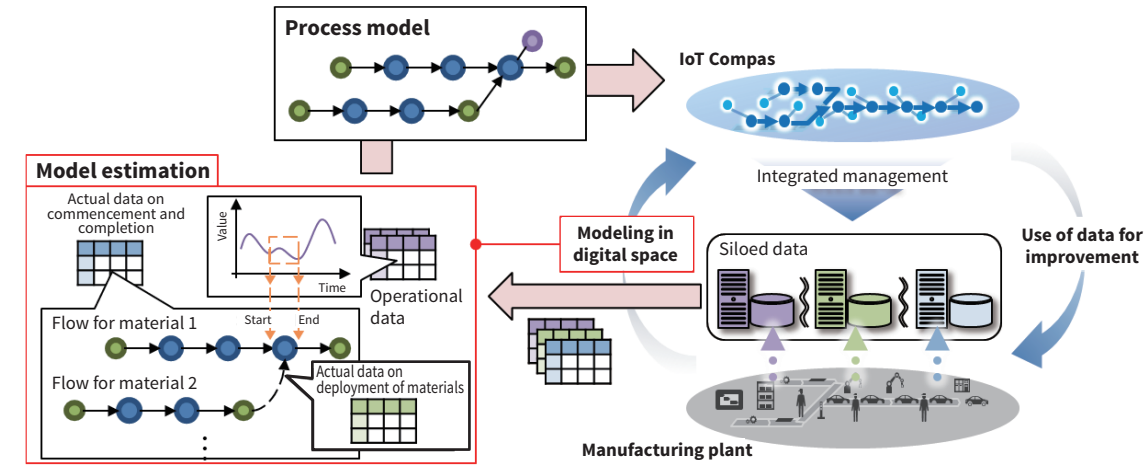
2 Automatic Generation of Process Models to Simplify Data Management

The use of data to optimize production processes has attracted interest in the manufacturing industry. However, the data generated by manufacturing plants is spread across different processes and systems, meaning a lot of time goes into collecting and managing the data. To overcome this problem, Hitachi supplies IoT Compas that simplifies the integrated management of this scattered data across all processes by linking it to process models that replicate the actual manufacturing processes in digital space, allowing it to be managed centrally.

Currently, model designers build these process models by gaining an understanding of the manufacturing processes and working out how to link the data. To improve this situation, Hitachi is undertaking research



1 Features of online CPS



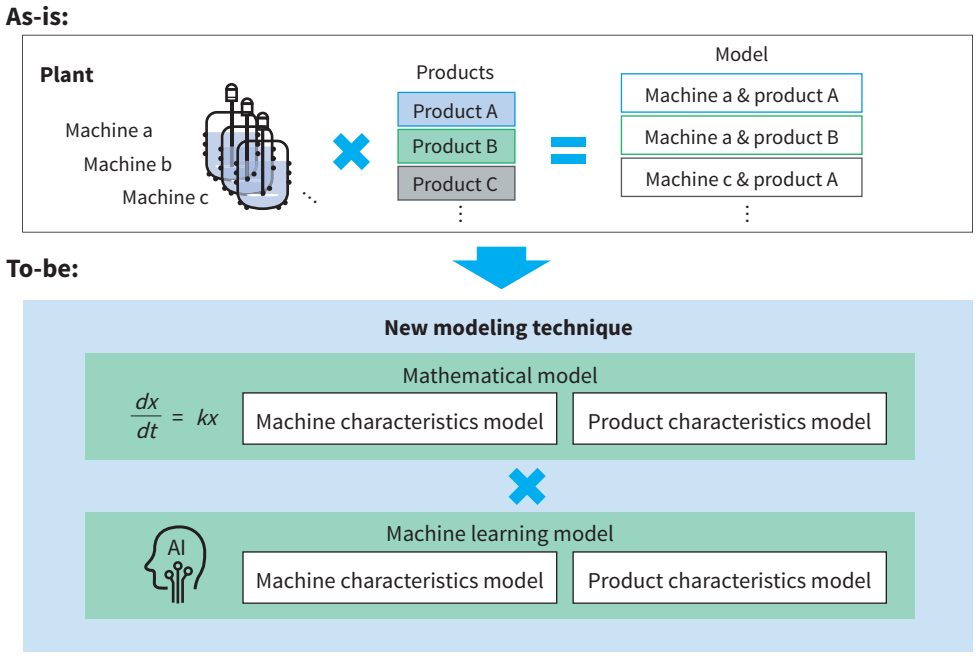
2 Using process mining to accelerate applications for IoT Compas

and development on ways of reducing the amount of time taken for model building, adopting a data-driven approach to model estimation that utilizes this plant data. This includes actual data on the commencement and completion of tasks and on the deployment of materials. Utilizing the results of this work, Hitachi intends to further simplify the integrated management of data by achieving an 80% reduction in the amount of time spent on the key task of process modeling.

3 Batch-specific Modeling of Reaction Process Characteristics Utilizing both Mathematical Formulas and Machine Learning

The automation of plant operation is one of the ways in which digital solutions can be applied to chemical processes. To this end, Hitachi has developed a technique for modeling batch processes.

Variability in production times and product quality due to chemical reactions not proceeding as intended is an issue of concern at plants that are operated manually.



3 Block diagram of modeling technique

One way to address this is to model the behavior of the process using mathematical formulas so that the appropriate control actions can be determined automatically. The problem with this is that plants use a wide variety of equipment to produce a wide variety of products. The need to model every combination of these makes the cost of model building very high.

In response, Hitachi has developed a way to use machine learning to model those product and machine characteristics that vary by type, and mathematical formulas for those characteristics that do not. A desktop evaluation found that this approach can deliver similar accuracy to that for mathematical formulas on their own. The result is that modeling costs less than when using only mathematical formulas, while having higher accuracy than machine learning could achieve on its own.

4 Development of FREEDi Sensor Glove for Tracking Actions of Workplace Staff

Hitachi has developed a sensor glove solution called "FREEDi" (an abbreviation of "FREE your data input") that can be used at plants where assembly or machining work is done manually to capture and present information about actions performed by workers, including the level of fingertip force exerted when picking objects up, hand movements, and the sounds made during work.

Data sent wirelessly from sensor-equipped gloves is received by a remote device where the particular characteristics of each action can be identified as needed and this information is passed to the worker or supervisor. Worker training is one use, providing a useful way to show differences in technique between an experienced worker and their trainee. It can also help to prevent manufacturing defects by detecting worker errors as they happen in the production line, such as missed actions or deviations from procedure.

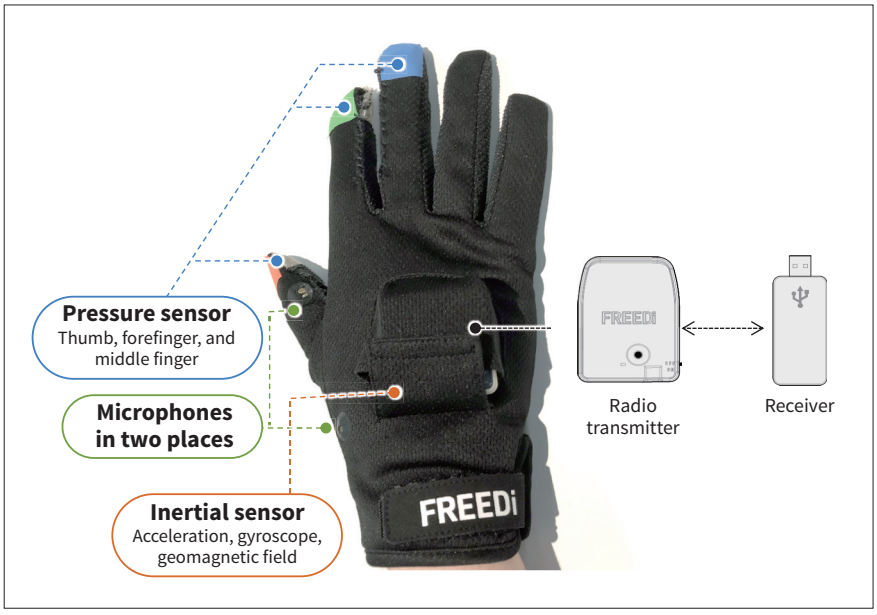
In the future, Hitachi intends to transform FREEDi into a solution that can be used in a wide variety of workplaces and address a wide range of customer needs by improving the glove's ability to detect actions and using it in tandem with other sensing methods. Hitachi also plans to create factory IoT solutions that combine the various ways in which records are collected at manufacturing plants.

5 Digitalization of Welding Expertise

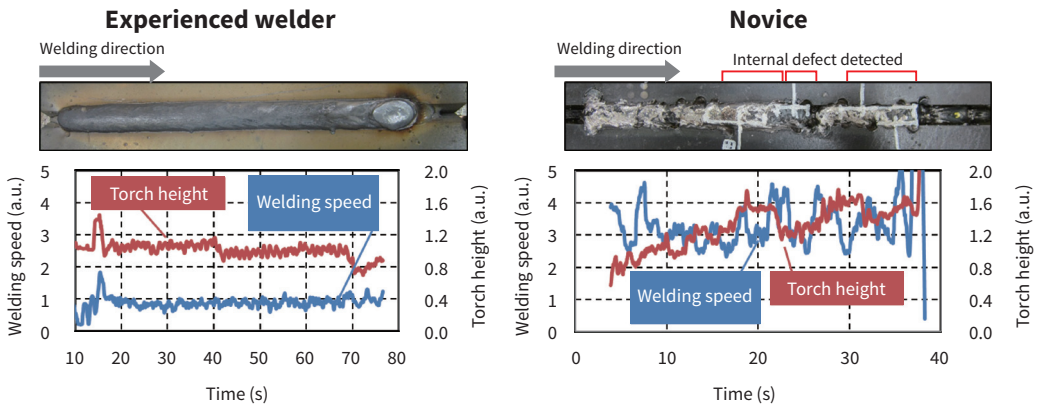
Hitachi has developed a way to digitalize welding expertise, having recognized the difficulties posed to society by the loss of skills and expertise in manufacturing as the population ages and the birthrate remains low.

A major feature is the ability to use techniques such as motion capture for the highly accurate measurement of feature values for welding actions identified on the basis of practical knowledge, and to make this information available.

A comparison of how an experienced and novice welder handle a welding torch found that, whereas the actions of the expert were steadier, with less variation in the torch height and welding speed, the novice welded more than



4 FREEDi glove



5 Comparison of welding actions of experienced and novice workers

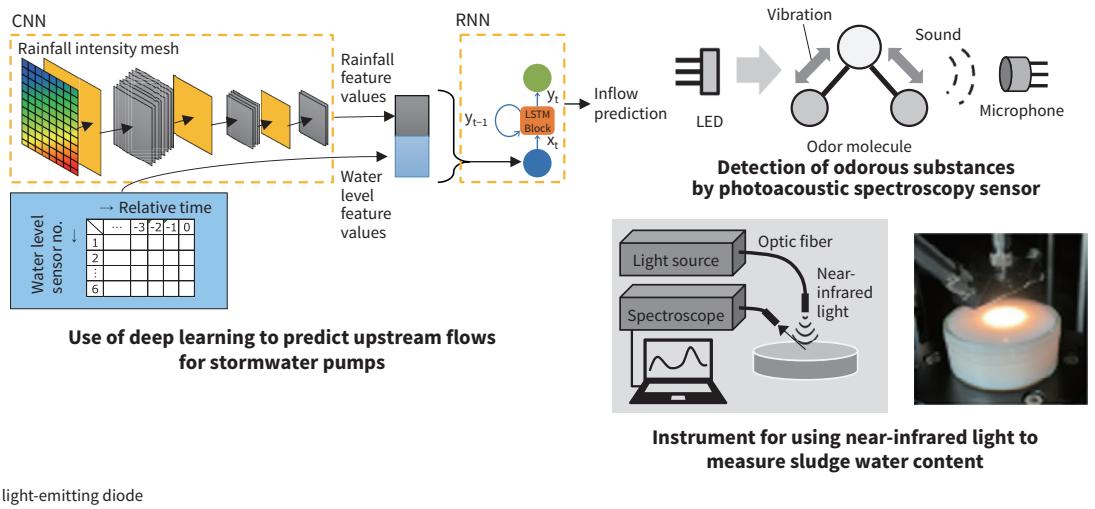
twice as fast and also lifted the height of the torch as they worked. Quality issues in the form of internal defects were also found in the work of the novice welder. These were believed to be the result of incomplete fusion, a consequence of insufficient heating of the weld due to the higher weld speed and torch height used by the novice.

This demonstrated that the technique can be used to assess weld quality based on the welding action. In the future, Hitachi intends to make use of this technique to facilitate the more efficient transfer of skills in the manufacturing workplace.

6 Digital Solution for Water Supply and Sewage Contributing to Sustainable Public Safety and Security

While maintaining a healthy environment supported by water and sewage infrastructure that underpins safe and secure ways of life is essential to the sustainable progress of society, the many challenges to achieving this include increasingly severe and frequent heavy rainfall events, workforce shortages due to a falling population, the retirement of experienced staff, and action on reducing greenhouse gas emissions. To address these societal challenges, Hitachi supplies water and sewage system operators with digital solutions that support many different aspects of their operation and maintenance work, including information presentation, labor-saving and efficiency measures, and skills transfer.

One example is the work currently under development on systems for predicting pumping station inflows, with models that combine convolutional neural networks (CNNs) and recurrent neural networks (RNNs). By assisting with the operation of stormwater pumps, these methods can help prevent flooding due to heavy rainfall events. For the operational management of plant and machinery, where the practice is for inspection staff



LED: light-emitting diode

6 Technologies for water supply and sewage solutions

to conduct regular onsite inspections that use smell to check for problems and identify when something has changed, Hitachi is responding to the needs of utilities experiencing workforce shortages by developing systems that use compact odor detectors based on techniques such as photoacoustic spectroscopy. For sewage sludge, a renewable resource that people want to see put to good use, Hitachi is also working on a system that utilizes a simple technique based on near-infrared light to measure sludge water content (an important parameter) and guide the operation of sludge dewatering systems. Along with helping to improve operating conditions, this is also intended to facilitate skills transfer.

7 Generation System Using Fuel Derived from Renewable Energy

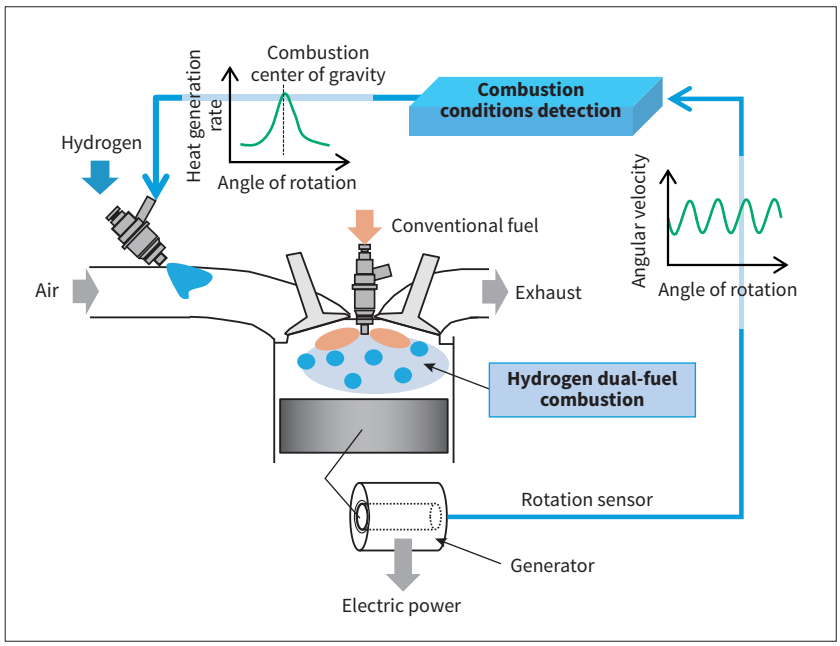
Hitachi is investigating the use of fuel derived from renewable energy to help achieve carbon neutrality, one aspect of which is the work it is doing with the stakeholders involved in the hydrogen supply chain on demonstrating its viability. This has included the practical implementation and operation of hydrogen dual-fuel generation systems that have a high level of compatibility with existing infrastructure. These systems work by burning hydrogen along with a conventional fuel (such as biofuel or diesel). As they are also able to operate on conventional fuel alone, they allow for a gradual transition to carbon neutrality.

Abnormal combustion caused by changes in ambient temperature or in the amount of hydrogen supplied to the engine are an issue on this system. Accordingly, Hitachi has also developed a technique for detecting combustion conditions that can identify such abnormalities in real time. The way this works is that the controller is equipped with a mechanism for detecting the combustion center-of-gravity time in real time based on changes in angular velocity measured by a sensor attached to the generator shaft. By working in tandem with the hydrogen supply system to adjust the supply of hydrogen when abnormal combustion occurs, this enables the safe use of hydrogen to generate electric power under variable ambient conditions.

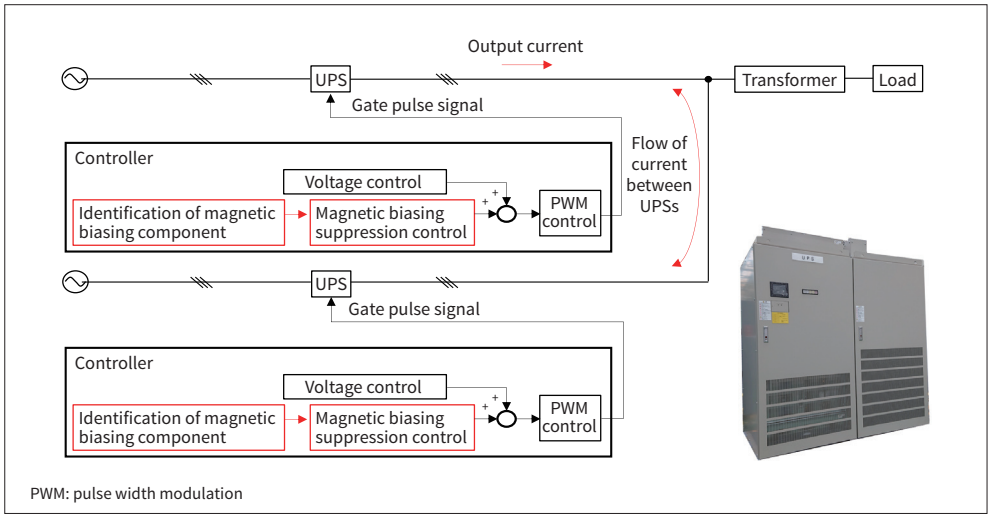
8 Compact and Highly Efficient 500-kVA UPS for Data Centers

Hitachi supplies uninterruptible power systems (UPSs) in a range of sizes to suit customer requirements, having developed a series of compact and highly efficient models designed for high reliability and capable of being connected in redundant configurations. Demand has been particularly rising from the large data centers that have come to play a key infrastructural role over recent years due to advances in digital technologies such as artificial intelligence (AI) and the IoT together with the growing prevalence of remote working and e-commerce. This has led Hitachi to develop a 500-kVA UPS for large data centers that combines high efficiency with small size.

To achieve a small size, the new UPS features a technique for suppressing magnetic biasing in the load



7 Block diagram of hydrogen dual-fuel generation system



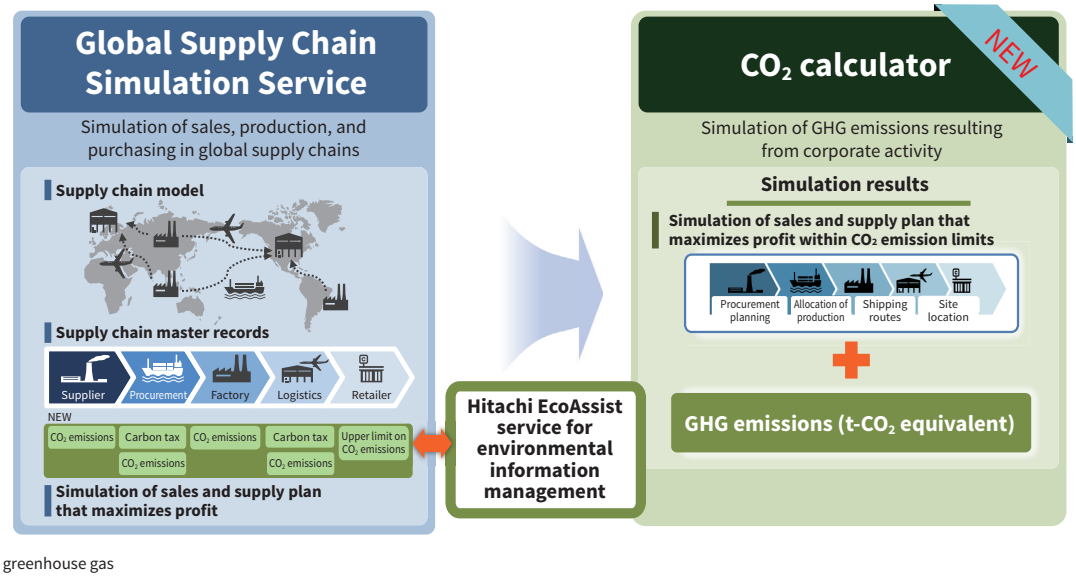
8 Magnetic biasing suppression and 500-kVA UPS

transformer without the need for a reactor. While this requires the magnetic biasing component in the output current to be determined, this is made difficult by the current that flows between UPSs connected in parallel. To overcome this problem, Hitachi developed a way to eliminate the influence of this cross-flow current and an associated magnetic biasing suppression technique. This eliminates the need for a magnetic biasing control reactor in the UPS.
(Hitachi Industrial Products, Ltd.)

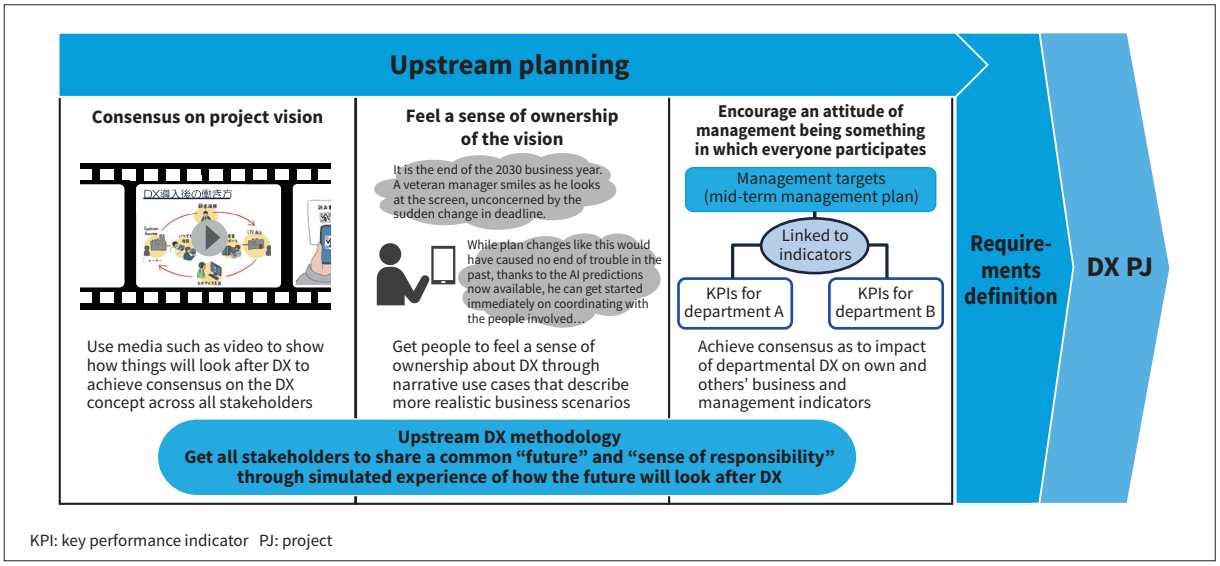
9 Global Supply Chain Simulation for CO_2 Reduction

As society pursues decarbonization, the manufacturing industry is being called upon to reduce the emission of carbon dioxide (CO_2) in its supply chains. While one way to reduce emissions is by producing locally to eliminate the emission of CO_2 during shipping, it is important to combine emissions reduction with economic efficiency as changes like this may result in higher procurement and production costs.

To address this issue, this solution uses mathematical optimization to automatically identify the supply chain configuration that maximizes profits while remaining within specified upper limits on the emission of CO_2 from specific sites or regions. In addition to being able to assess the CO_2 emissions associated with raw materials, procurement channels, production processes, equipment, and sales and freight routes, the solution also links to the EcoAssist-Enterprise-Light service for environmental information management from Hitachi Solutions, Ltd. to support the maintenance of master records on CO_2 emissions.



9 Overview of CO_2 calculator function in Global Supply Chain Simulation Service



10 Diagram of upstream DX methodology

In the future, Hitachi intends to contribute to the decarbonization of society by using this solution to support the review and restructuring of supply chains in the manufacturing industry.
(Hitachi Solutions, Ltd.)

10 Upstream DX Methodology Crucial to Success of DX Projects

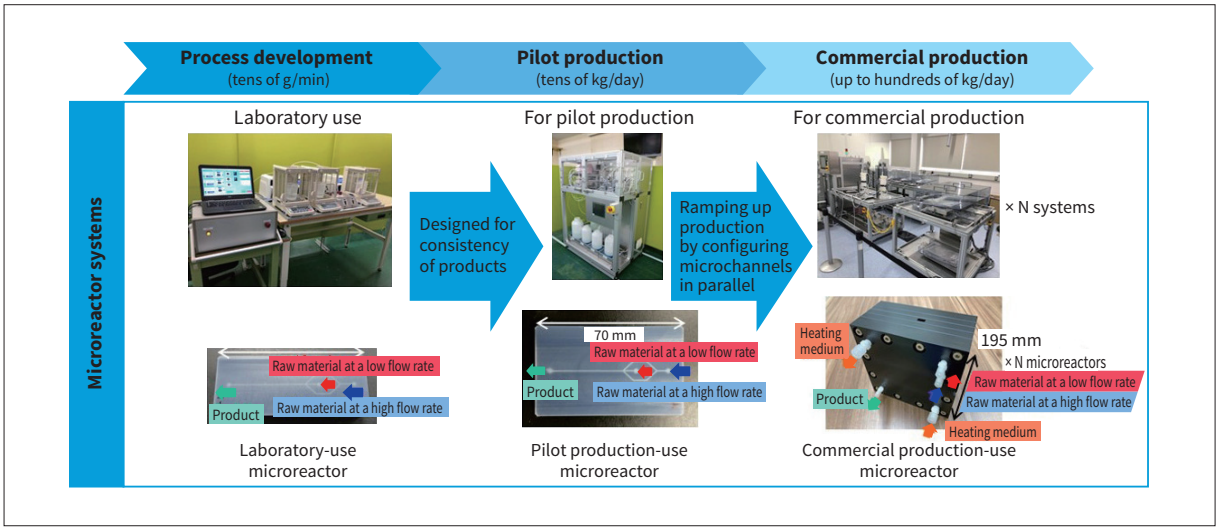
A key to the success of digital transformation (DX) projects is to discuss the concepts involved with a range of stakeholders during the early (upstream) stages of the project to build a consensus. To facilitate this, Hitachi has developed an upstream DX methodology whereby companies can clarify their vision for what it is they are seeking to accomplish with DX, accelerating the subsequent actions by getting their customers thinking with one mind as to what is entailed.

This methodology gets the participants to feel a sense of personal ownership by providing a simulated experience of the future world that DX is seeking to bring about. This is done by bringing the customer and Hitachi together to work through two processes: the formulation of a vision derived from management considerations and a narrative that describes what their post-reform operations will look like, starting with the assignment of respective responsibilities. It also confirms that staff and management are pursuing the project as a unified team by tracking the relationships between the various performance indicators used by stakeholders from different departments and levels of management at the company. This provides logical clarity as to the impacts that the different DX reforms will have on the business from a financial perspective.

The methodology was used in a project with an industrial machinery manufacturer. Quick agreement was achieved on a DX strategy that would simultaneously address management concerns and the problems that staff experience in the workplace, and the methodology also helped with the subsequent project implementation. In the future, Hitachi intends to continue contributing to DX at its customers as it further enhances the methodology.

11 Development of Microreactor Systems for Pilot and Commercial Production

Hitachi has developed plastic microreactors suitable for use in both pilot and commercial production that are able to mix two different raw materials at high flow rate ratios. As a continuous-flow chemical reactor that works by rapidly mixing raw materials in microchannels with precise control of reaction temperature, the microreactor can dramatically improve efficiency of production for pharmaceuticals and other products. The use of a sheath flow channel in which the flow of one of the raw materials is sandwiched between the other means that mixing can be performed with a wide range of flow rate ratios. Being made from highly corrosion-resistant polyethylene or polypropylene, the microreactors can also be treated as single-use (disposable) items, as is required in the manufacturing of biopharmaceuticals. For use in pilot production, it is designed to deliver products that are consistent with those of the already developed laboratory-use microreactor. In commercial production, the production volume can be ramped up by configuring microchannels in parallel.



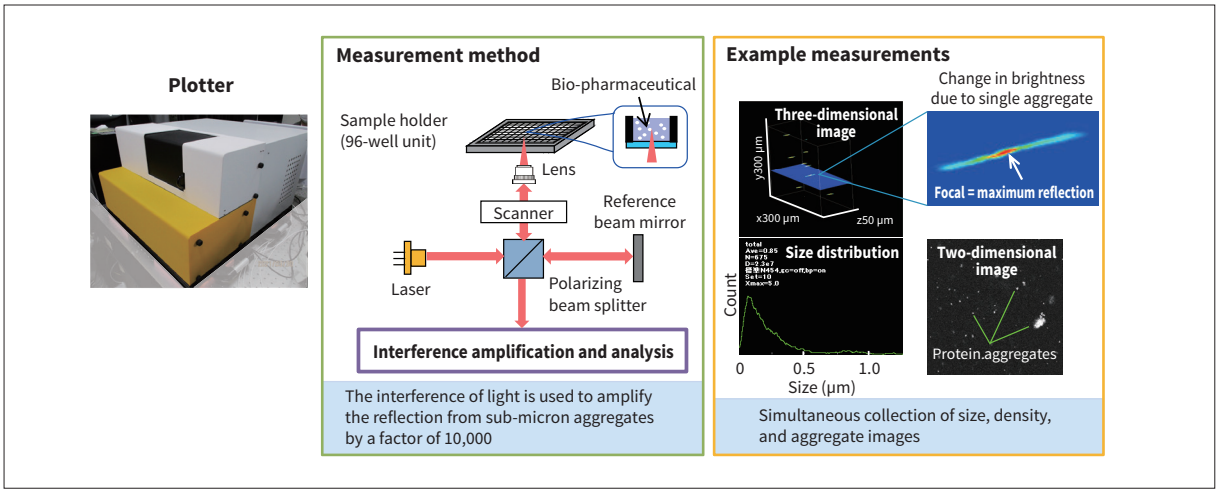
11 Microreactor systems that shorten the time from product development to commercialization

Hitachi has also developed a pilot production system equipped with three pilot production-use microreactors and a commercial production system with two commercial production-use microreactors. Compared to a conventional batch method, these systems can shorten the time taken from product development to commercialization and reduce the quantities of raw materials and waste products. In the future, Hitachi intends to continue testing its microreactor systems and expanding their applications.

12 Development of Aggregate Measurement Technique for Bio-pharmaceuticals

The focus of new drug development is undergoing a major shift away from low-molecular-weight drugs and toward bio-pharmaceuticals based on bio-technology. Having a convenient and accurate way to measure and control the size and density of the protein aggregates present in bio-pharmaceuticals is important to ensuring their efficacy and safety. While different techniques are used to measure protein aggregates depending on their size, the lack of a suitable means of measuring in the sub-micron (0.1 to 1 μm) range has been an issue.

To address this, Hitachi has utilized its own technology for high-resolution laser interferometry to develop a technique (three-dimensional homodyne light detection) that is able to perform measurements on drugs without the need for preliminary steps such as filtering or drying. It works by rapidly scanning the contours of the drug with a laser beam to build a three-dimensional image. Interferometry is used to amplify the scanning signal strength by a factor of about 10,000, enabling detection of the weak reflections from sub-micron protein aggregates. The three-dimensional image is then analyzed to identify the individual protein aggregates and the strength of the reflected light is determined to measure their size



12 Three-dimensional homodyne light detection

and density. Hitachi hopes to commercialize this technology in the near future to help improve the safety of bio-pharmaceuticals.

13 Testing Solution Using Tabletop Electron Microscope for Simple, Sensitive, and Rapid Antigen Testing

Rapid antigen testing is used for a wide variety of purposes, including testing for infectious diseases, food poisoning, and pesticide residue. The presence of viral or bacterial antigens is indicated by a color change in the testing kit's test line. This color change occurs when marker particles that bind the antigen accumulate along with the antigen in the test line. Unfortunately, antigen detection does not work when the quantity of antigen is small because the color change in the test line is too hard to see.

In response, Hitachi has participated in joint research with Hamamatsu University School of Medicine to develop a way to achieve high sensitivity in rapid antigen testing. The technique works by using a tabletop electron microscope to count the number of metallic marker particles. By doing so, it is able to achieve sensitivity similar to that of polymerase chain reaction (PCR) testing. Testing has also been made quick and simple by automating the acquisition and analysis of electron microscope images, tasks that in the past required special expertise.

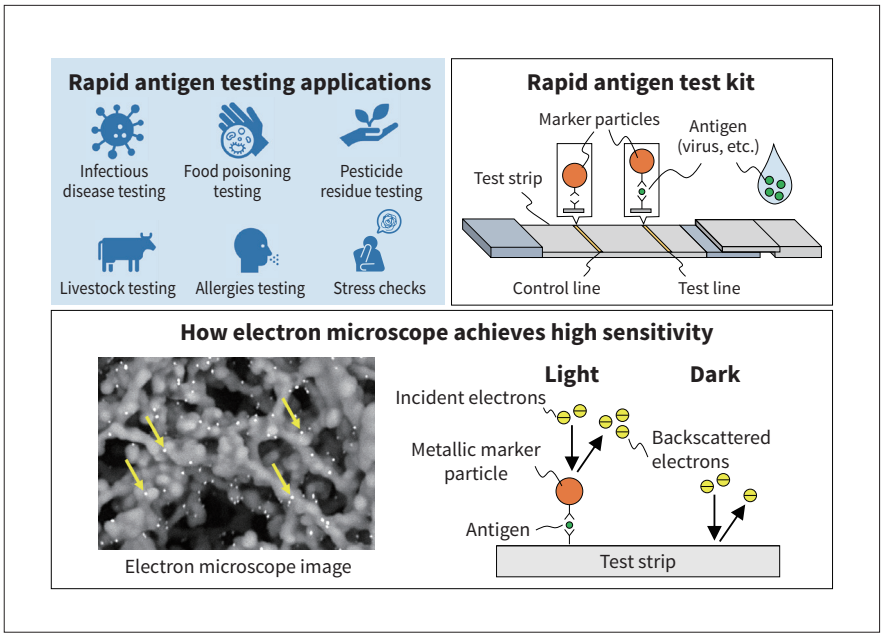
In the future, Hitachi plans to supply new solutions that utilize the data collected using this method in applications such as infectious disease and food testing.

14 Highly Efficient Materials Search Using Chemicals Informatics

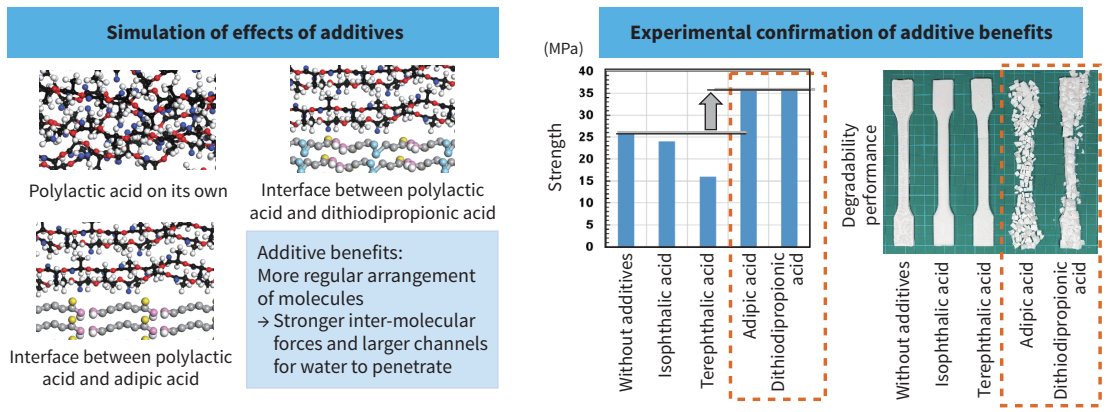
To help achieve carbon neutrality, Hitachi has used the Chemicals Informatics (CI)* materials search AI to look for additives that will improve both the strength and biodegradability of polylactic acid, a plastic produced from biomass. This led to the identification of adipic acid and dithiodipropionic acid additives. In a molecular simulation of the effect of these additives on the plastic, it was found that they increase inter-molecular forces by causing the molecules to arrange themselves a more regular pattern while also enlarging the channels that allow water to penetrate. By doing so, they improve both strength and water absorbance (an indicator of degradability). Experimental testing based on these findings likewise found that the additives increase strength in tensile testing while also improving degradability. This served as a demonstration of how effective CI can be as a tool for materials search.

Furthermore, the process from search to experimental testing was completed in only two months, indicating that the time taken for materials design can be significantly shortened compared to what it would have been had CI not been used (estimated at about three years). Hitachi intends to make use of CI in a wide variety of material search and design applications as it works to achieve carbon neutrality.

* Chemicals Informatics is a software package and service supplied by Hitachi High-Tech Corporation.



13 Rapid antigen testing applications and how high sensitivity is achieved



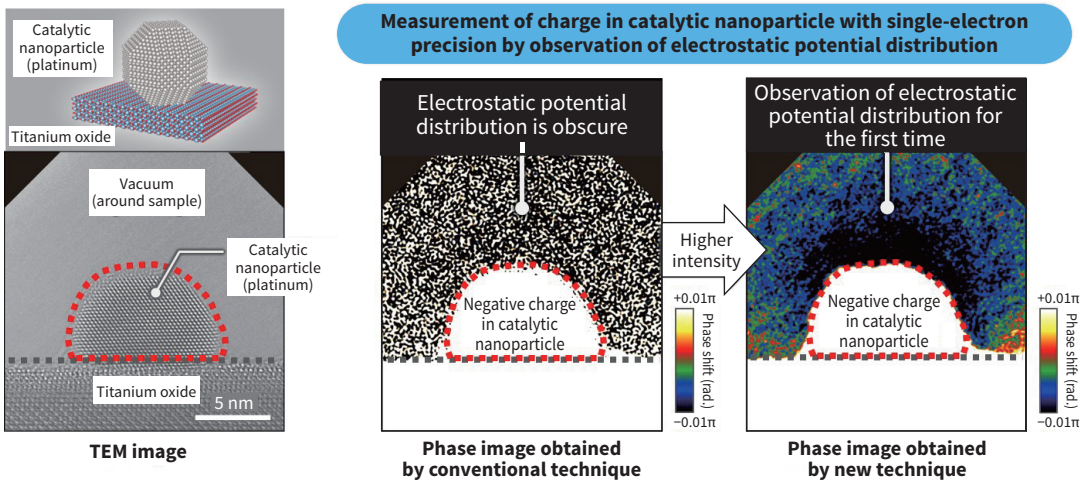
14 Results of simulation and experiment for additives identified by CI

15 Advanced Electron Microscopy for Environmental Applications

Catalysts, which promote a wide variety of chemical reactions, play an especially important part in overcoming global-scale challenges such as environmental cleanup and increased food production. To accelerate catalyst development through innovation in measurement techniques, Hitachi has worked with Kyushu University, Osaka University, and Akashi College of the National Institute of Technology (KOSEN) to achieve an order-of-magnitude improvement in the phase measurement accuracy of electron holography, a method for using transmission electron microscopy (TEM) to observe electrostatic potential distribution in a material. The method involved a unique research strategy that combined the latest techniques in electron microscopy with methods from information science for the extraction of extremely weak signals. This extreme sensitivity was then utilized to accomplish ground-breaking measurements whereby the extremely weak electric charges in the catalytic nanoparticles involved in chemical reactions were counted with single-electron precision[*1].

Electron holography is also a useful tool for measuring very small magnetic fields. In work that included Tohoku University, Hokkaido University, and the Japan Fine Ceramics Center, it has also been put to use in an extraterrestrial application involving the magnetic analysis of samples collected from the Ryugu asteroid by the Hayabusa 2 spacecraft. This succeeded in observing circular magnetic domain structures with high magnetic stability in particles of magnetite (Fe_3O_4) contained in the sample, and in making high-resolution measurements of the magnetic flux distribution of the adjacent magnetic fields[*2].

It is hoped that electron holography will also help in future research aimed at determining the magnetic field



15 Image of electrostatic potential distribution around catalytic nanoparticle obtained by electron holography

environment and empirical temperatures in which the sample was formed in the Ryugu asteroid 4.6 billion years ago.

*1 This research received funding from the Core Research for Evolutionary Science and Technology (CREST) of the Japan Science and Technology Agency (JST) (JPMJCR1664) and was published in the October 13, 2022, online edition of the journal Science. R. Aso et al., Science 378 (2022) 202.
*2 This research was undertaken by the Stone Analysis Team, a sub-team of the Hayabusa 2 Initial Analysis Team, with the electron holography measurements receiving funding from JPMXS0450200421 and JPMXS0450200521. The work was published in the September 22, 2022, online edition of the journal Science. DOI: 10.1126/science.abn8671

16 Refrigerant Leak Detection Technique for Remote Monitoring/Predictive Diagnosis IoT Solution "exiida" for Air Conditioning

Responding to a revision of the Fluorocarbon Emissions Control Act, which now permits automation of simple inspections currently performed visually, Hitachi has developed a technique for using remote monitoring data to detect refrigerant leaks.

The technique works by training on sensor data collected while the equipment is operating normally. When checking for leaks, it identifies signs of anomalies by detecting whether or not this data diverges from the acceptable range, using the existing fast-local subspace classifier (F-LSC) method to calculate the degree of divergence from the normal operation. Another feature of the technique is that an indicator of the refrigerant leak amount was created based on knowledge of how the cooling cycle works. This was done by identifying sensor data that is strongly correlated with the quantity of internal refrigerant, a parameter that is difficult to measure directly. When a sign of anomaly is detected, the system determines whether or not refrigerant has leaked by working through the flow chart for identifying changes in refrigerant amount from the refrigerant leak feature values. Testing using actual operational data found that the devised feature values can be used to determine refrigerant leaks with a high degree of sensitivity.

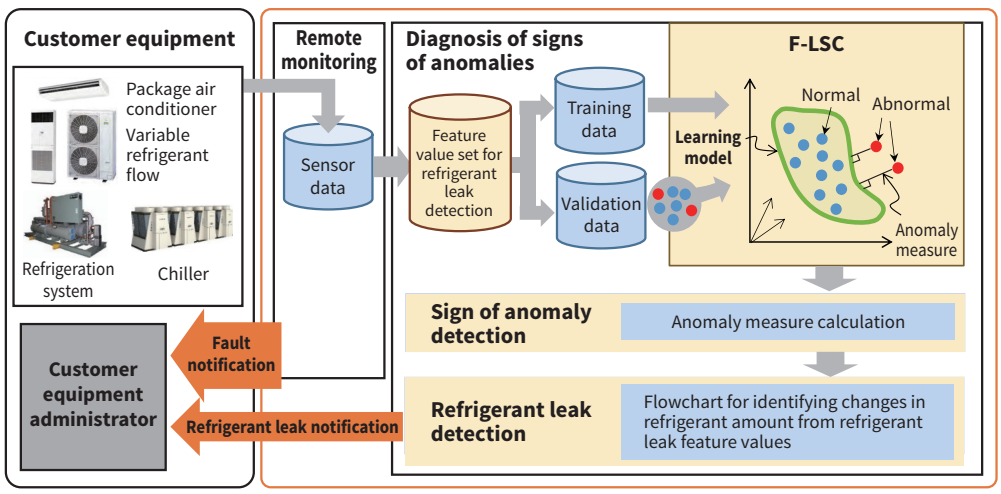
Hitachi is planning to make this new technique available in the services provided by its exiida for the remote monitoring and predictive diagnosis that has been updated for compliance with the August 2022 revision of the Fluorocarbon Emissions Control Act.

To deliver greater value for customers, Hitachi plans to develop diagnostic techniques for identifying the causes of a wider range of problems than just refrigerant leaks, and to implement them at an early date.

17 Designing for Greater Use of Renewable Materials

Plastic has long been used in home appliances and a host of other products. Unfortunately, when this plastic, which is produced in large quantities, is disposed of after use, it becomes a source of environmental problems such as soil or ocean pollution and contributes to global warming through the release of CO_2 when burned.

Accordingly, Hitachi has been working to bring about a highly circular economy by making greater use of renewable plastics in popular home appliances. With the PV-BH900SK cordless stick cleaner, Hitachi took on the challenge of increasing the percentage of renewable



16 Block diagram of refrigerant leak detection system included in Hitachi's exiida remote monitoring and predictive diagnosis

17 PV-BH900SK cordless stick cleaner

plastics to more than 40%, using it for external as well as internal parts without compromising the product's quality of appearance.

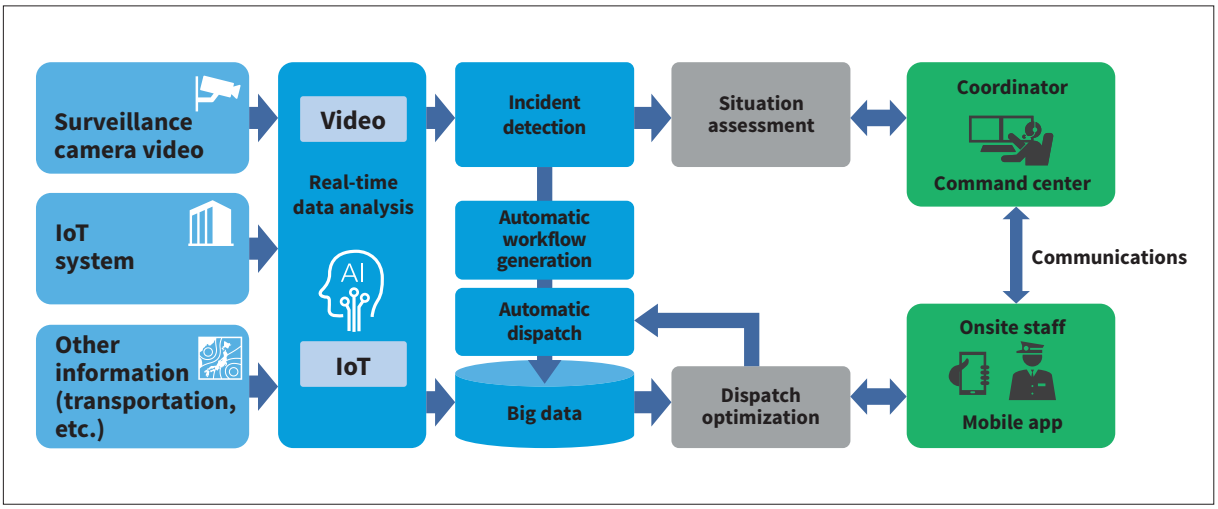
These efforts to bring about a highly circular economy while achieving strong visual appeal have been recognized by a Gold Award (Minister of Economy, Trade and Industry Award) at the Good Design Award 2022 run by Japan Institute of Design Promotion.

18 Development of Solution for Integrated Command and Control Centers through Co-creation with Singapore Institute of Technology

Making efficient use of human resources in the fields of public health and safety and in public transportation and other social infrastructure services is an important issue for Southeast Asia as it rapidly urbanizes. To address this societal challenge, Hitachi has developed a solution for integrated command and control centers.

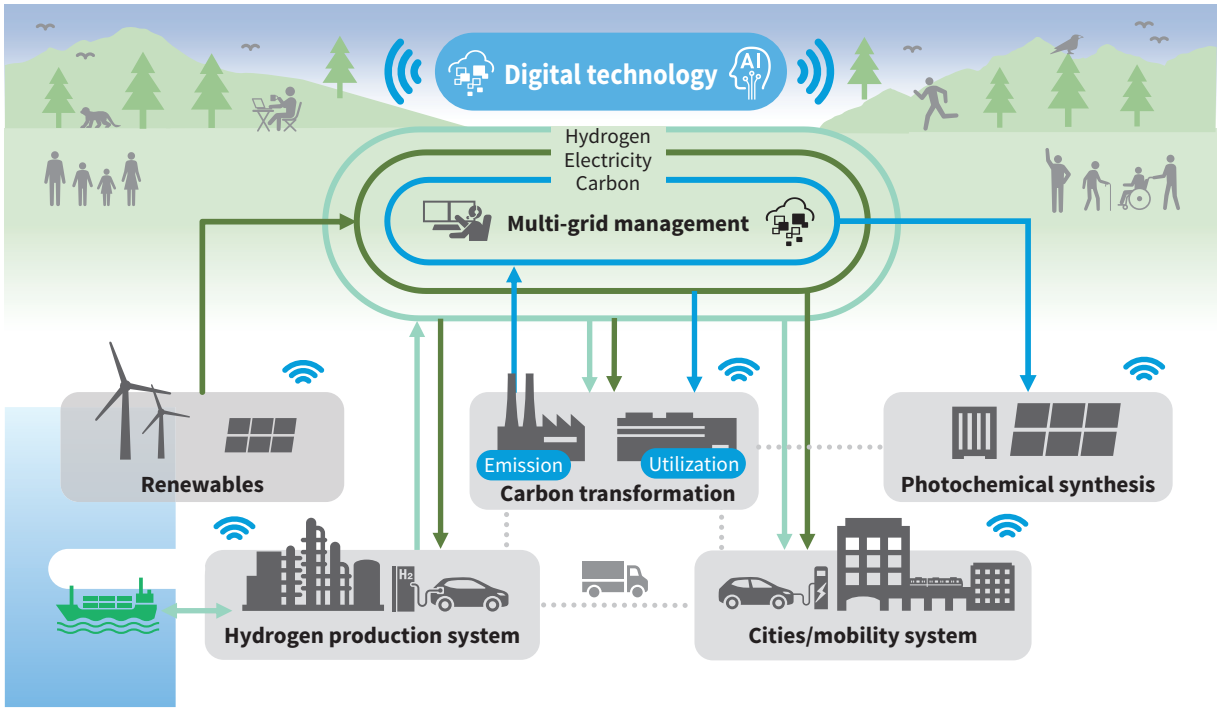
A staff dispatch function finds the optimal way to allocate staff and make more efficient use of available resources by modeling the constraints in terms of event priorities and staff capabilities, and then solving this as a problem in mathematical optimization. As the time it takes to obtain a solution increases exponentially as the number of events increases, Hitachi adopted a spatio-temporal segmentation algorithm to enable solutions to be obtained in real time. The company has also partnered with the Singapore Institute of Technology on the collaborative creation (co-creation) of a solution for dealing with COVID-19 that sends out staff to help disperse crowds when large numbers of people in close contact are detected in surveillance video. The effectiveness of the solution has been demonstrated in practical trials.

In the future, Hitachi intends to further develop this solution through co-creation with customers.



18 Architecture of solution for integrated command and control centers

Innovation for Addressing Future Challenges



AI: artificial intelligence

1 Innovation for a carbon-neutral society

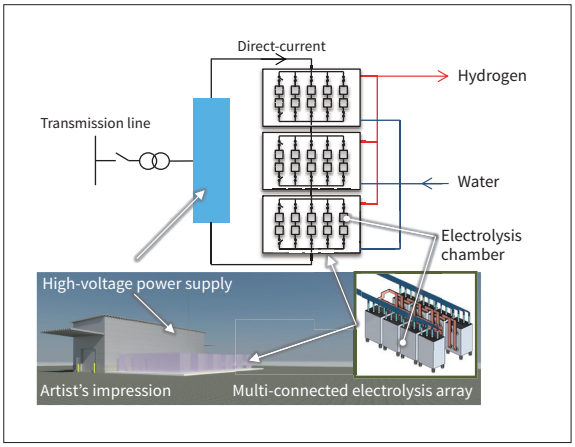
1 Innovation for a Carbon-neutral Society

Addressing wide-ranging issues to achieve prosperous societies within the planetary boundaries is an important element in Hitachi's Research & Development Group. Its research to address climate change is based on a "forecasting" approach, which focuses on immediate societal issues and their solutions, including the electrification of mobility, the promotion of non-fossil fuels, and the use of digital transformation (DX) to improve energy efficiency. On the other hand, a "backcasting" approach is also employed to focus on a vision of a social system in 2050 to help identify potential long-term opportunity areas, including the hydrogen value chain for achieving carbon neutrality and delivering other innovations for carbon-negative systems.

One example is the multi-grid management technology: it is being developed to address the issue of temporal and spatial mismatches of supply and demand for hydrogen and other renewables, ensuring that clean energy is stable and reasonable. To address the loss of biodiversity, Hitachi also seeks to develop technologies to transform carbon dioxide (CO_2) into production materials for food, clothing, and shelter, while building an ecosystem to enable collaborations among universities, national research institutions, and startup companies.

2 High-voltage Electrolysis System for Energy Storage and Supply

The production of hydrogen using electricity derived from non-fossil renewable sources of energy such as photovoltaics, wind, and hydro has attracted attention as one way to go about the decarbonization of society. Hitachi has been working on the development of a world-first* high-voltage electrolysis technique for producing hydrogen in high volume using minimal resources and electric power. Hitachi already has technologies for insulation, electrochemical device control, and high-capacity power conversion from its past work. The objective now is to



2 High-voltage electrolysis system

reduce the size and resource requirements of large electrolysis systems by leveraging these technologies to build arrays of electrolysis stacks that can utilize high voltages and to develop high-voltage management and control techniques.

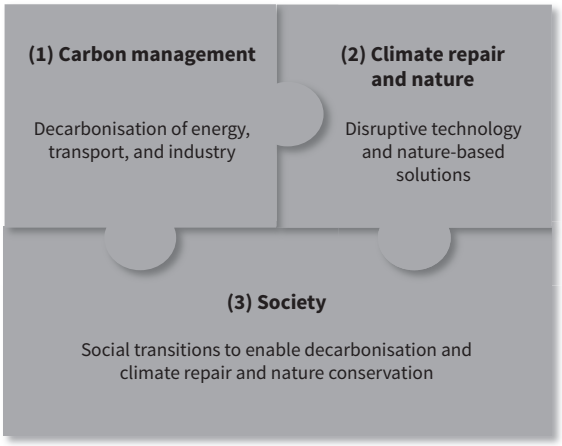
Along with plans to verify the benefits of a demonstration system that utilizes these technologies, Hitachi also intends to play its part in smoothing the transition from fossil fuels to hydrogen in Japan and elsewhere by supplying total solutions that also cover processes upstream of hydrogen production. These include developing ways of providing the necessary clean water and practices for operating these systems at sites suitable for photovoltaic, wind, or hydro power generation.

* Based on research by Hitachi, Ltd.

3 Hitachi-Imperial Centre for Decarbonisation and Natural Climate Solutions

A new research centre has been created in partnership with Imperial College London to address the largest sustainability challenges facing society today. Rapid decarbonisation is essential to avoid the worst impacts of climate change, which will require the transformation of industry sectors and lifestyles. Natural environmental systems must also be protected as they provide essential services, such as food production, clean water, and removing CO_2 from the atmosphere.

In response, the centre focuses on two key areas, decarbonisation and climate repair. Four initial research projects have initiated and will be delivered collaboratively with Hitachi colleagues in Europe and Japan. The projects will evaluate pathways for reducing CO_2 emissions, including direct air capture (DAC), optimising nature conservation, and identifying the necessary transition to be made by society.



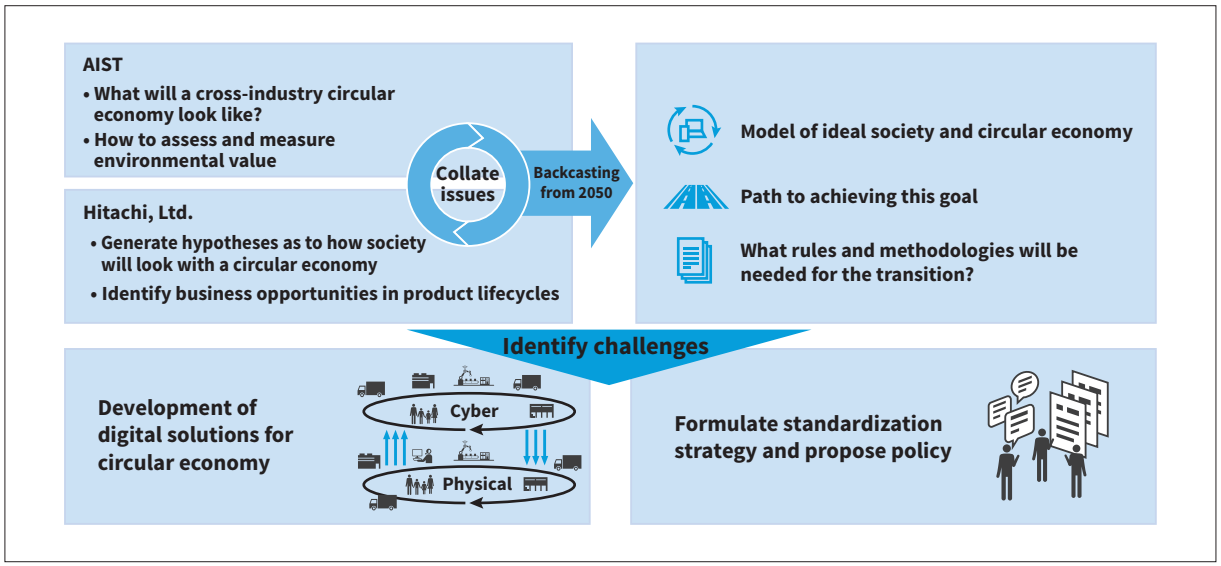
3 Projects within the centre focus on three main pillars of research

Hitachi intends to utilise the centre to build new relationships with industry, government, and academia and to ensure that Hitachi's research and development in sustainability is at the forefront of global themes to benefit society.

4 Hitachi–AIST Laboratory: Establishment of Joint Research Facility to Achieve Circular Economy

In October 2022, Hitachi, Ltd. and the National Institute of Advanced Industrial Science and Technology (AIST) jointly established the Hitachi–AIST Circular Economy Cooperative Research Laboratory at AIST Tokyo Waterfront. The laboratory will host about 40 specialists from Hitachi and AIST who will engage in joint research into what sort of society will be needed for a future circular economy that makes highly efficient use of resources across entire value chains through multiple industries. They will also study topics such as what rules should apply to this circular economy and measures for overcoming challenges.

The three-year joint research program involves drawing a grand design for a circular economy that lays out what such a society will look like, the path to reaching this goal from where we are now, and what form the rules and methodologies for making the transition will take. It will also develop digital solutions that utilize environmental and other data such as CO_2 emissions for corporate environmental reporting and for generating production schedules that have a low environmental impact. In relation to how data is collected and used, the laboratory also intends to produce policy proposals and participate in Japan's contribution to rule-making and standardization.

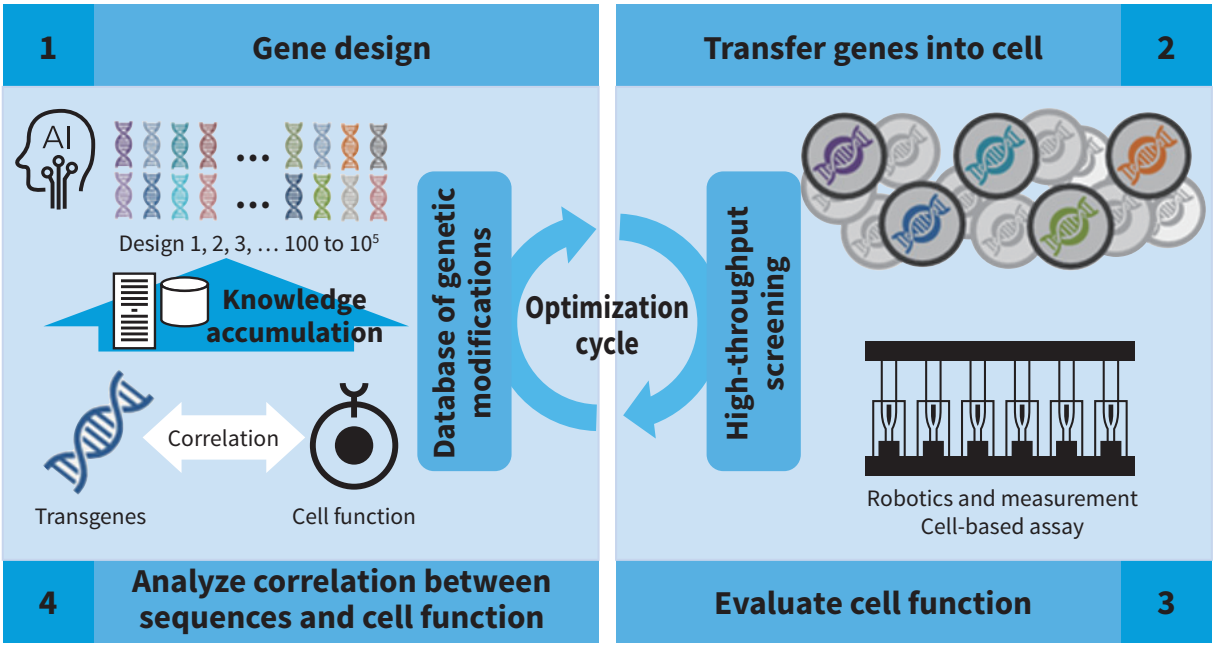


4 Formulation of a grand design for a circular economy

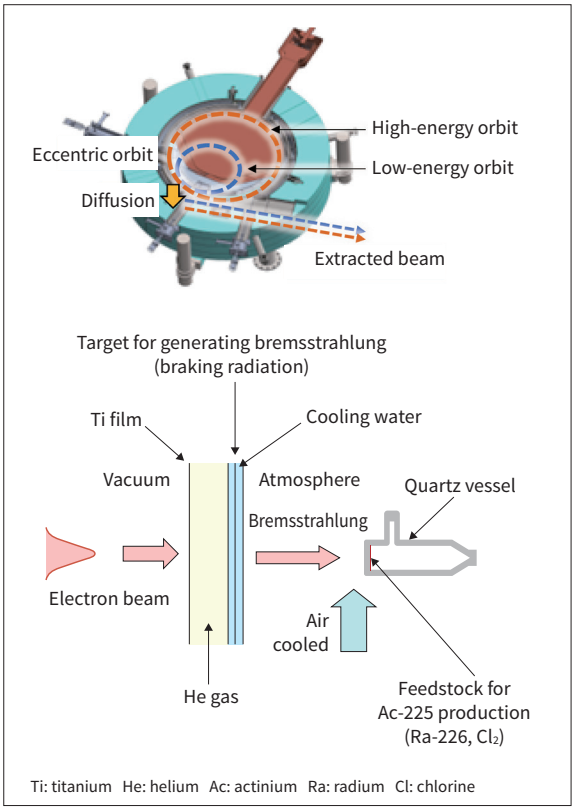
5 Designed Cell

Cell-based gene therapy, which involves the administration of genetically modified cells, is expected as a way to overcome diseases that are considered difficult or impossible to treat. One example is chimeric antigen receptor (CAR) T-cell therapy, which has already been approved for the treatment of certain cancers where it has demonstrated remarkable efficacy. With the use of genetic modification, it holds the potential to treat a wide variety of other diseases. CAR T-cell therapy has been an active topic of research and development since its initial approval in the USA in 2017. However, due to a lack of maturity in the relevant research and development practices, it cannot be said that this potential has been adequately realized yet. The work is also very costly and time-consuming.

In response, to support the research and development of CAR T-cell and other cell-based gene therapies, Hitachi has started working on a development platform for cell design that features a system for massively parallel gene design and cell function analysis. Work on the analysis of the next-generation CAR T-cell therapy conducted as part of this development was published in August 2022 in Frontiers in Immunology, an international journal.



5 Development platform for cell design



6 Diagram of new accelerator for particle beam therapy (top) and system for trial production of Ac-225 in MBq-range quantities (bottom)

6 New Accelerator for Particle Beam Therapy and Technique for Producing Actinium 225

Hitachi has developed a new accelerator that helps to reduce the burden on patients undergoing particle beam therapy and a technique for producing actinium 225 (Ac-225), an isotope used for targeted alpha-particle therapy.

Particle beam therapy is a form of radiotherapy that works by accelerating a beam of charged particles, such as protons or carbon ions, up to an energy that is chosen based on the depth of the target in the patient's body. The new accelerator currently under development works by offsetting the eccentric beam orbit toward the outlet and diffusion by high-frequency voltage to deliver a high beam current regardless of the target depth. Past work has confirmed beam extraction using an electromagnetic field distribution chosen for ease of fabrication and this is now a subject of detailed analysis to prepare it for practical deployment.

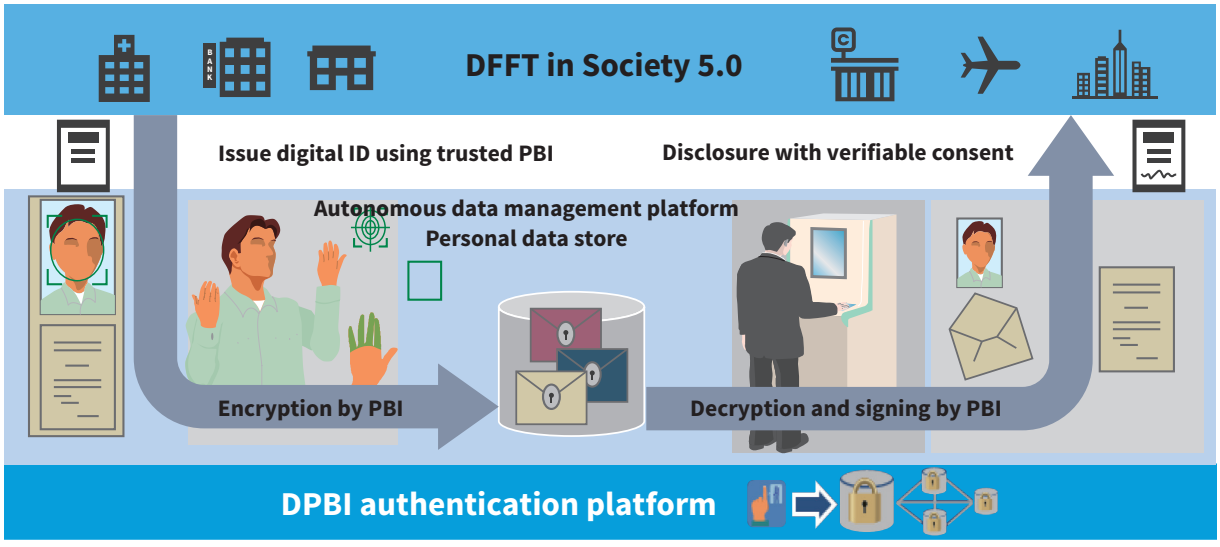
Targeted alpha-particle therapy is a new technique that attacks tumor cells from inside the body. It works by dosing the patient with a medication that is selectively taken up by tumor cells, but also contains radionuclides that emit alpha particles to destroy the cells. As Ac-225 is an effective choice of radionuclide for this therapy, Hitachi has been developing a manufacturing technique that uses an electron linear accelerator to produce this isotope with high levels of quality and efficiency. Working in partnership with Tohoku University and Kyoto University, the new technique was successfully used to produce Ac-225 in quantities measured in the MBq-range, a world-first*.

Future plans include detailed system studies aimed at high volume production and evaluation of its suitability for use as a medication.

* Based on research by Hitachi, Ltd.

7 DPBI Digital Identity Platform for Web3

While advances in the web have made the Internet an essential part of people's daily lives, the rising dominance



DFFT: data free flow with trust

7 Concept behind digital identity platform for Web3

of a small number of large platforms has come to be seen as a problem. While the sort of decentralized services that have come to be known as Web3, such as the trading of non-fungible tokens (NFTs) and crypto assets, have attracted a lot of attention over recent years, security issues (such as fraud and hacking) that arise from the lack of a central authority have also emerged.

With a view to the full-scale deployment of Web3, Hitachi has been working on the development of a digital identity platform that improves privacy and convenience while at the same time preventing fraud and hacking and helps to ensure the authenticity of NFT creation in the trading of NFTs and crypto assets. The core technology is a decentralized public biometric infrastructure (DPBI) for the generation of encryption keys from biometric information and the distributed management of authentication and identifiers (IDs). By linking the cyberspace presence of individuals or organizations to their real-world selves, the DPBI enables the delivery of Web3 services that can be used with confidence.

8 Silicon Quantum Computing

Quantum computers are recognized as a new computing paradigm that can solve problems that are intractable using conventional computers. As they unfortunately still lack the number of qubits (the basic building block of a quantum computer) required to solve meaningful real-world problems, the challenge for the future is to find ways of combining qubits numbering in the millions.

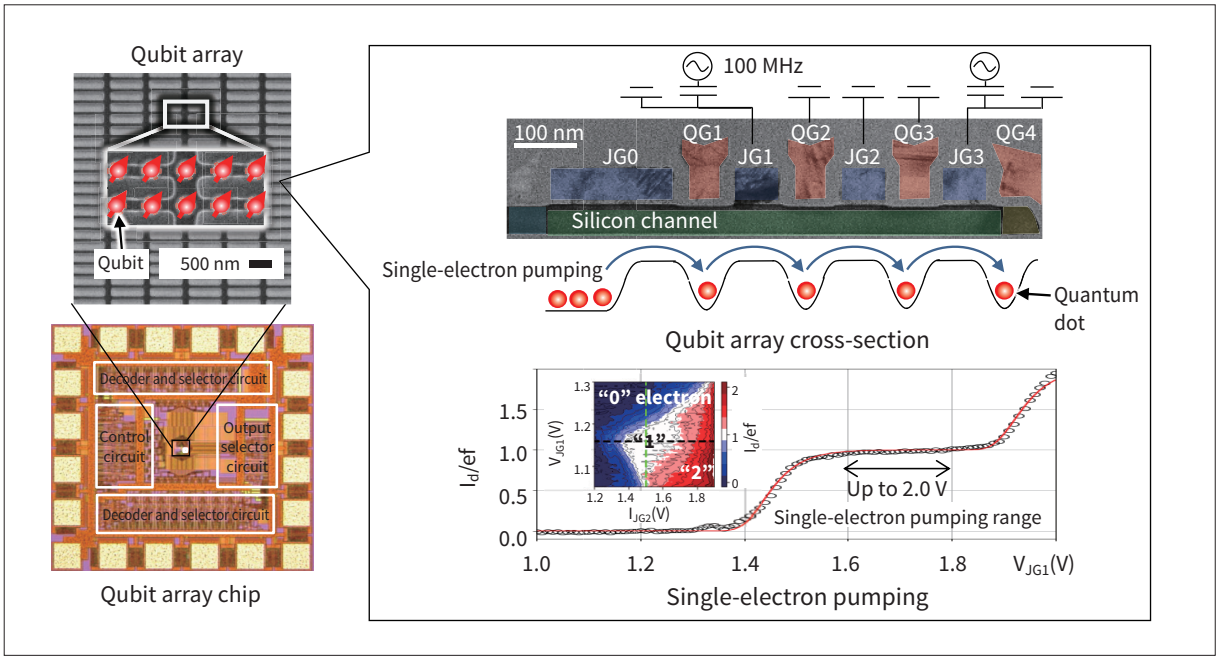
To this end, Hitachi has leveraged silicon integration in the development of a silicon quantum computer. To perform quantum computation, this requires the delivery ("pumping") of electrons into an array of qubits fabricated using large-scale integration to create quantum dots (the physical manifestation of a "particle in a box," the particle being an electron) and initialize their state. To achieve this, Hitachi has worked with the Tokyo Institute of Technology to develop a precise, high-speed single-electron pumping technique that can supply electrons individually to each quantum dot in the qubit array at a rate of 100 MHz. This is an important development required for the scaling of large arrays.

Future plans include establishing a way to initialize the entire qubit array and test quantum operations. The ongoing work on large-scale integration was recognized by an SSDM* Paper Award that was presented at the 2022 conference.

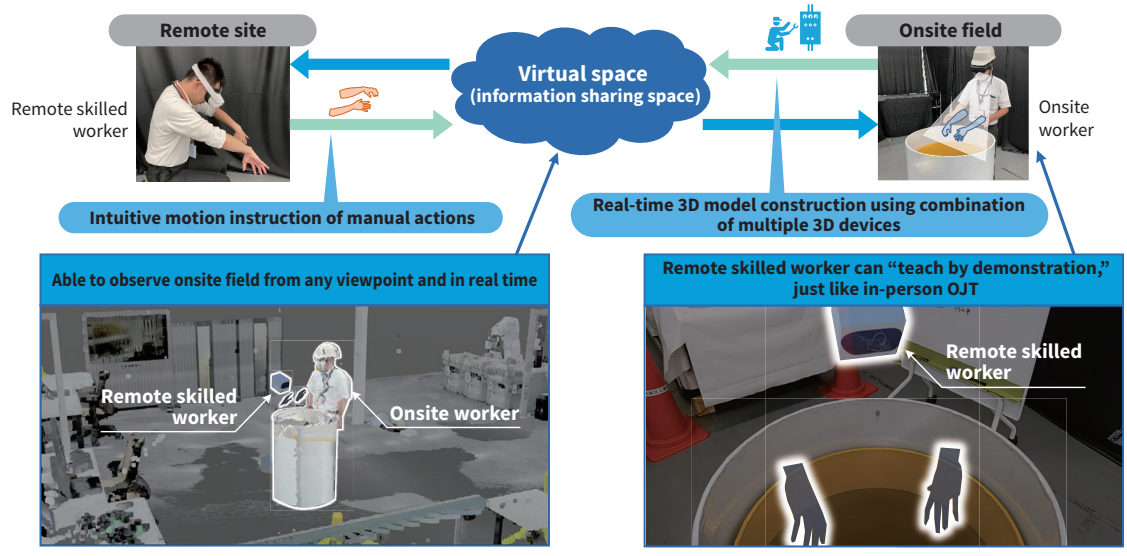
As it works to expedite the practical deployment of quantum computers, Hitachi has participated in open innovation, including involvement in the Moonshot Research & Development Program of the Japan Science and Technology Agency (JST), and collaboration with the Hitachi Cambridge Laboratory to develop not only quantum computing systems, but also quantum algorithms and error correction systems.

This work was funded by grant number JPMJMS2065 of the JST Moonshot Research & Development Program.

* International Conference on Solid State Devices and Materials



8 Precise, high-speed single-electron pumping technique using qubit array



3D: three-dimensional OJT: on-the-job training

9 Overview of prototype telepresence work support system

9 Telepresence Work Support

Labor saving in onsite field work is one way to improve the productivity of the field work and overcome shortages of skilled workers. To make this possible, Hitachi has developed a way to support remote work that allows remote skilled workers to observe a work field from any viewpoint in real time through a virtual space that replicates the work field, and to use hand motions to show onsite workers how to perform onsite tasks that would be difficult to explain verbally.

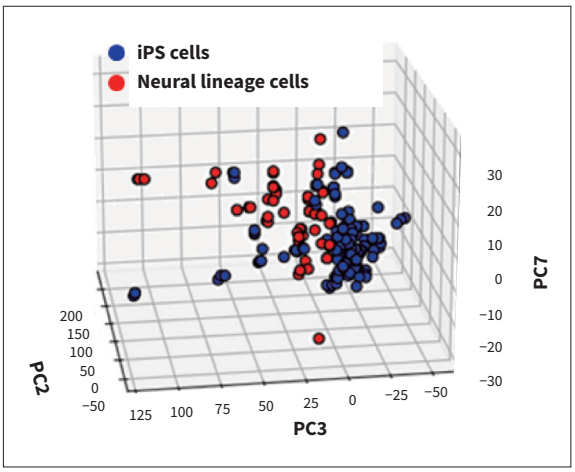
This combines three-dimensional sensing with technologies for virtual reality (VR) and augmented reality (AR) to replicate the work field in virtual space and in real time, allowing someone at a remote site to observe it from any viewpoint using VR goggles. The system can also provide virtual demonstrations of how to perform workplace tasks without the instructor being physically present. This is done by capturing the instructor's hand motions and having an avatar replicate them to the onsite worker wearing AR glasses.

With the metaverse expected to become more commonplace in the future, Hitachi is also looking to deploy the above technology in solutions that use this new medium. This will form part of its efforts to further improve the productivity of field work and address the shortage of skilled workers.

10 Hitachi Kobe Laboratory: Regenerative Medicine

Hitachi launched its ACC-200, automated cell culture equipment for commercial cell manufacturing in 2019 to help make regenerative medicine more widely available by producing the required cells with more reliable quality and lower production costs. The ACC-200 was supplied to a plant for cell therapies operated by Sumitomo Pharma Co., Ltd. and its first clinical application was in investigator-initiated clinical trials conducted by Kyoto University on the transplantation of neural lineage cells differentiated from induced pluripotent stem (iPS) cells to treat Parkinson's disease.

To ensure more reliable cell production, Hitachi has been developing a technique for the non-invasive



10 Plot of principal component of Raman signal due to extracellular vesicles in culture supernatant

monitoring of cells during culturing based on cell morphology and culture supernatant constituents. In particular, by looking at the extracellular vesicles secreted by cells into the culture supernatant, it was found that the expression of micro ribonucleic acid (miRNA) and proteins included in extracellular vesicles was indicative of cell quality*. In addition, Hitachi investigated the application of Raman spectroscopy for real-time evaluation of extracellular vesicles during cell culturing. As a result, it was found that iPS cells and neural lineage cells differentiated from iPS cells could be distinguished based on Raman signal patterns derived from each vesicle. This demonstrated the possibility for non-invasive monitoring of cell differentiation states during culturing.

Note that some of the work described in this article was undertaken through Japan Agency for Medical Research Development (AMED) project JP21be0404010.

* H. Saito et al., Journal of Bioscience and Bioengineering, 132, 381–389, 2021, the 30th Excellent Paper Award of the Society for Biotechnology, Japan

11 Hitachi-UTokyo Laboratory: Policy Proposal and Hosting of Open Forum

Policy development work at Hitachi-UTokyo Laboratory aimed at realizing Society 5.0 has included the publication of a policy proposal and the hosting of an open forum.

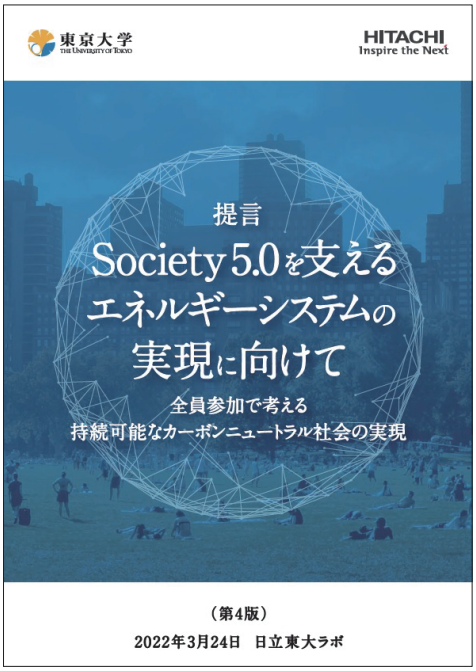
The Habitat Innovation Project has presented methodologies for the sustainability of people-centric smart cities to the Cabinet Office. Hitachi-UTokyo Laboratory has also hosted its third Habitat Innovation Forum entitled, “Creating People-centric Super-smart City—Five Key Factors for Sustainable Smart City” where a consensus on the gist of the proposal was forged through discussion between relevant stakeholders from industry, academia, and government.

With its Energy Project, meanwhile, Hitachi-UTokyo Laboratory has hosted the fourth Industry-Academia Collaboration Forum, “Toward Realizing Energy Systems to Support Society 5.0—Achieving a Sustainable Carbon-neutral Society in Terms of Universal Participation.” Along with a deep dive into the use of backcasting to validate society and its policies and systems, this also involved the publication of a fourth version of their energy proposal.

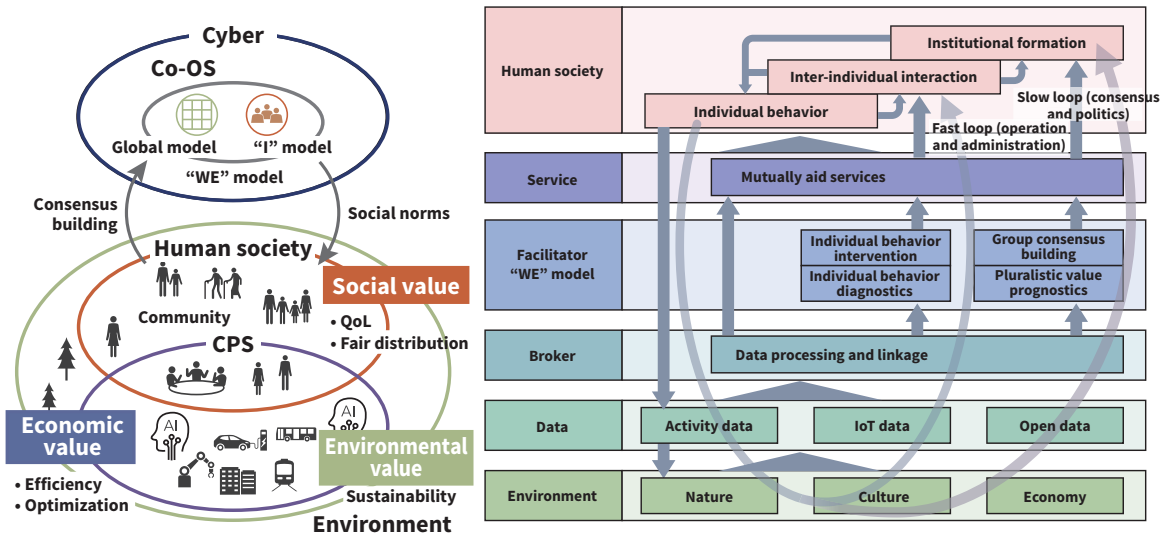
Following on from summing up the phase 2 activities that will finish at the end of FY2022, work will next start on the new phase 3 initiatives planned for FY2023 onwards.

12 Hitachi Kyoto University Laboratory: Cyber-Human Social Co-Operating System

Along with debate about what is meant by a super-smart society (Society 5.0) that is based on human values and made possible by cyber-physical systems (CPSs),



11 Habitat Innovation Forum (held online) (left) and cover of energy proposal (version 4) (right)



QoL: quality of life IoT: Internet of Things

12 CHSS concept and Social Co-OS architecture

technology is also being developed for the "wellbeing society" (as described in the book "Beyond Smart Life" from Nikkei Business Publications) that lies beyond that, one that cannot be achieved by smart technologies alone.

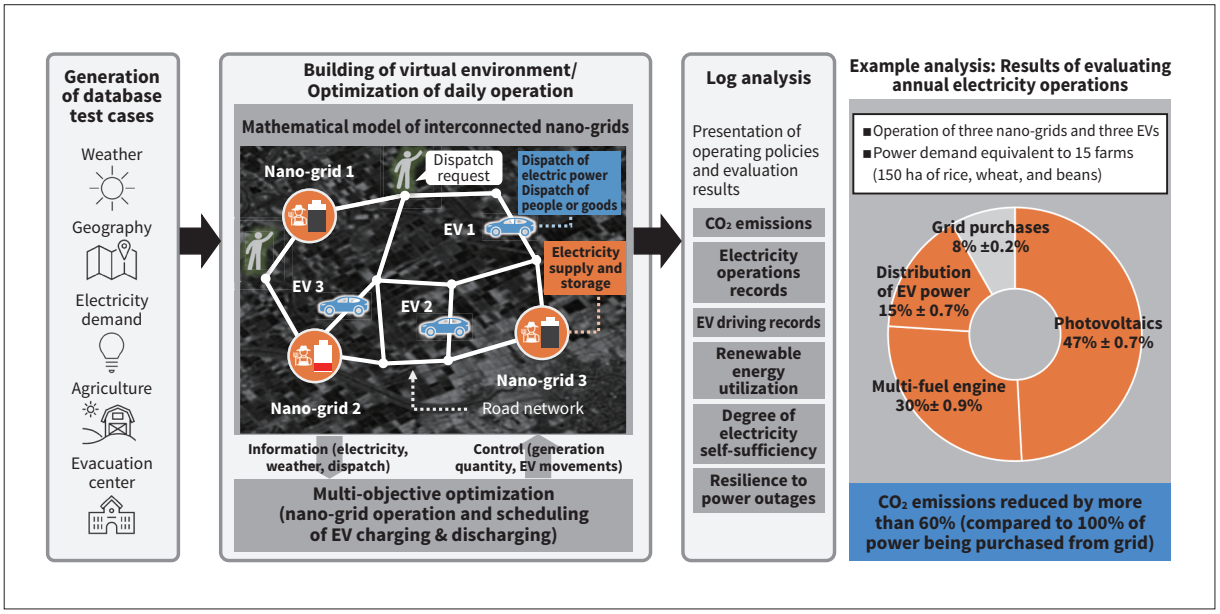
In pursuit of a "mixed-life society" that combines individual freedom and collective solidarity across diverse people, Hitachi Kyoto University Laboratory has proposed the new concept of a cyber-human social system (CHSS) that incorporates constructions from human society into CPSs to support prosocial behavior by individuals and consensus building among groups. To accompany this, it has also developed the cyber-human social co-operating system (Social Co-OS) as an architecture for putting this concept into practice. In the Social Co-OS, the cyber system and human society cooperate through a fast loop (operation and administration) consisting of individual behavioral diagnostics and intervention, and a slow loop (consensus and politics) consisting of pluralistic value prognostics and consensus building for groups.

In the future, there will be an expectation for contribution in the establishment and trouble-free operation of mutual aid communities and platform cooperatives. Accordingly, the laboratory will be partnering with Kyoto University in two national projects from FY2022, the Japan Society for the Promotion of Science's (JSPS) Topic-Setting Program to Advance Cutting-Edge Humanities and Social Sciences Research, and the Japan Science and Technology Agency's (JST) Responsible Innovation with Conscience and Agility (RInCA) program for addressing ethical, legal, and social implications/issues (ELSI).

Details of this work have been published in the September 2022 edition of IET Cyber-Physical Systems: Theory & Applications, an international academic journal.

13 Hitachi Hokkaido University Laboratory: Support Model for Low-carbon Agriculture Using Locally Sourced Energy

Hitachi Hokkaido University Laboratory has been developing a self-sustaining local energy system with the aim of setting up an electric power system that can supply locally sourced low-carbon electric power and maintain electricity supplies during disasters. The system is made up of small self-sustaining nano-grids providing electricity services that would not be possible on a single grid. It has the ability to distribute power from sources such as electric vehicles (EVs) between these nano-grids so as to avoid over- or under-supply while also using excess power for the transportation of people and goods. To facilitate system implementation, the laboratory has also developed a self-sustaining local energy system simulator that can optimize multiple objectives covering the operation of electricity and transportation services on the basis of local needs and circumstances while also allowing for the uncertainties of the weather and demand for those services. When the simulation was run for agricultural activities in Iwamizawa City, the results indicated that



13 Structure of self-sustaining local energy system simulator and example analysis

the system could reduce CO_2 emissions by more than 60% compared to sourcing electricity from the grid.

The aim for the future is to leverage collaboration between industry, academia, government, and communities to establish local industry models with a low environmental footprint that utilize locally sourced energy, and to provide communities with safe and secure foundations for their way of life.

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