NEDO
2023 No.87

focus NEDO

Reporting on Today and Tomorrow's Energy, Environmental and Industrial Technologies

Special Report

Paving Way to Realize Energy Conservation and Carbon Neutrality

Unutilized Thermal Energy Technologies

New Energy and Industrial Technology Development Organization

FEATURED NEWS

CO_2 emissions released from power plants used for carbon recycling research

Completion of Japan's First Demonstration Facility to Develop Carbon Recycling Technologies Using Multifaceted Approaches

Carbon recycling, which effectively utilizes CO_2 as a resource, is a key technology for realizing the global goal of carbon neutrality and the need to accelerate research and development on this technology is increasing in importance. In Japan, which relies on thermal power generation for much of its energy needs, the development of cutting-edge CO_2 reduction and capture technologies is making progress. In addition, R&D is taking place on technologies to convert captured CO_2 into valuable products for its effective utilization.

NEDO and Osaki CoolGen Corporation have conducted demonstration testing of next-generation thermal power generation that combines integrated coal gasification fuel cell combined cycle technology with CO_2 separation and capture technology at the Osaki Power Plant located at Osakikamishima-cho, Hiroshima Prefecture. In addition, with the aim of realizing carbon recycling technologies, construction of Carbon Recycling Research, Development and Demonstration Base was initiated at this location in 2020, and Base operations were started in phases. In May 2022, all research areas of the Base were completed and became fully operational.

This RD&D Base will be the first facility in Japan where CO_2 separated and captured from the adjacent power plant is directly supplied via pipeline for use in research on carbon recycling technologies. One major advantage of this facility is that R&D and demonstration tests can be conducted under conditions similar to those required for future commercialization.

The 14,300 m² RD&D Base consists of three research areas: the demonstration research area, the basic research area, and the algae research area. Research is currently being carried out at the demonstration and basic research areas for the NEDO Development of Technologies for Carbon Recycling and Next

Three areas in Carbon Recycling Research, Development and Demonstration Base

①Demonstration research area

This area consists of infrastructure constructed for supplying CO_2 and other materials to an outdoor site. Research teams will install necessary equipment and conduct demonstration testing in this area to evaluate the feasibility of carbon recycling technologies and level of CO_2 reductions.

②Basic research area

This area consists of six laboratories, and one common building for carrying out analytical studies and holding meetings. Basic and advanced research is carried out in this area with the aim of realizing future carbon recycling technologies.

③Algae research area

This area consists of facilities for cultivating and conducting analyses of microalgae in order for the standardization of measurement and analytical methods, testing conditions, and other topics with the goal of realizing technologies that utilize microalgae in the production of biojet fuels.

Generation Thermal Power Generation project and at the algae research area, research is being carried out for the NEDO Development of Production Technologies for Biojet Fuels project.

By establishing this RD&D Base, NEDO aims to promote intensive R&D on the world's most advanced carbon recycling technologies and put them to practical use as soon as possible. At the same time, the center will serve as an international showcase that promotes information exchanges and collaborations with overseas researchers. In this way, NEDO is contributing to the realization of carbon neutrality by promoting the practical application of carbon recycling technologies.

For further information, please refer to the following NEDO news release:
https://www.nedo.go.jp/news/press/AA5_101568.html
Only available in Japanese

Focus NEDO 2023 No.87

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Reporting on Today and Tomorrow's Energy, Environmental, and Industrial Technologies

"Focus NEDO" is the public relations magazine of the New Energy and Industrial Technology Development Organization (NEDO), introducing the public to NEDO's various projects and technology development activities related to energy, environmental, and industrial technologies.

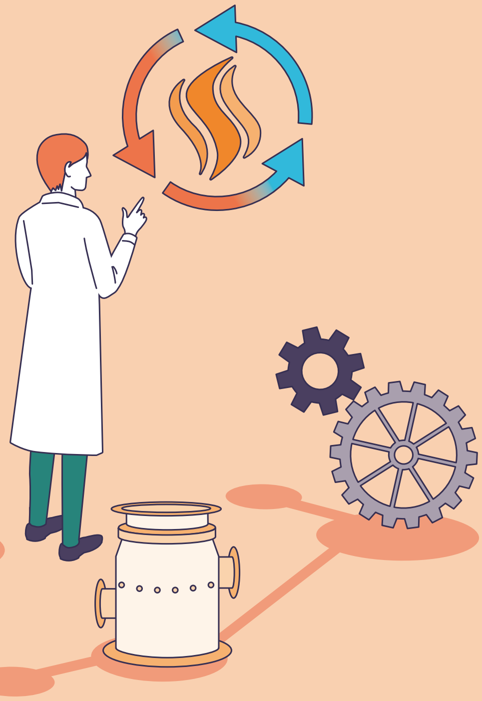
Note: To prevent the spread of COVID-19, persons appearing in photos wore facial coverings except during the time photos were taken.

Editor's Voice — A Few Words from the Editor

This issue features a special report on unutilized thermal energy technologies to support the realization of both energy conservation and carbon neutrality. The report highlights the wide variety of NEDO research and development activities taking place in this promising field, so we hope readers find the report useful and stimulating.

Special Report

Paving Way to Realize Energy Conservation and Carbon Neutrality



Unutilized Thermal Energy Technologies

Reusable thermal energy produced by factories, vehicles, and everyday activities
NEDO is supporting R&D from a medium- to long-term perspective
that reduces or makes effective use of the vast amounts of unused thermal energy
currently being released into the environment.

Making effective use of waste heat

Energy is ultimately released into the environment in the form of heat. In Japan, it is said that more than half of all energy consumed is not effectively utilized and is simply discarded in the form of heat.

Japan is working on the development of technologies that will facilitate its conversion to alternative energy sources and help realize virtually zero greenhouse gas emissions by 2050. A key to achieving these lofty goals is the effective utilization of thermal energy, which represents the majority of primary energy sources and, instead of being utilized, is simply released into the environment in the form of heat.

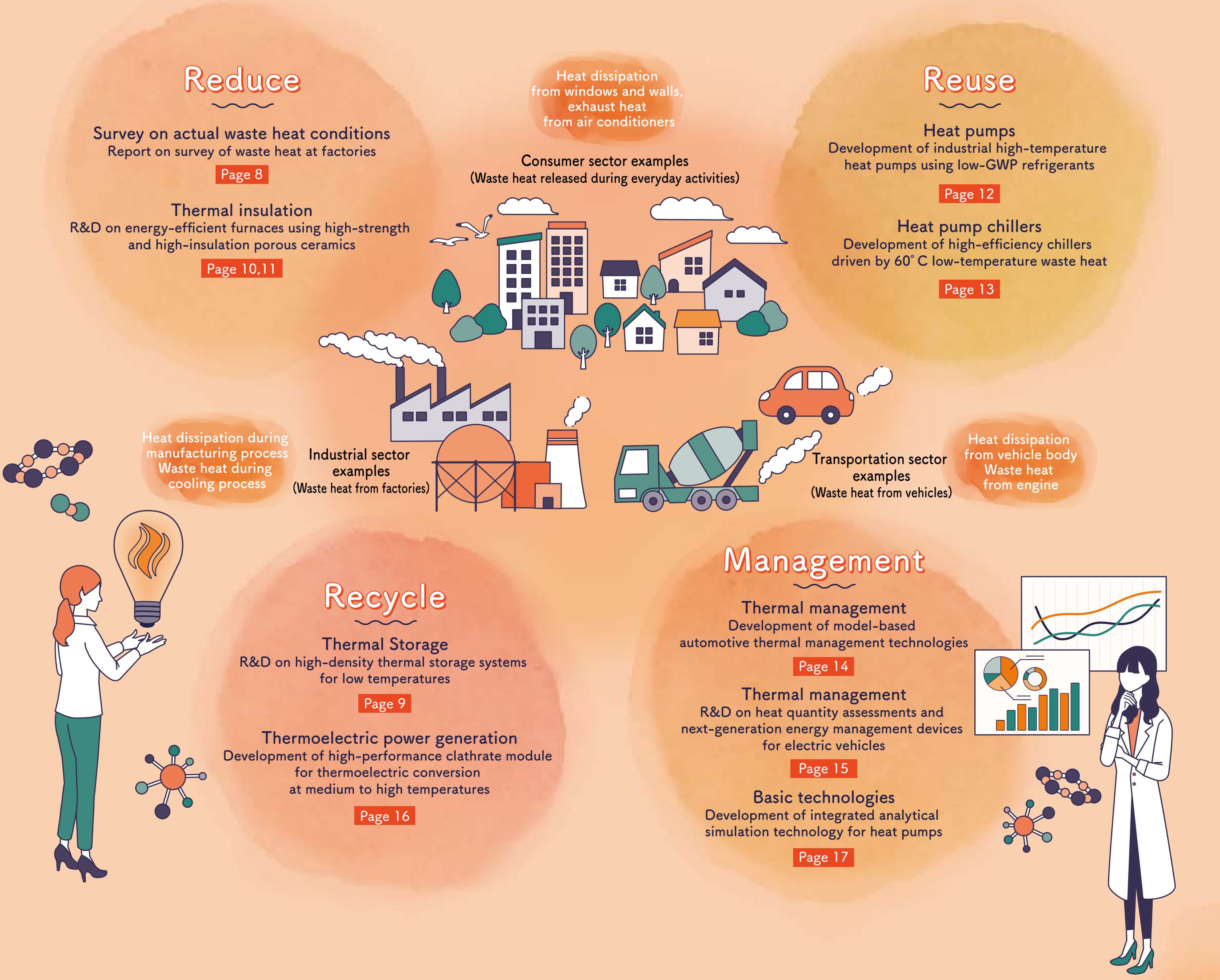
Since fiscal year 2015, NEDO has been carrying out the Research and Development Project on Innovative Thermal Management Materials and Technologies, and will finish the project at the end of March 2023.

This project aims to develop technologies to reduce (using thermal insulation, heat shielding, and thermal storage), reuse (using heat pump technology), and recycle (using thermoelectric conversion and waste heat power generation) unutilized sources of heat and utilize them as thermal energy. NEDO is also developing thermal energy management systems to promote the integration of these technologies, aiming for further energy conservation in the industrial, transportation, and consumer sectors.

Sources of unutilized thermal energy can contribute significantly to reducing the use of primary sources of energy if they can be recovered and converted into energy in an efficient manner. However, it has been difficult to overcome various technical challenges, such as the extraction and storage of thermal energy

Abundant in the natural environment

Reusable sources of unutilized heat



since most of it is released into the environment, and the high cost of transporting thermal energy due to its low levels of density.

Thermal storage technologies are indispensable to utilize heat released from factories, vehicles, and everyday consumer products where and when it is needed. In addition, insulation technologies are vitally important for reducing the quantity of released heat and realizing energy conservation. At the same time, in order to utilize heat sources in our everyday activities, it is also necessary to convert them into easy-to-use forms of electricity.

Global competition related to technology development in this area is intensifying, and industry-academia-government projects are being actively pursued in Europe, the United States, China, and other countries. With this in mind, NEDO is promoting the development of various advanced technologies for utilizing thermal energy together with the Thermal Management Materials and Technology Research Association (TherMAT), which is composed of companies in various industries.

With a view to realizing social implementation of project results, various products have already been developed under the project, including compact absorption chillers for vehicles, thermoelectric power generation modules made entirely of general-purpose elements, fiber-free insulators with high-strength and high-thermal insulation, and industrial heat pump simulators that enable quantitative evaluations of the impact of installing heat pumps.

In the following pages, we feature an interview regarding NEDO's efforts to develop technology related to unutilized thermal energy and introduce the results of R&D activities carried out during the course of this NEDO project.

PROJECT LEADER INTERVIEW

Project Leader for Research and Development Project on Innovative Thermal Management Materials and Technologies

Dr.OBARA Haruhiko

Dr. Obara is currently serving as Executive Officer and Director-General of the Department of Energy and Environment at the National Institute of Advanced Industrial Science and Technology (AIST). He received his Ph.D. in engineering from the University of Tokyo in 1992. After working as a researcher at the Electrotechnical Laboratory of the Agency of Industrial Science and Technology (predecessor agency to AIST) and at the Department of Condensed Matter Physics of the University of Geneva, he joined AIST in 2001 and assumed his current position in April 2021. Dr. Obara specializes in thermoelectric energy conversion and superconducting materials technologies.

INTERVIEWER

HARA Mitsuru

Director General
NEDO Energy Conservation Technology Department

Supporting Efforts to Realize Energy Conservation and Carbon Neutrality by Maximizing Use of Heat, the Ultimate Form of Energy, and Improve Japan's Competitiveness

Development of technologies to effectively utilize unused sources of thermal energy, which account for about 60% of primary energy sources, will contribute greatly to efforts to realize energy conservation and carbon neutrality. In this section, we present an interview with Project Leader Dr. OBARA Haruhiko who describes the significance of this NEDO project, its progress to date, and its future prospects.

Ten years of effort to realize effective utilization of unused sources of thermal energy

Hara: Could you tell us how you felt when you were appointed Project Leader?

Obara: Thermoelectric energy conversion, my field of expertise, has been attracting attention as one technology to support the utilization of unused sources of thermal energy. However, when I participated in a NEDO survey in 2008, I found that a comprehensive approach including thermal energy management was needed to maximize the utilization of unused sources of thermal energy. When I learned about this project, I accepted the position of Project Leader because I felt that, although this would be a difficult project, its potential rewards outweighed its challenges.

Hara: Over the past ten years, I think the challenges and needs of society have changed.

Obara: For example, the electrification of vehicles is progressing faster than originally expected and expectations for industrial heat pumps are also rising, so we needed to adjust the focus of our efforts in a resolute manner. I think NEDO support staff did an excellent job of managing the project in response to such changes.

Hara: The Thermal Management Materials and Technology Research Association (TherMAT) has been playing crucial roles. I also have the impression that companies, universities, and research institutes in a wide range of fields have worked in a collaborative manner under your able leadership.

Obara: Toward the midpoint of the project, a TherMAT working group conducted a simulation in which automakers disclosed actual vehicle data and the participating companies simulated the degree to which efficiency might be improved by applying their respective technologies. This event demonstrated the strength of teamwork.

Hara: I think this can be attributed to your flexible attitude and coordination ability as well as your talent in bringing people together. The fact that you work for a public research organization like AIST was also a factor in uniting everyone in pursuit of a common goal.

Obara: At its peak, the project was supported by more than a dozen universities, so I truly believe that research and development under this project was able to progress thanks to the collaboration of organizations representing industry, academia, and government.

Realizing carbon neutrality and enhancing Japan's competitiveness

Obara: Since the ultimate goal of the project is to realize social implementation of its results, it is obviously important to make effective use of heat, but we also need to create demand in the form of products and services. Fortunately, we were able to commercialize products like thermal barrier films prior to the conclusion of the project, which was a great achievement. I also understand that absorption chillers in particular are increasingly being used in Europe.

Hara: In addition to realizing social implementation, this project was notable because it strove to achieve such ambitious goals. In this context, it's remarkable that a product was commercialized at such an early stage of the project.

Obara: It's clear that the most effective way to achieve carbon neutrality is to use less energy. I believe that the utilization of unused sources of thermal energy can be a powerful tool to realize this goal, and that the technologies developed under this project will contribute to addressing global environmental challenges without negatively impacting the economy. I also hope the project can demonstrate Japan's technological prowess and provide the next generation with improved environmental conditions.

Hara: With a view to realizing carbon neutrality in 2050, I agree it is important to continue developing technologies that support the utilization of unused sources of thermal energy and promote their social implementation. Thank you very much for sharing your thoughts and experiences today.

Interview can be viewed
by scanning the below QR code:

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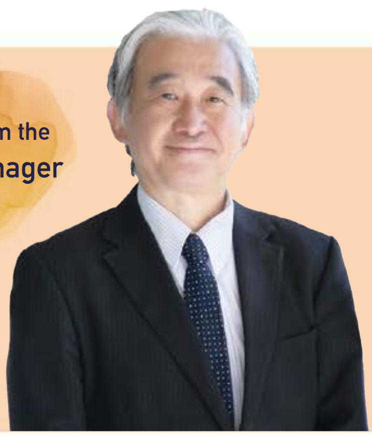


Thoughts from the
Project Manager

PROJECT MANAGER

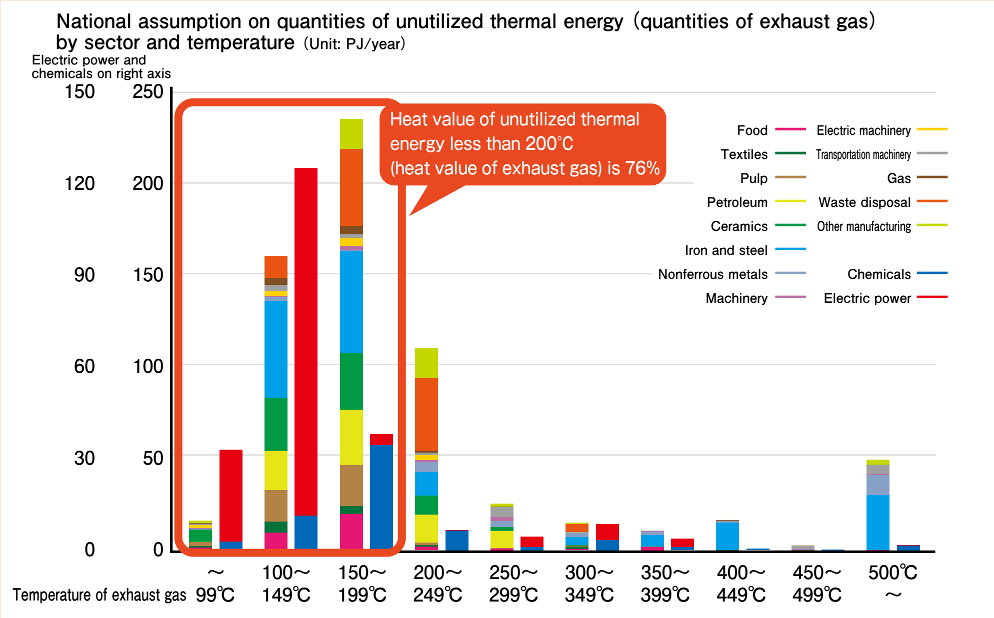
IWATSUBO Tetsushiro
Senior Project Coordinator
NEDO Energy Conservation Technology Department

It has been my pleasure to serve as the fourth project manager since 2020 and be involved with this project until its completion. I am also grateful to the previous project managers for their able supervision and Project Leader Dr. Obara for his guidance. After the completion of the project, I will continue to pursue, with the support of NEDO colleagues, the social implementation of technologies developed under the project.

Reduce

Survey on actual waste heat conditions

[Report on survey of waste heat at factories]



Survey Conducted on Conditions Related to Waste Heat for 1,273 Factories in 15 Sectors

How to utilize the temperature range of less than 200°C found to be core issue of new technology development

From 2014-2017, NEDO and the National Institute of Advanced Industrial Science and Technology (AIST) conducted a survey on the status of waste heat released at factories to determine what kinds of technology development would be necessary to enable effective utilization of unused sources of thermal energy. The survey looked at 1,273 factories in 15 sectors across Japan and included a questionnaire regarding the release and use of unutilized thermal energy. Survey results were compiled into a report released in March 2019.

The benchmark for the 2019 report was a survey conducted in fiscal year 2000 by the Energy Conservation Center, Japan on the energy system of a group of factories. Dr. HIRANO Satoshi, who supervised the conduct of the survey in his previous capacity as Associate Manager of the AIST Research Institute for Energy Conservation, says, “More than ten years had passed since the previous survey, and we wanted to find out whether the situation regarding the use of waste heat at factories may have changed and whether there were barriers to introducing new technologies, and then use this information to develop new technologies under the project.” For the private sector, data regarding waste heat is highly confidential, so the survey required cooperation from various entities. In this regard, Dr. Hirano notes that “Because it was a NEDO project, companies felt confident that their sensitive information would be handled properly. The survey would not have been possible without everyone’s cooperation.”

Dr. HIRANO Satoshi
Manager, Research Department
Research and Solution Division
The Energy Conservation Center, Japan

Survey responses indicated that 76% of unutilized thermal energy is found in the relatively low temperature range of less than 200°C, and that equipment for recovering and utilizing waste heat has been installed at many factories. Although psychological barriers to introducing new technologies were low, cost issues and lack of awareness and human resources were also found to be factors hindering the introduction of new technologies.

Dr. Hirano also notes that, “We believed our mission was to bridge the gap between voices at factories and the direction of R&D, so in addition to the questionnaire survey, we also worked hard on conducting on-site surveys. In this way, the survey results helped to make R&D activities better grounded in reality.”

The survey results, obtained with the assistance of many people, have served as a milestone in the story related to the development of technologies for the utilization of unused sources of thermal energy.

Recycle

Thermal energy storage

R&D on high-density thermal energy storage systems for low temperatures

Development of Thermal Energy Storage Technology to Meet Heat Demand of Around 10°C and Realize Energy Conservation

Model of high-density thermal energy storage system applied to food production process

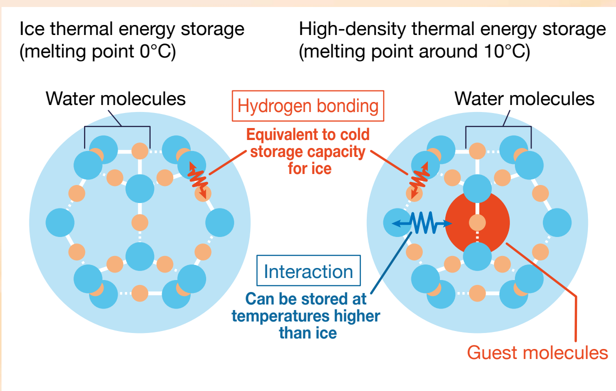
Achieving twice the heat storage density of conventional materials and realizing energy savings of about 30% in comparison with ice thermal storage

NEDO and Panasonic Corporation are working together to develop high-density thermal energy storage technology for low-temperature applications. Until now, the only thermal energy storage material for low temperatures in the industrial sector has been ice thermal storage, which requires cooling to temperatures below 0°C. However, there is also considerable heat demand around 10°C, so if heat can be stored in that temperature range, the operation of chillers can be made more energy efficient. In addition, using electricity generated at night to store heat can contribute to peak shifting.

To commercialize this technology, it was necessary to lower the cooling temperature due to the supercooling phenomenon, which increased cooling costs. In this project, basic research was carried out in collaboration with university laboratories to solve the mechanism of supercooling, and clathrate hydrate was developed that can store thermal energy at higher temperatures than ice.

SUZUKI Motohiro, Chief Engineer at Panasonic, says that "The NEDO project facilitated joint research with knowledgeable university professors in Japan as well as cooperation in carrying out analyses and simulations, all of which accelerated the development process."

A simulated system applied to food production has been developed and testing has confirmed solidification at 5-6°C and storage of the theoretically predicted quantity of heat.



Clathrate hydrates with guest materials encapsulated in caged structure of water molecules

TAKEGUCHI Shinsuke, Staff Engineer at Panasonic in charge of developing thermal energy storage modules, says, "Our understanding of the theory of supercooling was helpful in developing the module. We still need to verify the module in the field with actual users, and our challenge is how to fill in the gaps with a simulated system."

Dr. MACHIDA Hironobu, Chief Engineer at Panasonic in charge of developing thermal energy storage materials, explains the wide ranges of uses for such materials, noting, "Clathrate hydrate can be designed to have a temperature range from 2°C to just under 30°C, depending on the guest material."

Suzuki expresses his hope for the future of thermal energy storage technology, saying, "When renewable energy is introduced, storing electricity as thermal energy can meet the need to adjust supply and demand balances."

YAMAGUCHI Yasushi (left)
General Manager
Smart Energy System Development Department
Panasonic Corporation

Dr. MACHIDA Hironobu (center)
Chief Engineer
Smart Energy System Development Department
Panasonic Corporation

MATSUBAYASHI Shigeaki (right)
Public Relations Charge
Smart Energy System Development Department
Panasonic Corporation

TAKEGUCHI Shinsuke (center left)
Staff Engineer
Smart Energy System Development Department
Panasonic Corporation

SUZUKI Motohiro (center right)
Chief Engineer and Manager
Smart Energy System Development Department
Panasonic Corporation

Reduce

Thermal insulation

R&D on energy-efficient furnaces using high-strength and high-insulation porous ceramics

Development of High-strength Heat-resistant Fiber-free Thermal Insulators with World's Highest Level of Porosity

External view of conventional insulator (upper right) and newly developed insulator (lower left)
While conventional insulators weigh 2.9 kilograms, newly developed ultra-lightweight insulator weighs just 370 grams

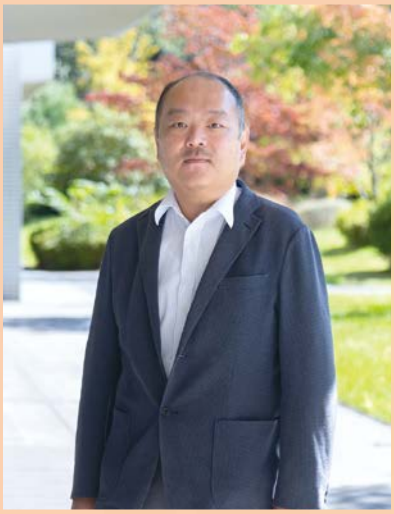
Aiming for 50% reduction in quantity of released from furnaces, representing trade-off between porosity and high strength

In the cement and ceramics industries, only about 2% of thermal energy input for firing furnaces used at temperatures above 1000°C is utilized to heat products, and about 98% is wasted as unused heat. To address these issues, it is necessary to develop thermal insulators that can be used at high temperatures. However, widely used fiber-based insulators exhibit very low strength and are carcinogenic, while fire bricks with high-strength exhibit lower porosity, which affects thermal conductivity.

NEDO, together with AIST and Mino Ceramic Co., Ltd. have been working toward the development of a new fiber-free insulator that combines elevated levels of strength and thermal insulation.

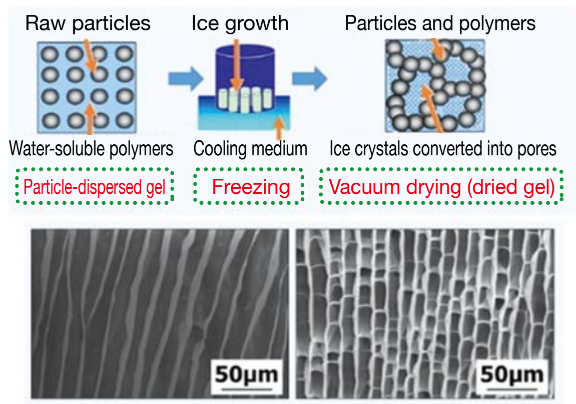
The project employs a gelation freezing method developed by AIST in 2008. By freezing a gel with 99% water content in which ceramic particles are dispersed, and then drying and sintering the gel, a thermal insulator can be realized that exhibits porosity levels of 98% or higher, the highest in the world. An insulator using particles of mullite, which exhibits low levels of thermal conductivity and high strength, has been fabricated that realizes high compressive strength of over 15 MPa, thermal conductivity of less than 0.25 W/m·K, and heat resistance at 1500°C.

In addition, the addition of fish-derived antifreeze protein (AFP) has resulted in more uniform and finer pores. Dr. FUKUSHIMA Manabu of AIST recalls, "Industrial furnaces are considered as a mature technology, and innovation has been slow in this field, but the NEDO project has created new excitement." Project Manager IWATSUBO Tetsushiro of NEDO's Energy Conservation Technology Department says, "I believe we were able to take on the challenge of realizing ambitious goals so the scope of this technology should expand. NEDO will continue to provide support for social implementation of this technology." Looking ahead to the future, Dr. Fukushima notes, "We would like to spread the utilization of previously unused sources of thermal energy to fields outside of ceramics, such as steel and metals."



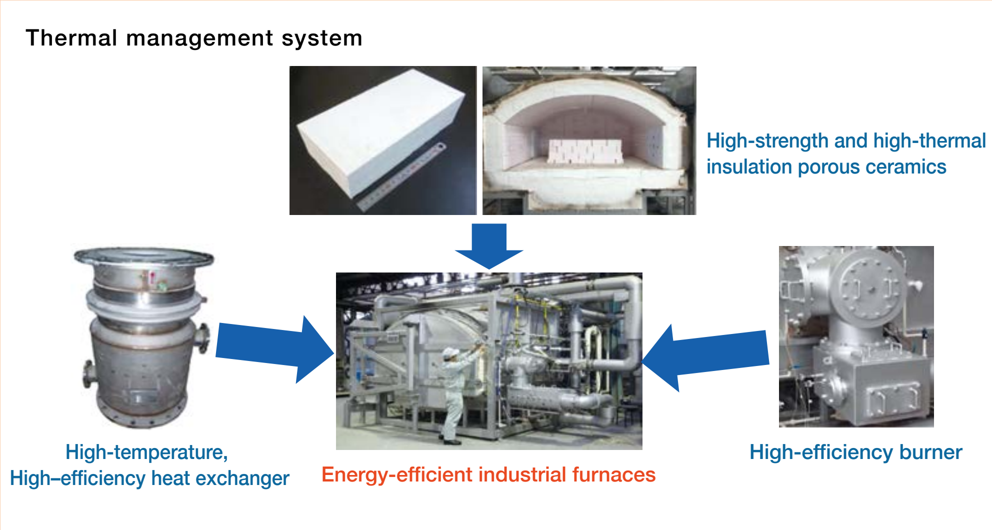
Dr. FUKUSHIMA Manabu
Group Leader
Ceramic Microstructure Control Group
Multi-Material Research Institute
National Institute of Advanced Industrial Science and Technology (AIST)

Outline of gelation-freezing method



Reduce
Thermal insulation

R&D on energy-efficient furnaces using high-strength and high-insulation porous ceramics



Thermal management system for energy-efficient industrial furnaces

Realizing High Levels of Efficiency and Energy Conservation in Industrial Furnaces by Combining Fiber-free Insulators and Peripheral Components

Realizing mass production of fiber-free insulators and heat recovery/combustion efficiency levels higher than those for conventional products

In industrial furnaces, where only about 2% of thermal energy input is used to heat products, efficient thermal management of the insulators used in furnaces and their peripheral components is essential to further improve the efficiency of thermal energy consumption.

In addition to R&D aimed at the commercialization and mass production of porous fiber-free insulators, NEDO and Mino Ceramics, working together with AIST, have carried out R&D on high-temperature-resistant and high-efficiency heat exchangers that improve the efficiency of heat recovery from high-temperature exhaust gas as well as high-temperature resistant and high-efficiency burners that improve combustion efficiency.

Fiber-free insulators produced through the gelation-freezing method take a long time to dry frozen bodies due to their high water content. Furthermore, when the water is frozen, large ice crystals can be often formed, resulting in non-uniform structure and lowered strength. By replacing the added water with air bubbles, a more uniform structure was realized with a 40% reduction in drying time.

In addition, the test furnace with fiber-free insulators successfully reduced fuel consumption by about 36%. Furthermore, a work was being carried out to develop a high-efficiency heat exchanger that could be operated at temperatures above 1500°C, achieving a heat recovery efficiency of approximately 23%, which is more than three times that exhibited by conventional heat exchangers.

To improve the combustion efficiency of the regenerative burner, a new thermal storage material which shaped like a ball was developed that is covered a metal core with large thermal storage capacity by a highly heat-resistant ceramic shell. The material has twice the high thermal storage rate and the thermal dissipation rate of existing ceramic thermal storage materials.

MATSUOKA Ayumi of the Mino Ceramic Technical Research Laboratory recalls, “We were able to take advantage of our company’s technical strength which we have cultivated in our plant engineering operations in the design and development of peripheral components. A great advantage of the NEDO project was the collaboration between industry, academia, and government researchers, including those at AIST and Nagoya University.”

In the same vein, Dr. TANAKA Yosuke of Mino comments, “We are receiving requests from many customers to save energy and reduce CO_2 emissions of industrial furnaces, but manufacturing costs are still an issue. We would like to conduct public relation work that highlights our efforts to reduce manufacturing costs while at the same time achieving greater energy saving.”

MATSUOKA Ayumi
Assistant Manager
Technical Development Section
Technical Research Laboratory
Mino Ceramic Co., Ltd.

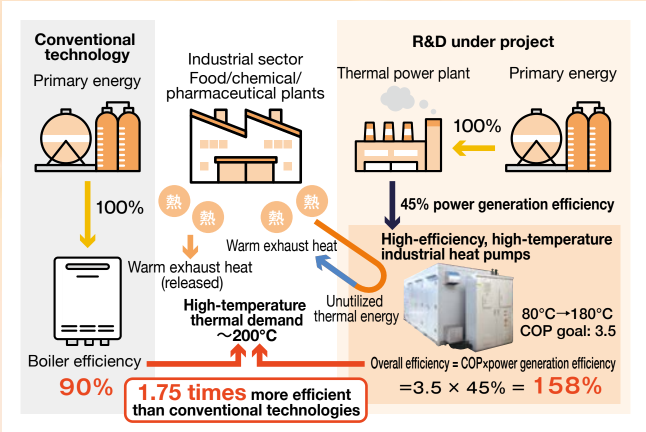
Dr. TANAKA Yosuke
Assistant Manager
Technical Development Section
Technical Research Laboratory
Mino Ceramic Co., Ltd.

YOSHIMI Yasutaka
Director
Technical Research Laboratory
Mino Ceramic Co., Ltd.

Reuse
Heat pumps

Development of industrial high-temperature heat pumps using low-GWP refrigerants

Second prototype of container-sized unit.
Future plans are to downsize unit for greater portability.



Realization of COP 3.5 brings overall efficiency to 158%, 1.75 times higher than that realized by conventional technologies.

Realizing Heat Pumps with Maximum Heating Temperature of 200°C to Efficiently Utilize Waste Heat from Factories

High expectations for use in wide range of industrial sectors, including food production, vehicles, and pharmaceuticals

Unused heat of 80-100°C is generally discarded during factory production processes. If this waste heat is utilized as heat source using heat pump technology and transformed into higher temperature thermal energy, it will contribute to energy conservation in factories and realization of carbon neutrality.

NEDO together with Mayekawa Manufacturing Co., Ltd., has been working on realization of high-efficiency high-temperature heat pumps that achieve a maximum heating temperature of 200°C and a COP energy efficiency rating of 3.5. By installing the heat pump being developed under the project, primary energy for the production process can be reduced by about 48% and the quantity of unused heat can be significantly reduced.

KUDO Mizuo
Deputy Head
Research and Development Center
Research and Development Division
Mayekawa Manufacturing Co. Ltd.

MACHIDA Akito
Executive Officer
Research and Development Division
Mayekawa Manufacturing Co., Ltd.

To realize this goal, it was necessary to develop basic technologies for refrigerants, compressors, and heat exchangers that could handle high levels of temperatures and pressures. Since it is difficult to use ordinary lubricants when the compressor discharge temperature exceeds 200°C, a non-contacting oil-free turbo compressor with magnetic bearings was developed, as well as new technology for heat exchangers to cope with high temperatures and high pressure levels. The first prototype used a hydrocarbon refrigerant, but the second prototype uses an HFO-based low-GWP refrigerant. At the same time, the number of compression stages were optimized from three to four and rotations were also revised, and as a result almost all targets have been realized during fiscal year 2022.

KUDO Mizuo, Deputy Head of Mayekawa's Research and Development Center, says, "In the development of compressors and heat exchangers, we obtained a great deal of guidance from Professors OHTA Yutaka and KATSUTA Masafumi of the Waseda University School of Science and Engineering. I believe that only a NEDO project could have made it possible for us to work with colleagues in academia." MACHIDA Akito, Executive Officer in Mayekawa's Research and Development Division, says, "Being selected for the NEDO project had the significant effect of raising awareness within our company of the challenge of addressing such social issues."

Mayekawa plans to downsize the system and conduct field tests to visualization its effects and begin full-scale commercial application in fiscal year 2025.

Reuse

Heat pump chillers

Development of high-performance chillers driven by 60° C low-temperature waste heat

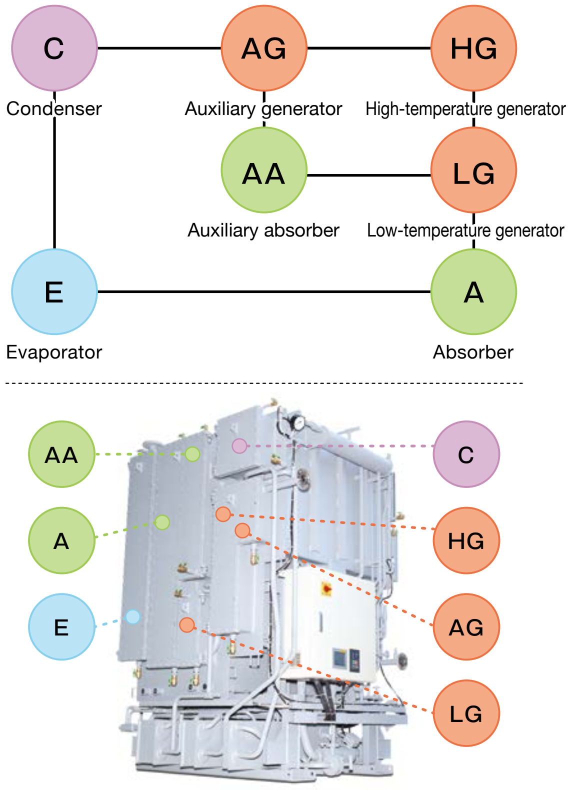
Promoting Use of Low-temperature Waste Heat for Commercial Air Conditioning and District Heat and Cooling

Absorption chillers that can utilize twice as much waste heat energy as conventional models

Of the waste heat generated by industries with high heat demand, most of it is discarded in the low temperature range of 60-80°C. NEDO has been working with Johnson Controls-Hitachi Air Conditioning, which has been involved in the development of absorption chillers for sources of heat, on R&D to develop a low-temperature driven heat pump that can recover waste heat in this temperature range and utilize it for cooling and other purposes.

Absorption chillers produce chilled water for cooling by repeating the cycle of evaporation, absorption, generation, and condensation of refrigerants. In this cycle, waste heat is utilized in the generation process, in which water vapor absorbed during the absorption process is broken down again into water and absorbent. In conventional absorption chillers, even if heat of 90°C is utilized in the generation process, hot water of about 80°C would still be discarded. The absorption and generation processes were therefore designed to be performed in two stages, and, by performing the first generation process using high-temperature waste heat and then performing the generation process again using lower-temperature waste heat, a single-effect double-lift absorption chiller was successfully developed that can potentially recover waste heat down to 55°C and utilize about twice as much of it.

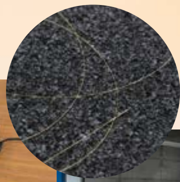
How the single-effect double-lift concept works



According to Dr. FUJII Tatsuo of Johnson Controls, there were many challenges to overcome prior to commercialization. Dr. Fujii notes, “It was necessary to figure out the optimal arrangement for the internal workings of the chiller, as well as its shape and size in consideration of the site where it would actually be installed. In addition, it was difficult to procure sufficient resources for the process from the laboratory research level to the final product stage. In this sense, the NEDO project made possible our product development.”

The chiller is currently being used in office buildings, factories, and hospitals in Europe. Dr. Fujii explains, “In Europe, where environmental awareness is high, the concepts of district heat utilization and cogeneration are well developed, and interest in and demand for utilization of discarded waste heat is also high. In Japan, understanding of the utilization of waste heat is still progressing, but social trends associated with energy security and carbon neutrality are creating greater interest. We would like to take advantage of these trends to promote the use of this technology in Japan and other countries as well.”

Dr. FUJII Tatsuo
Chief Engineer
Design Department
Engineering Division
Johnson Controls Building Efficiency Japan



Optical fiber utilized as sensor


TherMAT member Marelli wind tunnel test facility

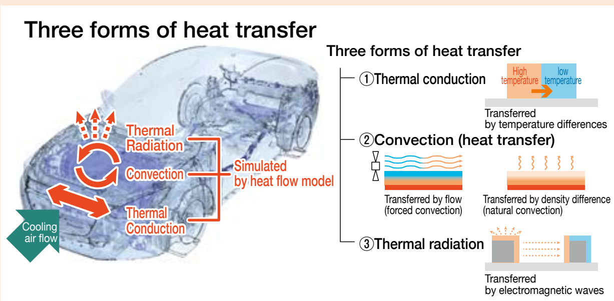
Development of Highly Accurate Electrified Vehicle (xEVs) Heat Flow Simulation Model

Realizing target accuracy for increasingly important thermal flow simulation models for electrified vehicles

The electrification of vehicles is progressing on a global scale. However, to increase the commercial viability of xEVs*, thermal management is essential to maintain optimal temperatures not just for conventional internal combustion engine components, but also for motors, batteries, and other components used by xEVs. To effectively address the increasingly complex thermal issues facing xEVs, it is necessary to realize more accurate model-based research and development (known as MBR and MBD).

In this context, NEDO and Mazda have been working step by step on the development of technologies related to heat flow measurement and analysis, actual measurements of xEVs, and the development of a heat flow simulation model. TANEHIRA Takafumi of Mazda’s Technical Research Center says, “Each component of the xEV possesses a different optimum temperature range, so we needed a heat flow simulation model that could accurately simulated temperatures to improve fuel/electricity efficiency, extend battery life and etc. ”

To simulate the three forms of heat transfer (thermal conduction, convection, and thermal radiation), the project developed a temperature sensor technology using optical fibers to measure spatial temperatures in the engine/motor compartment at a high resolution. In cooperation with AIST and TherMAT, a method to measure convection and thermal radiation separately by using two heat flux sensors with different levels of emissivity has been developed for use on xEVs (e.g. see upper right photo). By utilizing actual measurement data using these sensors, the target level of accuracy for the three-dimensional heat flow and one-dimensional simulation model was realized.



Regarding the NEDO project, Tanehira says, “At TherMAT, I was able to interact with a wide variety of researchers and engineers, which was very stimulating,” while SHINHAMA Makoto, a principal engineer at Mazda’s Technical Research Center, says, “I believe the project has been significant in terms of training engineers. We also received third-party evaluations on a regular basis that helped us stay on track.” As the percentage of BEVs increases in the future, KOIKE Yusuke, a technical leader at Mazda’s Technical Research Center, points out, “We need to develop BEVs in a flexible manner while responding to changes in user values and social infrastructure.” In this way, the value of using MBR/MBDs to accelerate vehicle development is increasing.

※Types of xEVs: HEV= hybrid electric vehicle, PHEV= plug-in hybrid electric vehicle, BEV battery electric vehicle, FCEV=fuel cell electric vehicle

Source: METI homepage:
https://www.meti.go.jp/shingikai/mono_info_service/jidosha_shinjidai/pdf/002_01_00.pdf

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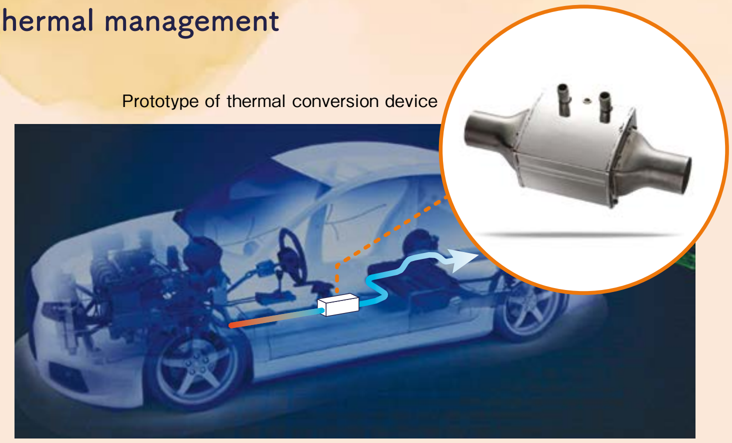
Management

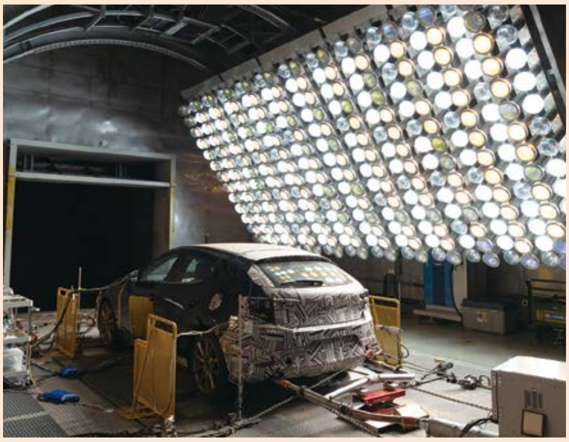
Thermal management

[Heat quantity assessments for electrified vehicles and R&D on next-generation energy management devices]

Prototype of thermal conversion device



Depiction of energy management device selection and installation

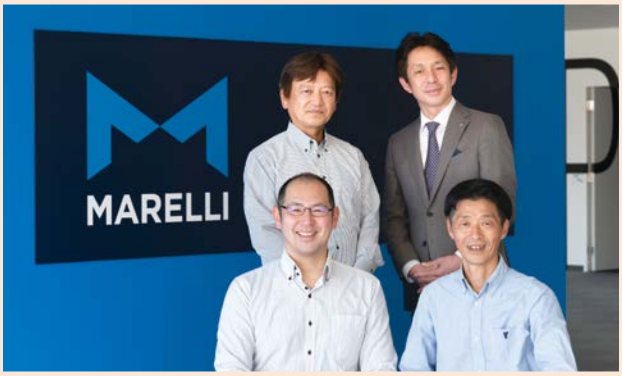


Wind tunnel test facility for vehicles that can reproduce ambient temperatures from -40 to 55 degrees Celsius and humidity conditions from 30 to 100%

Development of Thermal Measurement Technologies Capable of Selecting Optimal Devices for Variety of Electrified Vehicles

Analyzing quantity of heat in exhaust gas to assess technical value and determine optimal installation locations for newly developed devices

With a view toward reducing CO_2 emissions and improving the energy efficiency of electrified vehicles (xEVs), energy management devices (e.g., exhaust heat recovery devices, thermoelectric conversion devices, and heaters) must be developed that are tailored to the vehicle's thermal energy flow. Moreover, it is also necessary to understand the quantity of waste heat, level of energy utilization, and effect on energy efficiency prior to vehicle development.



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TANAKA Hideo
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Testing Research Center Administration Department
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With this in mind, NEDO and Marelli Corporation have been working together to develop simulation models that can estimate the thermal energy flow of a variety of xEVs with different types of powertrains and conduct R&D to realize fundamental technologies for determining optimal thermal energy management devices tailored to each type of vehicle.

Work under the project measured the energy flow of series-parallel HEVs under ambient temperatures ranging from -20°C to 35°C, as well as the heat content of exhaust gas from series-type HEVs, PHEVs and micro HEVs, to determine the amount of unutilized heat attributable to differences in powertrains, then project researchers were able to quantify the differences in the quantity of heat recoverable from each type of vehicle.

In addition, the quantity of electricity and level of energy efficiency realized when a thermoelectric device is installed that converts thermal energy recovered from exhaust gas into electrical energy were measured during simulations, thereby making possible the determination of the optimal location to install such devices. These measurements will be used to improve the accuracy of future simulations and determine optimal energy management devices.

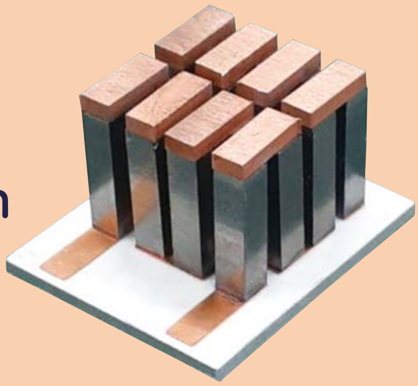
NAKAJIMA Shirou of Marelli recalls, "It was very meaningful to collaborate with the other companies and universities participating in TherMAT to gain a better understanding of the vehicle," while TANAKA Hideo of Marelli also notes that "One of the results of the project was that we were able to measure exhaust heat at low temperatures using the wind tunnel facility." HISANAGA Toru comments, "In Japan, where energy resources are scarce, it is essential to improve the thermal efficiency of internal combustion engines. Although many are calling for a shift to BEVs, we would also like to continue work on developing PHEVs and HEVs, while keeping track of developments in the market."

Recycle

Thermoelectric power generation

Development of high-performance clathrate module for thermoelectric conversion at medium to high temperatures

Realizing Thermoelectric Conversion Efficiency of 15% in Support of Environment-friendly Society



Configuration of thermoelectric module used for prototyping and evaluation

Achieving targets related to development of thermoelectric modules and enhanced performance of clathrate compounds

Thermoelectric conversion, which converts heat into electricity, is a promising technology for utilizing waste heat released by factories and other facilities in the medium to high temperature range. However, thermoelectric materials currently used commercially are expensive, harmful to the environment, and their conversion efficiency is not sufficiently high, so the development of inexpensive, environment-friendly, high-performance thermoelectric materials has been awaited for many years.

To address these challenges, NEDO and Furukawa Electric Co., Ltd. have been co-working on research and development of next-generation materials with high conversion efficiency. MIMURA Yu, General Manager at Furukawa's Sustainable Technology Laboratory, says, "Under the project, we set a high target of 15% conversion efficiency to take advantage of the fact that the module has no moving parts and is maintenance-free."

A multi-junction thermoelectric module capable of realizing high levels of energy conversion efficiency has been developed using P-type and N-type elements of environmentally friendly clathrate compounds. The calculated conversion efficiency has reached 16%, as a result of the innovative design of the module. Demonstration testing is currently being conducted to confirm the target value.

A single-piece U-shaped module consisting of P-type and N-type sintered bodies made of silicon clathrate compound has also been developed. Mimura describes the module's superior design, "Since this module has no joints, it is stable even at high-temperatures and it can be held over an open flame."

YAMAMOTO Takahiro, a Furukawa Electric researcher, observes, "Even slight changes in material composition or sintering conditions can significantly change the product's characteristics, so we had a hard time in optimizing the module. However, as the NEDO project enabled us to conduct joint research with academia, the data and guidance we received from university researchers were extremely helpful for the product's development." Mimura also touches on the benefits of this project, saying, "We have been able to exchange information and discuss with companies participating in TherMAT and these exchanges have led to very fruitful collaborations."

For the future, Yamamoto observes, "We need to consider how to increase the size of the system while maintaining the level of performance achieved in the laboratory." Mimura describes the path toward commercialization by saying, "To use exhaust heat from factories, we also need to build a thermoelectric power generation system and, based on our research with customers, we would like to develop and install operative systems."

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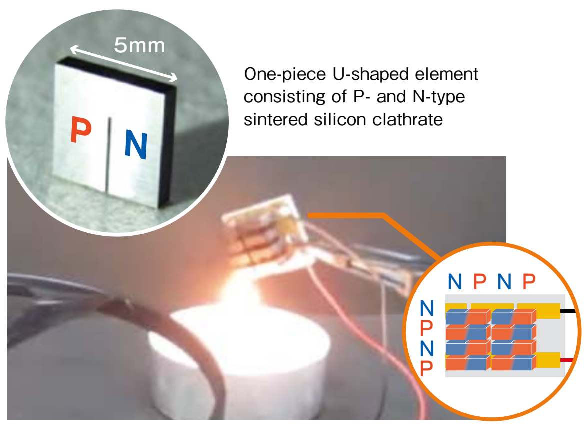
Research and Development Division
Furukawa Electric Co., Ltd.

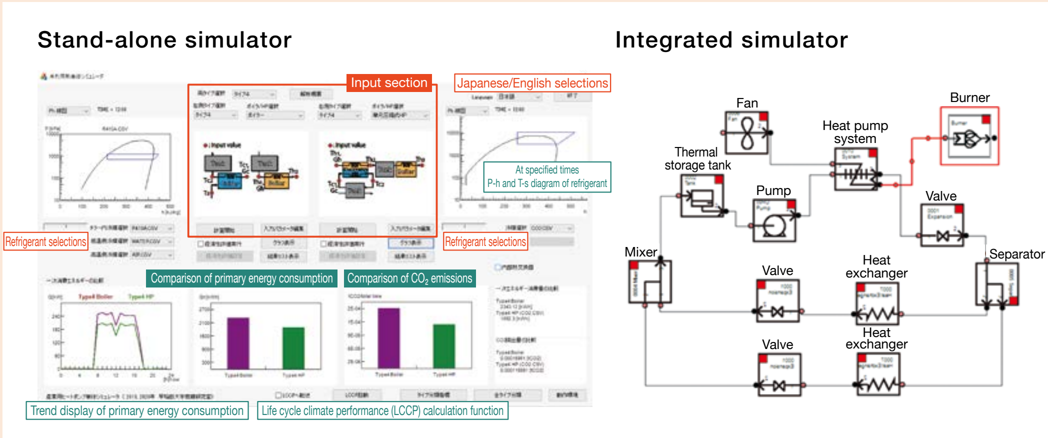
MIMURA Yu
General Manager and Chief Researcher
Advanced Technologies Research Department
Sustainable Technology Laboratory
Research and Development Division
Furukawa Electric Co., Ltd.



Thermoelectric module with U-shaped element made of sintered silicon clathrate. When held over an open flame, the module generates electricity.

Management
Basic technologies

[Development of integrated analytical simulation technology for heat pumps]



Visualize installation performance with simple inputs! Industrial Heat Pump Simulator

Significantly reduces the cost and time required to estimate primary energy consumption and CO_2 emissions and to analyze system installations

Expectations are growing for the introduction of industrial heat pumps to replace burners and steam boilers due to their efficient utilization of industrial waste heat and their lower environmental impact. However, the time and cost required to obtain a comprehensive spectrum of data for assessing the feasibility and benefit of heat pump installations has been a major barrier to their deployment.

With this in mind, NEDO has been supporting the research and development of an industrial heat pump simulator that can readily analyze the impact of heat pump installations in comparison with conventional boilers and burners.

The three organizations involved in the project, the Japan Research and Development Center for Metals (JRCM), Mayekawa Manufacturing Corporation, and Waseda University, surveyed usage patterns in factories and recognized eight main patterns based on a combination of three categories: heating method (circulating or non-circulating), intended use of heat pumps (preheating or replacement), and simultaneous use of heating and cooling (yes or no). A stand-alone simulator for heat pumps, which can accurately estimate primary energy consumption and CO_2 emissions by simply selecting the corresponding pattern and entering information regarding the rated heating capacity, feed water temperature, flow rate, and refrigerant, was then developed and released. In addition, the development group also took on the challenge of developing an integrated industrial energy simulator to evaluate the performance of complex systems, including boilers, tanks, valves, and other components.

Professor SAITO Kiyoshi of Waseda University says, “Japan’s thermal energy technology is outstanding, but costs are still high, and it is difficult to visualize the benefit of implementing this technology. However, if the advantages in energy conservation and profitability can be demonstrated, I believe it will support the deployment and diffusion of heat pump systems.” Dr. TOYODA Shunsuke of JRCM, which organized a working group of companies and industry associations, says, “The significance of the NEDO project stemmed from bringing together people from different fields and backgrounds who shared the awareness of the issues and worked toward common goals.” In the future, NEDO will work toward the practical implementation of the industrial energy simulator so that it can be applied by different fields to visualize the impact of installing heat pump systems.

Dr. TOYODA Shunsuke
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The Japan Research and Development Center for Metals

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Dean, Sustainable Energy & Environmental Society Open Innovation Research Organization
President, Consortium for the Research Strategy of Next-generation Heat Pump Technology

Promising NEDO Startups

Startups growing into the future with NEDO's support

Innovator File.23

Mobility Energy Circulation Co., Ltd.

Representative Director
MAEZONO Shinji

Development of system using ultra-compact waste heat power generation and batteries to power conventional freezing and refrigeration devices on-board vehicles

https://www.mobenecircu.com/

Only available in Japanese

Air-cooled binary power generator with 1kw output mounted under cargo bed of vehicle (CG image)

Demonstration testing of on-board system

2019 Founding of Mobility Energy Circulation Co., Ltd.
Received funding from Energy & Environment Investment Inc.

2021 Selected for NEDO Research and Development on New Energy Technology for Discovering Technology Seeds and Commercializing Developed Technologies
(Phase C: R&D on Commercial Applications)

Q1. How have you taken advantage of NEDO's support programs?

We were able to improve the efficiency of the ultra-compact waste heat power generator* and demonstration testing of the enhanced system produced the results we were hoping for.

We are currently conducting testing that focuses on the operation of equipment controls to realize the maximum amount of power generation under actual operating conditions.

The NEDO program was extremely helpful because we had just finished basic testing of fuel efficiency improvements using a truck and it was time to improve the system's ORC binary power generation.

Q2. What is Mobility Energy Circulation's vision for the future?

While continuing to develop the ORC controller, we plan to conduct demonstration testing with the cooperation of businesses who use trucks in their operations.

We have signed an NDA and are in the process of selecting vehicle models. We are planning to build several units and test them in diverse types of operations before formally adopting them. Based on the testing results, we plan to expand sales to other businesses and are also planning to install the system on ships such as cruisers and fishing vessels.

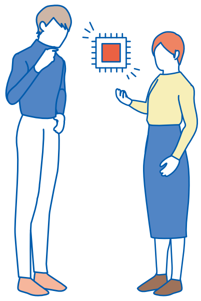
Air-cooled binary power generator used to power light bulbs

＊Air-cooled binary power generation system with 1kw specification for on-board use

NEDO Comment

This startup is developing a system to generate binary power from the waste heat released by vehicle engines, a power source that has not been utilized until now. This system has been installed on a refrigerated truck that uses the power for cold storage and enhancing fuel efficiency. In the future, we look forward to greater utilization of low-temperature waste heat.

To revitalize the economy, it is important to foster entrepreneurs that have competitive innovative technologies.
NEDO provides startup support from a variety of perspectives to develop research and development-oriented startups and entrepreneurs.
Here, we examine notable startups that are continuing to grow toward the future.



Innovator

File.24

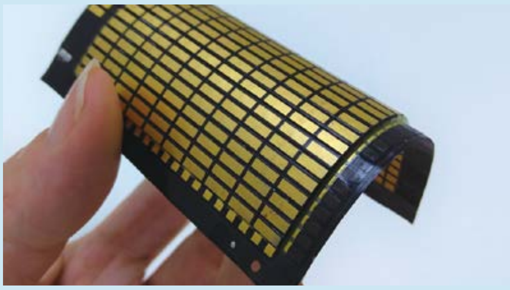
E-ThermoGentek, Co., Ltd.

Representative Director/CEO
Dr. NAMBU Shutaro

J-Startup KANSAI

Manufacturing, sales, and R&D on thermoelectric power generation devices and systems

Japanese website http://e-thermo.co.jp/
English website https://e-thermo.securesite.jp/E-ThermoGentek_2104v1.pdf



Curved thermoelectric module known as Flexina®

2013	Founding of E-ThermoGentek Co., Ltd.
2016	Selected for NEDO Seed-stage Technology-based Startups program
2017	Selected for NEDO New Energy Venture Business Technology Innovation Program (Phase B)
2018	Selected for NEDO New Energy Venture Business Technology Innovation Program (Phase C) Received Rank A certification from Kyoto Venture Company Connoisseur Committee
2020	Selected for NEDO Research and Development on New Energy Technology for Discovering Technology Seeds and Commercializing Developed Technologies (Phase C) Selected for NEDO Strategic Innovation Program for Energy Conservation
2022	Selected by METI Kansai for J-Startup Kansai program

Q1. How have you taken advantage of NEDO's support programs?

Through the NEDO project, we were able to develop basic technologies for our uniquely flexible thermoelectric energy generation module ; Flexina®. The module recovers low-temperature waste heat below 300°C currently released into the environment in enormous quantities and converts it into electric energy with a cost-performance ratio that justifies commercialization for the first time as thermoelectric power generation. Thanks to NEDO's support, we have attracted world-wide attention as a startup that is a leader in its field and laid the groundwork for great advances in the future.

*Flexina® is a registered trademark of E-ThermoGentek Co., Ltd.

Q2. What is E-ThermoGentek's vision for the future?

Together with partner companies, we aim to create a sustainable society by reducing global warming through the promotion of businesses that utilize our thermoelectric power generation technologies to recover enormous quantities of low-temperature waste heat and convert it into electricity. This type of stand-alone thermoelectric power generation system will promote the full-scale diffusion of IoT in a variety of industrial sectors and contribute greatly to the development of a virtual power plant (VPP) distributed power supply system, expected to be greatly used in the future due to its resilience in the face of natural disasters.

Our IoT stand-alone power supply series, which was commercialized under a NEDO project, is expected to be a key device for promoting the rapid diffusion of IoT systems in industrial settings. We have already received more than 400 inquiries from various businesses in the industrial sector regarding low-temperature waste heat recovery systems.

We will initially promote our business development in Japan, but by expanding overseas as soon as possible, we aim to become a company that sets the global standard in this field.

NEDO Comment

The company's unique technology, which has been realizing steady results, demonstrates that highly efficient recovery of low-temperature waste heat can address customer needs in a wide variety of sectors. We hope the positive outcomes realized by the company under NEDO support programs will be put to practical use and contribute greatly to society.

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March 2023