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Research and Development at RTRI toward the Achievement of Net-Zero by 2050

Muramoto On November 10, 2021, RTRI hosted a lecture session with the theme "Railway Technologies Required for decarbonization." This was the first time RTRI has announced decarbonization as a major research goal and publicly shared our prospect of research and development on this net-zero carbon emissions. It has been about 6 months since both of you made presentations at the session. Today, I would like you to talk about RTRI's research and development of the achievement of net-zero by 2050.

First, I would like Dr. Furukawa to review RTRI's research efforts over the last year. Dr. Furukawa delivered a keynote speech as executive director responsible for the Research and Development Promotion Division at RTRI.

Furukawa In recent years, management of railway operators have been increasingly interested in decarbonization. In particular, since the then prime minister Suga set Japan's goal of achieving net-zero by 2050, they have asked us frequently, "What is RTRI doing to contribute to this goal ?" This is one of the reasons why we chose decarbonization in the railway sector as the theme of the session.

In the past, we haven't conducted research projects featuring "decarbonization" as their major goal, but we have done a lot of research to reduce energy consumption in train operation. In the session, we focused on two aspects of decarbonization:

reducing CO_2 emissions and reducing energy consumption, in other words, "energy saving." We also reviewed our research and development achievements, classifying them into the two aspects, and presented the prospect of our research of the achievement of net-zero by 2050.

Furthermore, in 2022, we started to include in RTRI's business plan "decarbonization of railways of the achievement of net-zero by 2050" as one of our research policies. In addition to starting new decarbonization projects, we will further intensify the research in the on-going projects to contribute to this goal.

Muramoto I think this is what we need to do and all of the research divisions and sections at RTRI need to address.

Now we would like to hear about future prospects of decarbonization of railways from Dr. Shigeeda. Dr. Shigeeda is Director of Power Supply Technology Division that covers core technologies regarding decarbonization.

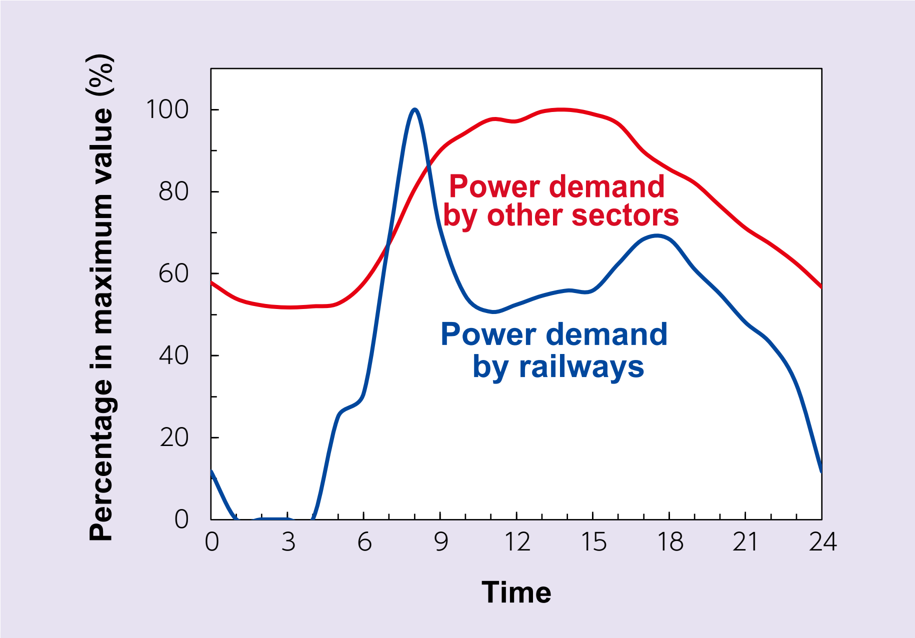
Let me ask you a candid question. In the longer term, the ratio of renewable energy in the commercial power grid is expected to increase and Japanese railways are already highly electrified. So, it seems that the carbon footprint of Japanese railways will be inevitably reduced in due course, is that right?

Shigeeda It's true that the power supply side roadmap shows that direction. However, if you are asking whether railways will be automatically decarbonized, that is not so simple. Railways' energy demand peaks in the morning and evening. So, in terms of leveling the peak, railways' energy consumption pattern matches well with the overall power demand that peaks during the daytime. (*Power demand fluctuation in a day*)

However, even if the daytime power supply amount is increased by a rising ratio of photovoltaic power, currently railways cannot use it effectively. It makes no difference, basically, whether we use the commercial power grid or private power generation.

So we need to adjust demand and supply by using energy storage systems, and the demand and supply adjustment function through the power exchange market has been gradually improved. However, it is still unclear whether the business can be commercially viable, and probably railway operators will have to watch carefully how the business develops before they make decisions to advance into the market.

Furukawa By 2024, a diverse lineup of the demand-supply adjustment products is likely to be introduced into the market. However, at this moment, the design of the entire adjustment system is still in progress. We will need to share information with other related organizations and keep watching their development closely.



Power demand fluctuation in a day

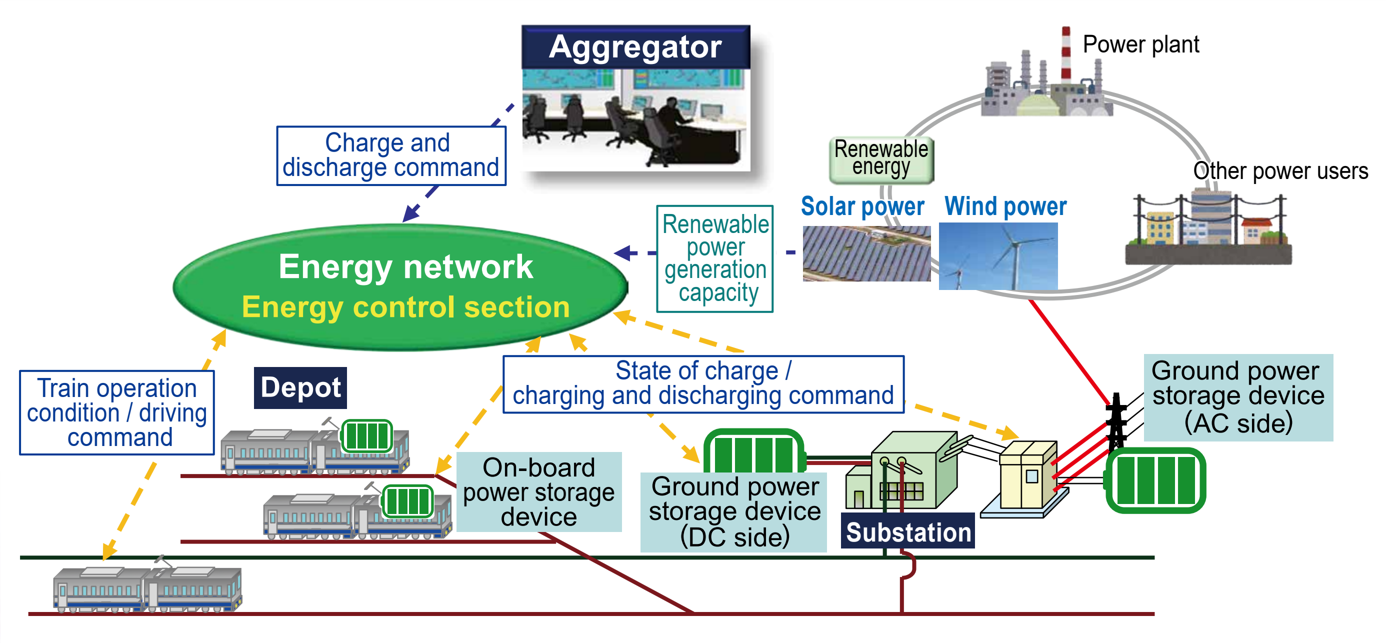
Research at RTRI toward decarbonization

Muramoto Now we are going to review RTRI's research and development to decarbonize railways. Table 1 lists R&D projects related to decarbonization that we have implemented in more than 20 years since the master plan "RESEARCH 21" started in 2000. Actually, we have completed 3 times as many projects, but are only showing representative and distinctive ones here. How do you evaluate these accomplishments?

Furukawa Frankly speaking, I have the impression that we have been doing well, and at the same time, I think we still have a long way to go. As I have said, railway people have been addressing the issue of energy saving for a long time and several projects have already been implemented. But until around 2015, the year that

R&D Projects at RTRI regarding Decarbonization

	RESEARCH 21 (FY2000 to 2004)	RESEARCH2005 (FY2005 to 2009)	RESEARCH2010 (FY2010 to 2014)	RESEARCH2020 (FY2015 to 2019)	RESEARCH2025 (FY2020 to 2024)
CO_2 Emission reduction	・Basic Research to use fuel cell as power source to run railway vehicles ・Development of fuel cell system for railway vehicles	・Development of railway vehicles running on fuel cell ・Research into geopolymer concrete	・Long-term deterioration characteristics of fuel cell ・Development of geopolymer concrete and application to railway facilities	・Development of a power converter for fuel cell trains ・Research into biomass as material for sleepers	・Development of a fuel cell hybrid train ・Reduction of carbon emissions by fuel cell railway systems ・Performance assessment of bio-fuel diesel engine
CO_2 Emission reduction and energy saving	・Development of systems for power-recycling vehicles ・Power storage at substations	・Development of battery-powered vehicles using regenerated energy ・Research into the control method for power storage device ・Basic research into flywheel power storage device for railways using superconducting magnetic bearing ・Research into superconducting magnetic bearing for flywheel power storage device for railways	・Development of battery-catenary hybrid train for conventional AC-powered railway lines ・Improving efficiency of flywheel for railways ・Development of flywheel for railways using high-performance superconducting magnetic bearing	・Development of an assessment method for lithium-ion fuel cell degradation under the on-board conditions ・Technical development to introduce flywheel for railways to commercial operation ・Development of energy-network controlling method based upon predictions of energy consumption by vehicles and ground facilities	・Durability assessment of batteries to drive vehicles under highly frequent charging ・Improving the charging and discharging performance of superconducting flywheel ・A design method of compact superconducting flywheel requiring less maintenance ・Development of basic technologies for superconducting magnetic energy storage systems ・Development of control method for smart power storage systems ・Real-time coordinated energy control
Energy saving	・Development of traction transformer for train vehicles ・Methods to reduce air resistance on railway vehicles and evaluation of them ・Development of energy saving driving support systems ・Research into reduction of energy consumption by changing parameters of traction circuit	・Development of the method to calculate energy consumption by railway vehicles	・Development of sophisticated rectifier ・Building technologies to develop long-length superconducting feeding cable ・Building a method to optimize vehicle structures to improve carbody strength ・Proposal on building carbody using pressed shell ・Evaluation of impacts of turbulence field on a railway train ・Development of high-efficiency induction motor	・Development of high-performance power converter for high-voltage power supply ・Development of element technologies to introduce superconducting feeding cable to railway operation ・Development of superconducting power supply systems ・Evaluation of energy-saving effects using advanced train operation power simulator ・Design method for disc-type motor	・Kilometer-class superconducting power supply systems ・Building technologies to connect components in superconducting power supply systems ・Development of real-time energy-saving driving techniques ・Development of energy-saving train timetable considering passenger convenience ・Development of the method to estimate energy consumption by freight trains ・Development of disc-type direct driving motor
Promoting modal shift to railways	・Ride comfort evaluation of tilting trains and research into technologies to improve ride comfort ・Development of intelligent truck for high-speed running on curves ・Development of low-cost semi-active vibration control device for Shinkansen ・Analysis of carbody elastic vibrations and research into vibration reducing techniques ・Research into sources of cabin noise and methods to prevent noise transmission ・Analysis of sickness-inducing factors on a swaying train and research into mitigating techniques ・Development of ride comfort assessment methods	・Development of carbody vibration control systems with controlled axle damper ・Development of vertical vibration control systems with variable axle damper ・Research into evaluation and improvement of carbody damping performance ・Research into assessment methods for station and cabin conditions from passengers' viewpoint ・Assessment of combined impacts of vibrations and low-frequency noise on high-speed trains on passengers	・Development of carbody tilting and steering technologies to conventional trains' speed increase ・Development of running gear for commercial services meeting both desirable curve-negotiating speed and ride comfort ・Research into technologies to improve ride comfort in different running modes ・Methods to model and reduce carbody elastic vibrations considering different running modes ・Research into ride comfort based upon characteristics of human sensitivities to vibration and noise ・Building a prediction model for ride comfort in changing temperatures	・Development of carbody tilting system to improve ride comfort ・Development to extend use of vertical-vibration damper and to improve its performance ・Improving ride comfort by insulating longitudinal vibration between truck and carbody	・Improving performance of tilting-control system corresponding to high-speed running on curves ・Development of low-cost integrated vertical-vibration damping system ・Promoting commercial use of cabin-noise reducing technologies based upon noise transmission characteristics ・Assessment method for comfortable cabin temperatures under sunlight ・Assessment method for the comfort level of air-conditioned cabin using feeling-temperature prediction model



Smart power storage system

"RESEARCH 2020" started, reduction of carbon footprint had not been such a hot topic in society. So, most of the projects shown in the table were mainly aiming at energy saving, improving ride comfort and speed increase, and they were not directly targeted at decarbonization. To be honest, I would say, we restarted our effort to pursue decarbonization and net-zero, when our new master plan RESEARCH 2025 was launched.

But it is true that having accumulated these research experiences and outcomes gives us a great advantage. We would like to accelerate new projects based on the expertise we have developed so far.

Muramoto In this table, we can recognize that RTRI had already started to develop a fuel cell for railways and the energy storage system at a substation under the RESEARCH 21 started in 2000. We are still working on the development of a fuel cell vehicle. How about the energy storage at substations?

Shigeeda In those days, we were exploring a energy storage system to save energy by efficiently using regenerative power. Since that system is required to repeat charge and discharge cycles frequently, depending on acceleration and deceleration of trains, we developed a energy storage system using an electric double-layer capacitor. This device was expected to have shorter response time and longer service life than other rechargeable batteries. Later on, the performance of the lithium-ion battery was improved significantly and became the mainstream energy storage cell. But we have gained extensive expertise on device controlling through the development of energy storage system. We have shifted our research target to the energy management system and currently are developing technologies to store renewable energy in order to enhance values of energy storage system. We have used our expertise, such as in control methods, to store renewable energy in this system.

Muramoto So, you are saying that, regarding the hardware like batteries, RTRI will choose the best products of the time, devices of excellent cost performance, and pursue the efficient management of them in railway operation.

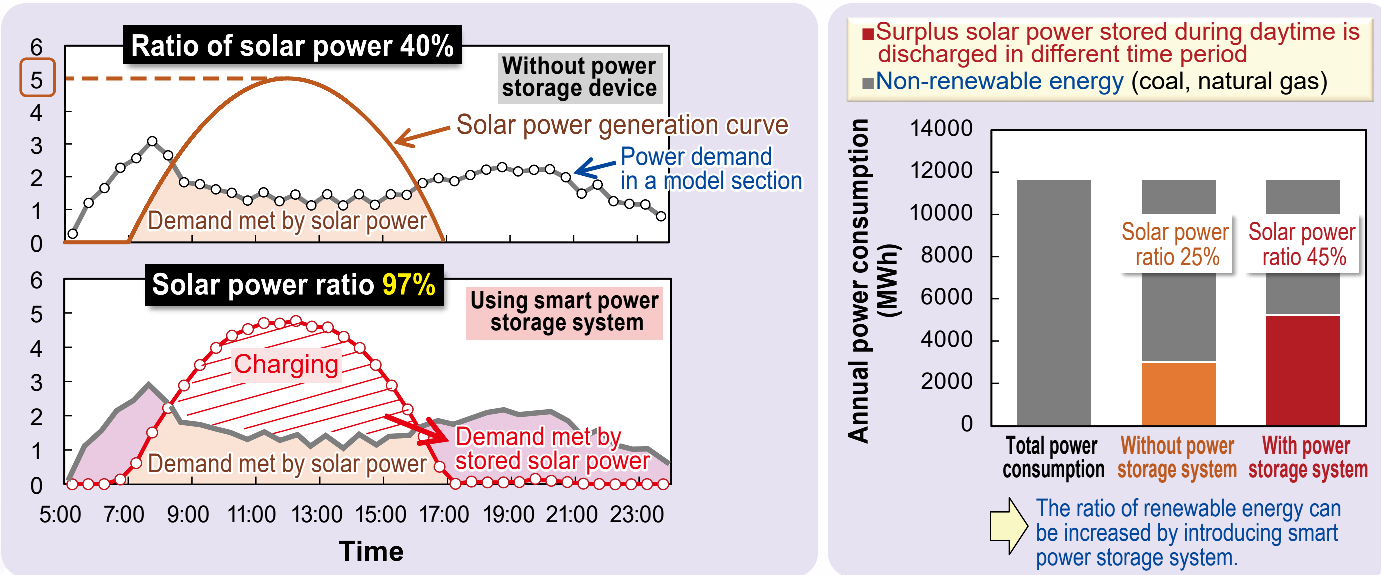
Achievement of net-zero in 2050

Muramoto Please talk about the prospect of RTRI's research and development of the achievement of net-zero in 2050.

Shigeeda In addition to the target year 2050, we also need to address the current task of 46% reduction (from 2013) of greenhouse gas emissions including CO_2 by 2030. As I mentioned earlier, the use of renewable energy cannot be increased without adjusting demand and supply balance. RTRI has set "reducing carbon footprint by coordinated power control in power supply network" as one of the major research targets in RESEARCH 2025. As one of the projects in this field, I would like to introduce our smart energy storage system to promote energy saving and use of renewable energy in the railway power supply systems. (*Smart power storage system*)

Shigeeda *"Increasing solar power ratio by smart power storage system"* shows an example of the power supply patterns for a model line calculated by the train operation power supply simulator that we have developed. During daytime, the electricity from photovoltaic power generation exceeds the amount consumed in railway operation. The surplus is stored and discharged in the morning and evening to meet the peak-hour demand by railways. In the simulation, if the photovoltaic generationplant's capacity can cover the entire power demand for one railway line for a day and the energy storage device is capable of storing the entire amount of the power, 97% of the power necessary for train operation can be covered by photovoltaic power alone in the summertime, when the photovoltaic power amount is highest. The annual average ratio also reaches 45%. In the smart energy storage system, train-equipped energy storage devices share the role with the devices at substations.

Shigeeda And, in order to finally attain the goal by 2050, it will be essential to develop high-performance, large-capacity energy storage system for commercial use. RTRI will continue to develop toward commercial use the Flywheel-type energy storage system using the super-conducting technologies that RTRI has accumulated. Furthermore, we have undertaken the development to use the superconducting magnetic energy storage (SMES) for railway operation based on the expertise we have gained in developing a super-conducting power supply cable, which is getting closer to commercial use.



Increasing solar power ratio by smart power storage system

Furukawa It was in 1970's, at the time of the so-called oil shock, that the concept of energy saving was widely recognized for the first time in Japan. So, until recently, the phrase "energy saving" has meant reduction of fossil energy consumption. Most recently, however, it has started to also imply raising the ratio of non-fossil energy toward the achievement of net-zero, and I hear the government is working on the revision of the energy-saving law (Law concerning the Rational Use of Energy) in that perspective. We are going to further improve the systems and technologies to use renewable energy for railway operation by continuing to develop the smart energy storage system. In addition, we will address carbon footprint reduction by developing other technologies as well. We will develop fuel cell vehicles and battery trains to decarbonize non-electrified train lines, and technologies to use biofuels to run diesel vehicles.

However, fierce battles for biofuels are expected among industrial sectors and it will be increasingly difficult to obtain rare metals including lithium, which is used for batteries. So we will need to keep an eye on broad-ranging technical fields in medium- and long-term perspectives, without narrowing our research possibilities.

Furukawa In the longer term, all of our research and development projects will be evaluated based on whether they can contribute to attaining a sustainable society or not. So far cost performance has been the first priority in introducing research outcomes to commercial use. But going forward, we may have to make clear evaluations on whether the technologies can contribute to decarbonization or not. Currently, for example, construction methods using cement and concrete components are prevailing. But cement and concrete components emit a large amount of carbon dioxide when they are produced. So, it may not be long before we can have alternatives of using lower-carbon or carbon-recycling materials and construction methods such as geopolymer. But after all, everything, including CO_2 emissions, needs to be calculated into cost. So, regarding the overall cost reduction, the Materials Technology Division will be playing a major role in the research to keep the entire cost at a reasonable level.

As we mentioned earlier, we are seeking to reduce the greenhouse gas emissions by 46% in 2030, as a midterm goal to attain net-zero by 2050. The projects started under the current master plan RESEARCH 2025 which contribute to decarbonization will be continued under the next master plan (fiscal 2025 to 2029). We will continue the research and development in cooperation with divisions at RTRI and other organizations ranging over different fields and sectors in order to create outcomes contributing to the goal of CO_2 reduction in 2030.

Muramoto Dr. Furukawa, Dr. Shigeeda, thank you for being with us today.