focus NEDO
2016
No.61
Reporting on Today and Tomorrow's Energy, Environmental, and Industrial Technologies

1st Featured Article

Plant-Based Materials Attract Global Attention!

How Cellulose Nanofibers Have Come a Long Way

2nd Featured Article

Utilizing Databases to Assist the Development of Solar and Wind Power Generation

New Energy and Industrial Technology Development Organization

Lessons from the Merits and Demerits of LEDs

Motoko Ishii
Lighting Designer

Within the last few years, LED lighting has expanded around the world. In Japan, it has become commonplace to use LED lighting in new buildings.

Certainly LEDs have numerous benefits, such as reduced power consumption, long lifespan, small form factor, and free dimming control. In addition, the ability to easily create any color of light by integrating the three colors of light red, green, and blue on a single chip is a very attractive feature.

With so many advantages, LED lighting has created new possibilities for us. With such a long lifespan and low power costs in particular, LEDs can be used in ways that weren't possible before. For example, they can easily be used for indirect lighting or be embedded into a shelf.

However, those merits can become demerits when LEDs are used incorrectly.

Recently, I feel that the view of Tokyo at night has become hideous. As the number of high-rise buildings in Tokyo has increased, the skyline has become a jumble of randomly arranged building blocks. During the day the glare of sunlight obscures the scene, but once night falls the colors begin to shine. Among those lights, numerous bad use cases are revealed.

A building with multiple overlapping horizontal lines of blue lights, a building studded with red and yellow points of light, a building plastered with a myriad of green horizontal lines… It looks like every one of those buildings has arbitrarily chosen strong colored lights thinking only of how to make themselves stand out.

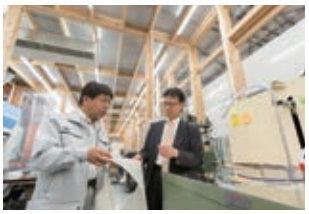
As I look up the night sky, I unconsciously feel like screaming, "Ah, I don't want to see this night view!"

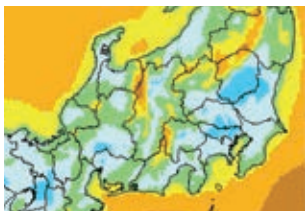
With LED light sources that have so many advantages that weren't available before, shouldn't we think about how to preserve harmony with our surroundings and explore how to use them in moderation more? Our mission in developing technology does not end when it finally enters the market, and my hope is that we can build a future where society and technology can work more in unison.

Motoko Ishii

A lighting designer who has developed a wide range of lighting installations, from urban and architectural lighting to lighting-based performances. Well known in both Japan and overseas, her major projects include Tokyo Tower, Rainbow Bridge, Tokyo Gate Bridge, landscape illuminations in Hakodate and Kurashiki, the Historic Villages of Shirakawa-go, Soene Akari Park, and Kabukiza Theatre. In 2000, she was a Purple Ribbon Medal of Honor recipients, and she is currently an advisor for the Tokyo Organizing Committee of the Olympic and Paralympic Games.

Contents





focus NEDO 2016 No.61

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

"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.

1st Featured Article

Plant-Based Materials Attract Global Attention!

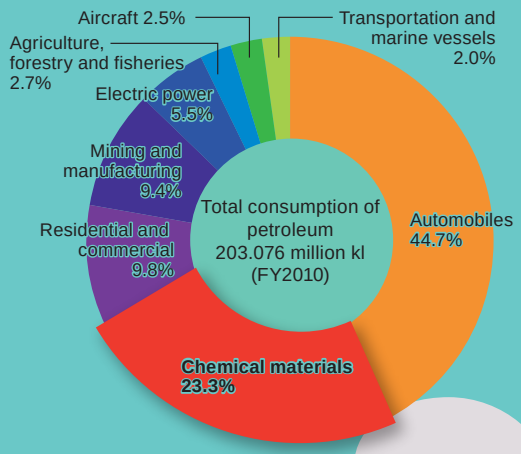
How Cellulose Nanofibers Have Come a Long Way

Many of the products that surround us are composed of materials like resin, which generally require the use of large amounts of petroleum as a raw material. In collaboration with research institutions and private companies, NEDO is working on research and development of technologies that can enable the substitution of plants for petroleum as a source of raw materials. Currently Japan mostly relies on imports for most of its resources, but we can see the prospect of a future as a "plant resources superpower" where plant-based materials can contribute to reducing the risks posed by oil depletion and global warming.

Automobiles

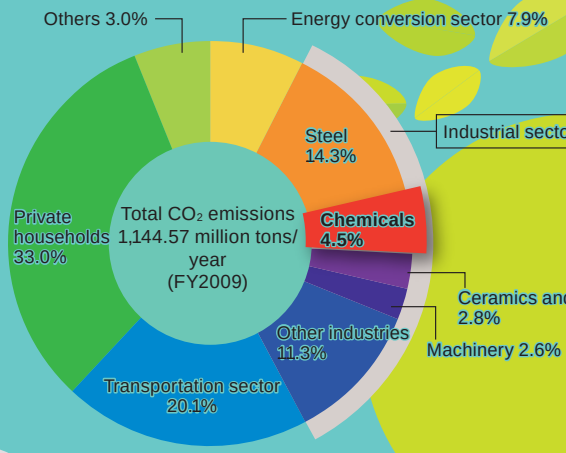
Components & Materials

Consumption of petroleum products by use



Source: Petroleum Association of Japan "Oil Industry Today 2012"

CO_2 emissions in Japan by energy source



Source: National Institute for Environmental Studies Greenhouse gas emission/absorption database

Global Warming

Convert

Resource Exhaustion

Manufacturing Everyday Items from Plant-Based Materials Contributing to Solving Environmental Problems from Our Dependence on Oil

To manufacture products in our daily life such as vehicles, home electric appliances, and household items, many chemical products including plastics and synthetic fibers are used. The main source of raw materials for such products right now is petroleum oil. In fact, approximately 23% of the overall consumption of petroleum in Japan is used to produce chemicals.

However, the use of petroleum is always associated with risks like price fluctuations, and it is well known that if we continue to use petroleum it will eventually be exhausted. Furthermore, in the process of producing chemicals from petroleum the carbon dioxide (CO_2) is emitted. About 4.5% of overall CO_2 emissions come from manufacturing chemicals, and it accounts for approximately 13% of the total emissions from the industrial sector. Because of these issues, there is a need to review the continued use of petroleum as a source of raw materials for manufacturing.

Under this situation, plant-based materials are drawing attention from the world as alternative raw materials for chemical products to petroleum. In the past, plant-based materials have been used in producing everyday items such as rubber and scotch tape, but plants including lumbers contain materials that can be used as raw materials for components used in vehicles such as aircraft and automobiles, next-generations electronics such as flexible displays and a wide variety of typical commodities.

Japan has an abundance of trees, and it is possible to become a resource-rich powerhouse if we can produce chemicals from trees. Furthermore, plant material is one example of the renewable resource called biomass, so it could also be effectively used to resolve issues such as CO_2 emissions caused from using petroleum.

Therefore, NEDO has been working on research and development of technologies for manufacturing chemicals from non-edible plants, which do not compete with plants grown for food. From FY2009 to FY2012, we developed chemical manufacturing processes utilizing non-edible biomass under the “Development of Fundamental Technologies for Green-Sustainable Chemical Processes” project. Since FY2013, we’ve been working on the “Technology Development of Manufacturing Processes for Non-edible Plant-derived Chemicals” project.

Starting on the next page, we introduce those two projects and their potential future impacts.

The Future of New Materials Created from Non-Edible Biomass

Interview with the Project Leader

Kazuhiro Mae
Project Leader

What will the future created by plant-based resources be like? Kenichi Sasaki, Chief Officer of the NEDO Materials Technology and Nanotechnology Department, along with Project Leader Kazuhiko Mae, discuss the purpose, features, progress, and future goals of the "Technology Development of Manufacturing Processes for Non-edible Plant-derived Chemicals" project.

Kazuhiro MAE
Graduated from Kyoto University Faculty of Engineering in 1980. After working as a corporate researcher, joined Kyoto University Faculty of Engineering as a research assistant. Professor of Kyoto University Graduate School of Engineering Department of Chemical Engineering since 2001. Holds a Ph.D. in engineering and specializes in environmental process engineering.

Implications for Solving Environmental Problems and Creating a Domestic Industry

Sasaki: NEDO's "Technology Development of Manufacturing Processes for Non-edible Plant-derived Chemicals" project was launched in FY2013 and since then it has been working on two commissioned projects and two grant projects. As the Project Leader who oversee the whole project, how did you feel when you were assigned to this position first?

Mae: I accepted it so I could take a small step towards transforming the situation in Japan. As you know, biomass is one kind of renewable energy resource. If you use it as fuel, you can only use it once. However, if you create chemical products from it, you can use it for carbon fixation for a certain period of time, creating a condition where CO_2 absorption exceeds CO_2 emission, which is even better than being carbon neutral. As countries around the world face dangers like global warming, Japan aims to create a sustainable carbon cycle society, and I believe we can contribute to realizing such a society by manufacturing chemical products from plant-based materials.

Additionally, this project can contribute to revitalizing domestic industry. If we create manufacturing hubs to produce high value added chemical products from plant-based materials in Japan, there is a good chance it can become a pillar of a new industry. If paper mills located in every region across Japan are used to produce the raw materials for chemical products which then are used by the chemical industry in the production of commercial products, it can create a new geographically decentralized industry structure.

Chemical Products Produced from Non-Edible Plants Integrated Manufacturing Processes Are the Key

Sasaki: It seems what distinguishes this project is the development of an "integrated manufacturing" process for producing chemical products from non-edible plants.

Mae: That's right. From the beginning, the idea has been that, with an eye towards practical application, it is critical to overcome the associated cost challenges, and that an integrated manufacturing process is necessary for this to be viable.

Sasaki: Also, among the four projects you've been working on each has a different difficulty level. How do you feel about that?

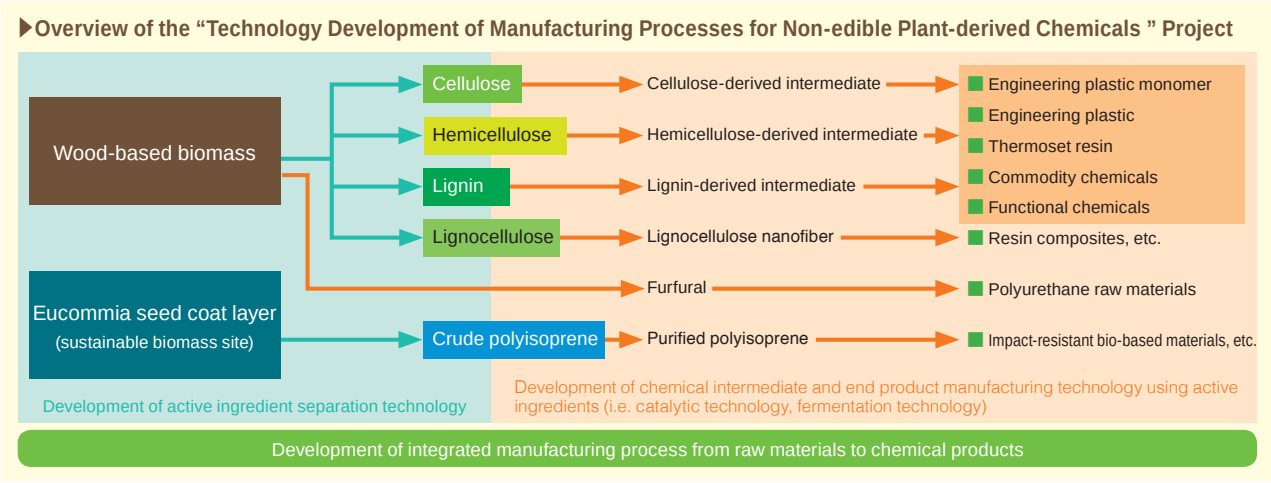
Mae: With regards to the two grant projects, one is using hemicellulose, a component of wood-based biomass, and the other one is using fruit skins as the basis of developing material manufacturing processes, and I think both projects have shown steady progress.

On the other hand, the two commissioned projects are more challenging because we try to utilize not only cellulose and hemicellulose but also lignin, which has been used only for combustion in the past. For one of those projects, as part of the lignocellulose nanofiber integrated manufacturing process

KEYWORD

Biomass
Organisms including plants that can be used as an energy source or raw material for chemical products. The use of non-edible biomass, which is biomass that people can't consume as food, can avoid competition with food supplies so it is seen as an effective resource to use for chemical products.

Carbon Neutral
The status that the amount of emission and absorption of CO_2 are balanced. Burning plants and causing CO_2 emission wouldn't affect the fluctuation of CO_2 amount since plants absorb CO_2 in the process of growing.



Dr. Mae (left) and Chief Officer Sasaki (right) discussing the potential of non-edible biomass.

development project led by Prof. Hiroyuki Yano of Kyoto University, we have been pursuing Prof. Yano's unique idea to manufacture chemical products that keep the special characteristics of wood by retaining the lignin (see p. 08-09). The other project is focused on developing an integrated manufacturing process that can separate the three materials of lignin, cellulose, and hemicellulose without losing their special characteristics, decompose on the molecular level, and build up chemical products. From a cost perspective turning lignin into high value-added chemical products is a major problem, and we are exploring solutions.

Sasaki: This is a seven-year project and it's been three years since it started. It seems that the project is going smoothly. What do you think about the progress of the project?

Mae: I think we've managed close to a perfect score. We began the project working on basic research, and we received very high marks as part of our mid-term evaluation three years into the project. Currently we're in the middle of technical data collection. However, I think the hurdles we face will get progressively higher from here. The challenge is the amount of lignin available to use as resin. One of the merits of this project is that it involves both the paper and chemical industries. Paper manufacturers can't feasibly manufacture resin, but on the other hand resin manufacturers want increased access to lignin. Therefore, through mutual communication we can reach a point of agreement. This is why integrated manufacturing such an important meaning.

Creating the Kind of Industry that Can Lead the World

Sasaki: While NEDO has been working on fundamental research into bioplastics since FY2009, the development of chemical product manufacturing processes using non-edible biomass has accelerated in Europe and the United States recently. Japan has been ahead of the world in achieving results in developing integrated manufacturing processes, but I think we would like to continue addressing challenging issues.

Japan has paper mills throughout the country, and those mills can take advantage of this technology in their production processes. In the future, if the results of our integrated manufacturing process development can be used in regions throughout Japan, it could lead to the revitalization of regional economies.

Mae: Nowadays, the potential of the "Internet of Things (IoT)" to connect all our items to the Internet has grabbed everyone's attention. If an industry based around biomass as a resource arises across Japan in the future and functions as a whole by adding tools like information technology, it could become a major national strength for Japan. Many entities are involved in this project including corporations, and all of them are very serious and have a strong will to realize chemical product manufacturing from biomass. I hope to establish the kind of industry that can lead the world.

Kenichi Sasaki
Chief Officer of NEDO Materials Technology and Nanotechnology Department
Project Manager, "Technology Development of Manufacturing Processes for Non-edible Plant-derived Chemicals"

Cellulose
A polysaccharide which is the primary component of plant cell walls and plant fiber. Accounts for half of the content of wood. Used as the raw material for pulp to make paper, as well as rayon and cellophane. If you compare wood to steel-reinforced concrete, cellulose serves the function of the rebar.

Hemicellulose
A hydrophilic low-molecular-weight polysaccharide accounting for approximately one quarter of the content of wood. Used as raw material for various synthetics and chemical resins through decomposition into sugar.

Lignin
A hydrophobic phenolic polymer accounting for approximately on quarter of the content of wood. Provides adhesion and solidity in between plant cells. If you compare wood to steel-reinforced concrete, lignin serves the function of the concrete.

Integrated Manufacturing of Strong and Light-weight Resins from Woods!
Progress towards Mass-Production by Establishing the "Kyoto Process"

For the practical use of non-edible plants as chemical products, people have great expectations for composite materials utilizing "lignocellulose nanofibers" (ligno CNF). Now an integrated manufacturing process called the "Kyoto Process" has been established, representing a major step towards the mass-production of the new materials.

Wood chips. Japan's abundance of trees can become raw materials for strong and lightweight resins.

Integrated Manufacturing Plant for New Materials Established at Kyoto University's Uji Campus

In March 2016, a test plant for the integrated manufacturing of new materials was completed at Kyoto University's Uji Campus. Using lignocellulose nanofibers (ligno CNF) derived from wood and plastics like nylon to create composites, the facility is working to produce strong and lightweight materials.

"It's been about twelve years since we started this research. We've been working on this as a NEDO project for eight years, and finally we have established an integrated manufacturing process," said Professor Hiroyuki Yano of the Kyoto University Research Institute for Sustainable Humanosphere with deep emotion as he stands in front of the test plant.

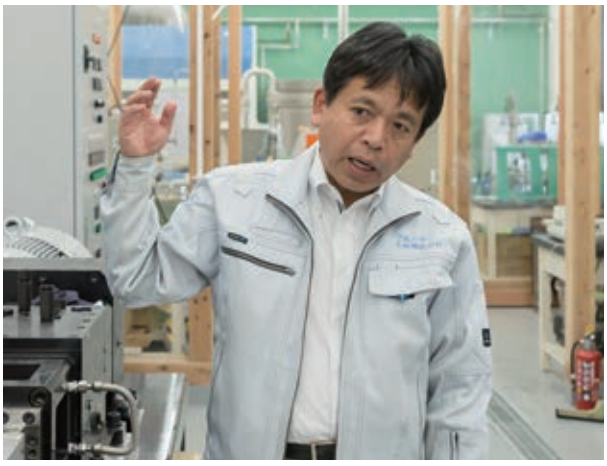
Two Breakthroughs Enable Manufacturing Costs Ten Times Lower than Conventional Methods

This project has been implemented as a part of the "Technology Development of Manufacturing Processes for Non-edible Plant-derived Chemicals" project under the theme of "The Development of Production Process for High Performance Lignocellulosic Nanofibers and their Applications." The people including Prof. Yano who have been involved in the development have named the integrated manufacturing process the "Kyoto Process". In this process, using wood from trees like conifers that are abundant in Japan, a pulp containing lignin (see p. 07) is created and then unraveled into fibrous ligno CNF. Then by mixing them into plastics such as nylon at a proportion of 10%, highly functional materials that are similar to carbon fiber reinforced resins and glass fiber reinforced resins already in practical use can be produced.

Researchers around the world have treated the lignin in wood like a nuisance and tried to manufacture cellulose nanofibers (CNF) without lignin. On the other hand, Prof. Yano has dared to keep a small amount of lignin in the mix. "If you remove the lignin, the cellulose (see p.07), which acts as the "bones" of the wood, gets damaged and the material loses its heat-resistant characteristics. However, if you keep the right amount of lignin, the CNFs can withstand the high-temperature treatment," Yano explains. As a result, it becomes possible to create composites with highly functionality and a high melting point such as "nylon 6".

To mass-produce the materials, the cost performance of the process needed to be improved as much as possible. So Prof. Yano examined two solutions and incorporated the outcome into the "Kyoto Process".

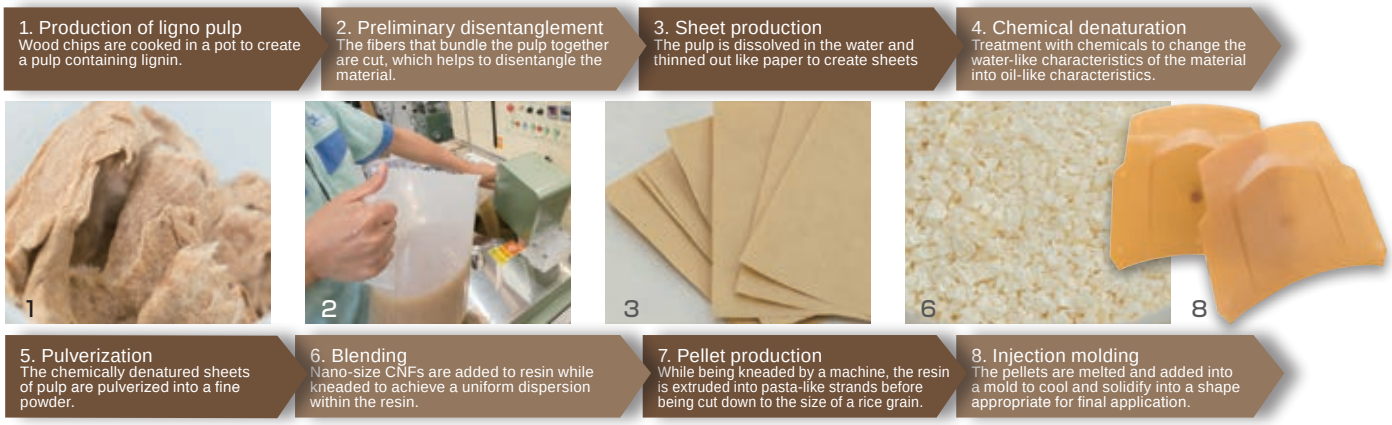
One solution was to enable "chemical denaturation" (see p.09 for the process overview). "Resins, including nylon, have characteristics similar to oil. On the other hand, cellulose has characteristics similar to water. Even if you try to combine these two, they won't blend,



Hiroyuki YANO
Graduated from the Kyoto University Graduate School of Agriculture Forestry Engineering Department in 1984. Received his Ph.D. in agriculture in 1989. After serving as a research assistant and instructor at Kyoto Prefectural University, he joined the Kyoto University Wood Research Institute as an assistant professor in 1998. Currently serving as a professor at the Kyoto University Research Institute of Sustainable Humanosphere's Laboratory of Active Bio-Based Materials since 2004.

Nanofiber

▶The Flow of the “Kyoto Process”



just like oil and water. So we asked Prof. Fumiaki Nakatsubo, a specially-appointed professor at Kyoto University Research Institute of Sustainable Humanosphere, for help and he developed a method to make the characteristics of cellulose compatible with oil through chemical processing.”

The other breakthrough was to break down and loosen the bundled fibers into “nano-size” particles to create composite materials with plastics like nylon later in the process during resin kneading. “Creating nano-sized particles before chemical denaturation makes the following process more difficult and increases costs. So we decided to create the nano-sized particles toward the end of the process to control the cost.”

Prof. Yano and his colleagues addressed their challenges and established the “Kyoto Process”. The manufacturing cost of the process is ten times less than the previous methods. Chief Officer Akira Urano of NEDO, who is in charge of this project, said, “With the unique idea from Prof. Yano’s team, we are much closer to the practical realization of this concept. This is a huge accomplishment for this NEDO project.”

The Huge Potential Impact on Japanese Industry and the Global Environment

As for CNFs, the Ministry of Economy, Trade and Industry (METI) has set a goal of “mass-producing CNFs by 2020, and achieving growth of the CNF-associated market to one trillion-yen by 2030.” Also, the government’s “Japan Revitalization Strategy 2016” clearly states that Japan will “promote efforts to facilitate the use of CNFs in materials through cellulose nanofiber research and development,” adding to the growing national momentum behind CNF development.

But how will CNFs actually be used in society and what impact will they have? “There are many different applications,” says Prof. Yano. “They can be applied to electronic components as well as serve as a viscosity modifier for cosmetics and food. But the most widely expected application will be the use of large volumes of CNFs as reinforcing fibers. If they are used for major parts of automobiles and in the body of consumer electronic products, the annual production amount of CNF in Japan would reach the one to two-million-ton level in the future. Moreover, Japan has a tree plantation capacity that exceeds this level of production. Japan can become a country that exports highly functional material resources to the world. The secret to making this possible is CNF.”

Furthermore, the use of CNFs in automobile parts could lead to lighter cars, which has benefits for energy conservation, and the ability to use conventional pulp manufacturing processes used by paper manufacturers is cited as a potential advantage that could lead to the creation of a new industry without huge investment costs. In fact, through this NEDO project, besides Kyoto University, Oji Holdings Corporation, Nippon Paper Industries Co., Ltd., Seiko PMC Corporation, and the Kyoto Municipal Institute of Industrial Technology and Culture have been involved in research and development work, and in May 2016, they introduced a prototype CNF composite engine cover that was 30% lighter than conventional parts at the Ise-Shima Summit government exhibition.

In such ways this R&D project has been steadily producing results, but NEDO has set a goal to “establish cost competitive manufacturing technologies for ligno CNF material and chemical products” by FY2019, the end of the scheduled project term. In October 2016, NEDO plans to provide samples of ligno CNFs manufactured via the “Kyoto Process” to companies and public institutions.

“We would like to further improve the quality of the ‘Kyoto Process’,” Yano continues. “We’ve been examining eight different kinds of woods including cedar, cypress, and bamboo to figure out which types work best as raw material. Also, to use in lighter weight and harder to deform materials, we’ve been working hard on the technology to create foam materials.”

That’s ligno CNF, a technology that is ready to contribute to strengthening Japanese industry and improving the global environment. As we strive to achieve our huge expectations, NEDO will continue our efforts to promote further development of practical applications.

Chief Officer Urano (right) of the NEDO Materials Technology and Nanotechnology Department stands with Prof. Yano in front of the wooden building of the Kyoto University Uji Campus Research Institute of Sustainable Humanosphere.

Cooperating with Chemical and Paper Manufacturers to End Dependence on Petroleum-Based Chemicals!

Without wasting any of the wood used, high value-added chemical products is manufactured from three kinds of wood components. To realize the manufacturing process, the research project "Development of an Integrated Process for Manufacturing Chemicals from Woody Biomass" has been conducted with the involvement of 18 organizations.

Fusion of Paper and Chemical Manufacturing Technologies Realizing an Integrated Manufacturing Process for Creating Chemical Products from Wood

If we can turn the three main components of wood, lignin, cellulose, and hemicellulose, into chemical products with a minimum of waste, we can reduce the relative manufacturing cost and make wood-derived chemical products competitive with oil-based chemicals in the market. Accordingly, NEDO has been conducting research and development for the realization of an integrated manufacturing process that can separate the three components of wood simultaneously and then use them to produce a variety of chemical products. The current project involves 18 organizations, including paper manufacturers, chemical manufacturers, universities, and research institutions.

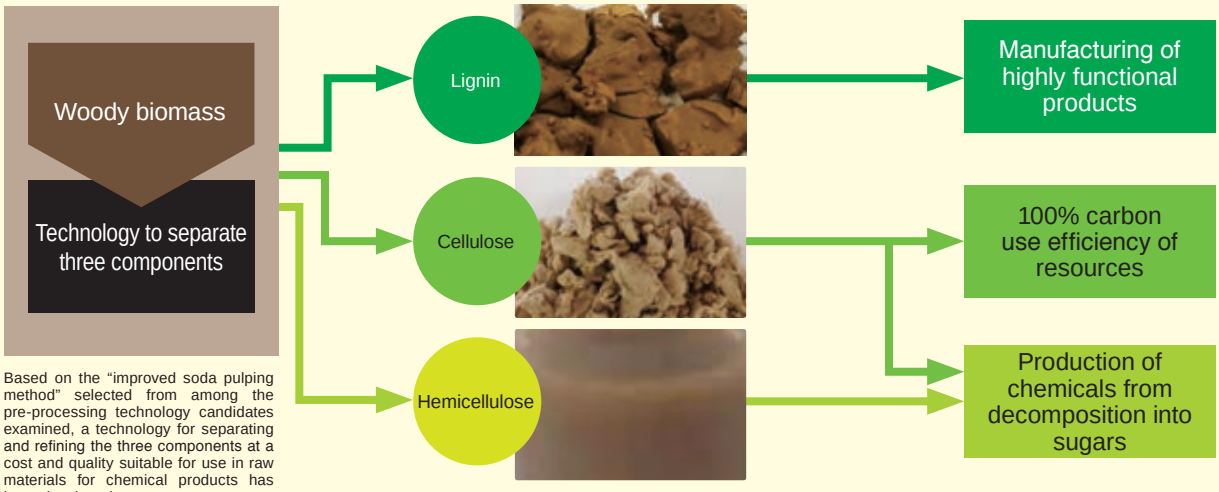
Originally, paper manufacturers developed the technology for creating pulp as a raw material for creating paper from wood over many years. They used a technique of dissolving wood chips in sodium hydroxide known as "soda pulping". On the other hand, chemical manufacturers have technologies to make products by fermenting, refining, and denaturing raw materials. So the integrated manufacturing process being developed utilizes the technology from paper manufacturers first to separate the three components. Then, the paper manufacturers provide them as raw materials to chemical manufacturers, who use their technologies with the aim of producing a variety of high value-added chemical products from lignin, cellulose, and sugars produced from cellulose, and hemicellulose.

The research and development period is scheduled for seven years beginning in FY2013. So far, we have conducted research focused on technologies to separate the three components. With regards to lignin, which has a complex structure that limits use, technology development is underway to make it easier to produce commercial chemicals through conversion into low-molecular-weight substances. As for utilizing cellulose, the project has thoroughly studied processes for efficiently producing substances used as raw materials in plastic like levulenic acid. And with respect to sugar, the project developed a technology to produce a substance called deoxy-scyllo-inosose (DOI), which is useful as raw material for creating pharmaceuticals and functional resins, by using genetically engineered E. coli bacteria. In the future, NEDO plans to transition from the research phase to a phase involving testing of the technologies by the manufacturers involved in the project.

Estimated Costs and Yields from the Prices of Final Products Are Common Indicators

The ultimate goal is to develop a technology suited to mass production and demonstrate the integrated manufacturing processes at the bench scale (factory scale trials). NEDO also aims to ensure that this integrated manufacturing process is both cost-competitive and produces chemical products of equal or higher quality than petroleum-derived chemicals.

▶An Integrated Manufacturing Process to Realize the Creation of High Value-Added Chemical Products from the Three Components of Wood, Lignin, Cellulose, and Hemicellulose



Based on the "improved soda pulping method" selected from among the pre-processing technology candidates examined, a technology for separating and refining the three components at a cost and quality suitable for use in raw materials for chemical products has been developed.

Functional Materials from the Hardy rubber tree (Eucommia)! Practical Applications Coming Soon



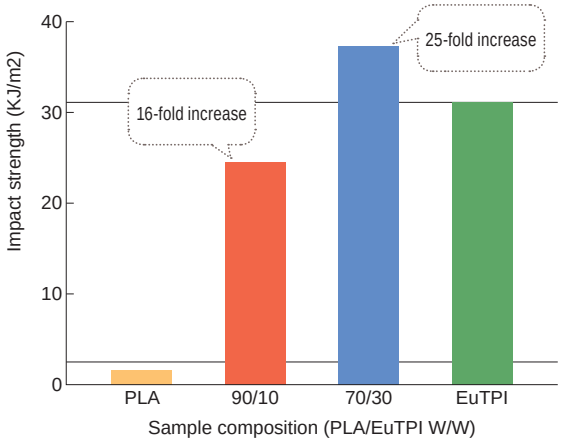
Expected product applications



Some of the research and development projects aiming to realize manufacturing processes for plant-derived chemicals are close to achieving commercialization. NEDO's goal is to refine highly functional materials from the Eucommia and utilize them in a wide range of products from sports to nursing care.

(above) An Eucommia forest. Plantation programs are underway in places like Henan, China.
(left) Tearing off the pericarp of the Eucommia seed reveals crude bio trans-polyisoprene. Once purified, this is blended with polylactic acid by melt-mixing.

▶Impact-Resistance Compared to Polylactic Acid



Comparison of impact characteristics of different combinations

PLA: polylactic acid
EuTPI: bio trans-polyisoprene

Bio trans-polyisoprene, derived from the Eucommia, is characterized by stereoregularity and a high molecular weight. With dynamic cross-linking technique, polylactic acid / bio trans-polyisoprene blend could have high impact resistance property.

Extracting Superior Polymers from the Eucommia of "Tochu Tea" Fame

Eucommia is a deciduous tree native to the southwest region of China, and is used as an ingredient in "Tochu Tea" in Japan.

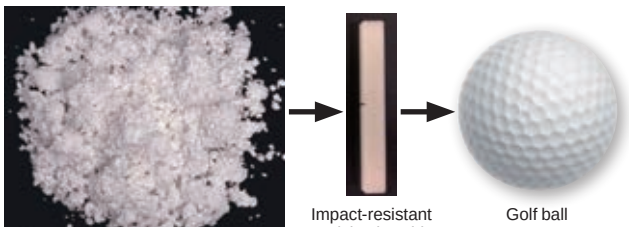
One of the components found in Eucommia is called "trans-polyisoprene". This is one of the commercial polymers which is currently synthesized from petroleum. NEDO has been promoting research and development into replacing those chemicals with materials derived from Eucommia as part of a grant project, and an industry-academia collaboration led by Hitachi Zosen Corporation has successfully developed highly functional bio-composite materials as a result.

The production process started with the isolation of crude bio trans-polyisoprene from dried pericarps of Eucommia seeds, followed by the purification. Next, we blended these refined materials with polylactic acid, one kind of biodegradable plastics, by melting-mixing. The dynamic cross-linking technique, applied to the melt-mixture between Eucommia-derived bio trans-polyisoprene and polylactic acid, contributes to the increasing of impact resistance of the resulting materials up to 16 - 25 times, compared with the neat polylactic acid. It is also found that the functional properties of bio trans-polyisoprene such as tensile strength are superior to those of petroleum-derived trans-polyisoprene.

Bio trans-polyisoprene originated from Eucommia has high impact resistance and strength. It is expected to have a wide variety of practical applications beginning with sporting goods such as golf balls, medical and dental materials, automobile supplies such as door components, household products such as reinforced gloves and suitcases, and nursing care products such as walking sticks and hand rails.

*Dynamic cross-linking technique: A method for improving the impact resistance and ductility of compound materials by combining polylactic acid, Eucommia elastomers, and a small amount of cross-linking agents in a kneading machine to achieve an even dispersion of molecules within the compound.

▶Sporting Goods Made with Impact-Resistant Polymers



2nd Featured Article

Utilizing Databases to Assist the Development of Solar and Wind Power Generation

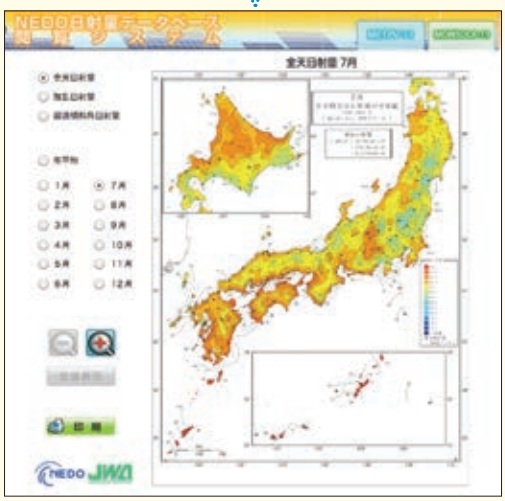
NEDO has taken advantage of its many years of experience in new energy technology development and released a variety of databases useful for estimating the capacity of solar power generation or wind power generation installations.
Please utilize these databases when you consider introducing new energy projects.

Solar Power Generation

Solar Radiation Database

Enabling the easy simulation of solar power generation estimates for all areas of Japan

With this database, you can understand the amount of solar radiation received per hour or month at any of over 800 locations for any arbitrary azimuth and inclination, as well as view the distribution of solar radiation on a map.



The national solar radiation map, found within the national solar radiation database browsing system. Just choose the solar radiation conditions and the monthly period, and the solar radiation levels across the country will be displayed on a color-coded map. A simple mouse click allows the user to enlarge the image.

What you can find through this database

1 Learn the hourly solar radiation levels over the course of a day

MEteorological Test data for PhotoVoltaic system (METPV-11)

Based on the solar radiation data from 837 locations across Japan collected over 20 years (1990-2009), you can calculate the hourly solar radiation based on azimuth and inclination to estimate the power generation by azimuth or inclination. You can also learn the precipitation and temperature.

2 Learn the annual or monthly solar radiation

MONthly mean SOLAr radiation data throughout Japan (MONSOLA-11)

Based on the solar radiation data from 837 locations across Japan collected over 20 years (1990-2009), it displays monthly total solar radiation based on azimuth and inclination. You can estimate annual and monthly power generation (JIS C8907 “Power Generation Estimation Method for Solar Power Systems” recommended data).

3 Map the solar radiation around the country

Solar Radiation National Map

It displays the MONthly mean SOLAr radiation data throughout Japan (MONSOLA-11) on a map of Japan. You can learn the geographical distribution of monthly and annual averages of solar radiation.

From the Public to Professionals, Please Take Advantage of the Databases When Thinking About Introducing Solar Power

Since solar power is a system to generate electricity from the light emitted by the sun, the amount of solar radiation available is essential information for calculating power generation potential. If you are considering introducing a solar power generation system, why don’t you begin by checking how much sunlight is received at the location?

In addition, the “Solar Spectrum Database” NEDO recently added is essential data for developing solar cells and solar power systems. NEDO thinks it will prove to be a big help for solar power researchers. Please take advantage of them.

By the way, when you look at solar radiation levels across Japan you’ll find it differs by location. When travelling, if you look at the solar radiation characteristics of the place you are visiting, you may come to have a different impression of the sunlight you feel. I use the data in that kind of way too.

Hiroyuki YAMADA
NEDO New Energy Technology Department
Director, Solar Energy Systems Group
Project Manager

Comments from Users

It was very helpful because the optimum inclination can be viewed by month and in an easy-to-understand format. (residential builder)

We are planning to use this Solar Radiation Database to examine the solar radiation level when we investigate the cause of gaps between the expected level of power generation and the actual measurements. (energy company)

I have been using this data to analyze the solar power generation at my home. (homeowner)

It is helpful for my solar cell research for university. (university student)

We are considering using this database to present the estimates for a specific location when we develop a plan for our clients. (solar panel manufacturer)

Let's Try! How to Use the Solar Radiation Database

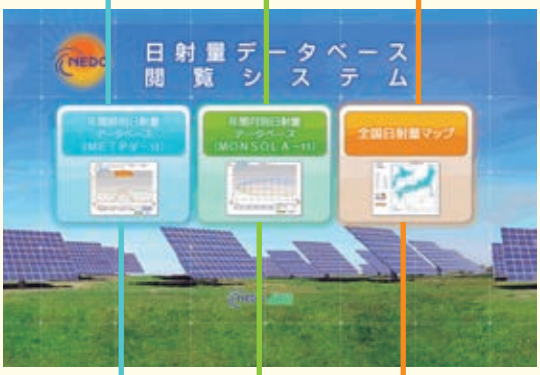
Now you can use these databases on our website directly, there's no more need to download it on your computer. Let's follow along to learn how to use the database.

To find out the solar radiation in Tokyo on April 15

To find out the average solar radiation in Tokyo during the month of April

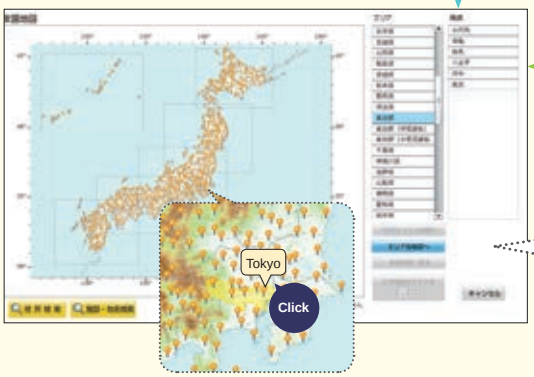
To find out the solar radiation distribution across the country in the month of April

Top page of the Solar Radiation Database



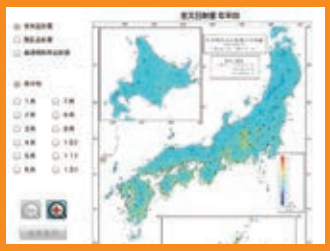
When you open the "Solar Radiation Database Browsing System", three titles will be displayed on the top page. Under each title, the dark-color part in the box is the button, so choose the data you want to examine and click the button.

To see the data for Tokyo, click the "Kanto/Koshin/Hokuriku/Tokai" region on the map and then move the cursor to examine the pins on the map and click when it displays "Tokyo". Then after clicking the specific area that contains the location that you are interested in, click the pin that is placed the closest to the location that you want to check. You can also use the list on the right side to choose the area and specific location.

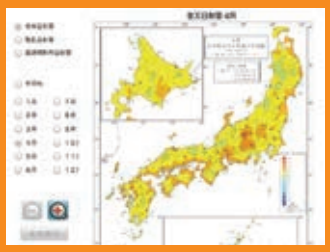


When you choose the location, the button at the bottom right of the page "Display graph for this location" turns orange and you can click it.

Solar Radiation National Map

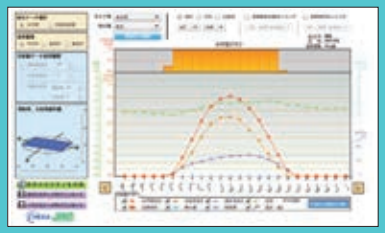


It displays the "annual average" of "total solar radiation" first. When you choose "April" on the left of the page, you can find out the "total solar radiation distribution around the country in April".



You can also choose "diffuse solar radiation" or "minimum inclination solar radiation". By clicking "+" and "-" you can zoom in and out the area displayed on the map.

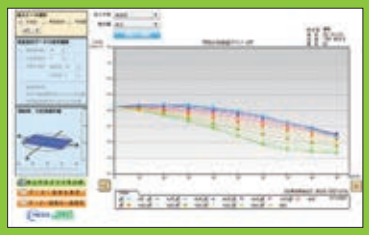
MEteorological Test data for PhotoVoltaic system (METPV-11)



It displays the graph of daily solar radiation in Tokyo for January 1. Change the month and date at the top to "April 15", and it shows the "solar radiation in Tokyo on April 15" for a non-inclined surface.

Choose "inclined solar radiation" by using the button on the left of the screen, and you can set the inclination or azimuth you are interested in. It can also display the average annual high or low solar radiation.

MONthly mean SOLAr radiation data throughout Japan (MONSOLA-11)



It displays the graph of monthly solar radiation in Tokyo for the month of January. By switching the display data on the left of the screen to "April", you can see the "average solar radiation in Tokyo during the month of April".

By choosing "designate angles" using the button on the left of the screen, you can set the inclination or azimuth you are interested in. It can also display the "optimum inclination".

We've added the "annual variation" function so you can see the range of variation by month, the annual average, or seasonal variations. Choose "annual variation" on the left of the screen, and it displays the changes in the average as well as the annual and seasonal variation and monthly maximum and minimum amounts.

How to access

Solar Radiation Database Browsing System | Search

Please visit the website at:
http://app0.infoc.nedo.go.jp

The user manual can be found at:
http://www.nedo.go.jp/content/100484811

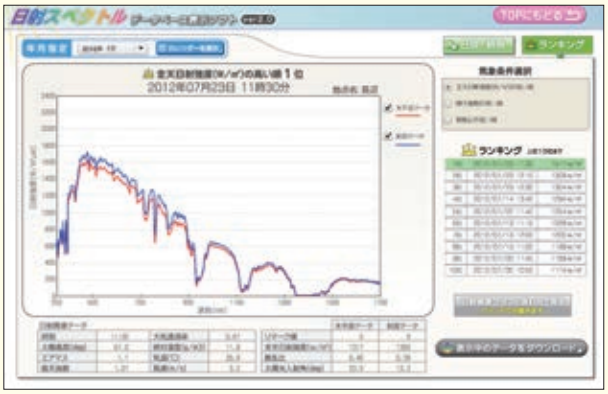
More Convenient! Introducing the New Databases

In addition to the widely used solar radiation database, NEDO released newly prepared "Solar Spectrum Database" and "Solar Radiation Database for the Asian Region" in March 2016.

Solar Spectrum Database

Great potential for use in research and development of new types of solar cells!

Top page of the database. Choose the location, year and month from the five locations listed around the country, click the button and the graph will be displayed.



Graph of Naganuma-cho, Hokkaido, in July 2007. This screen displays the ranking of the 10 highest periods of total solar radiation for July 2007 in descending order.

The solar radiation spectrum is the distribution of solar radiation energy across different wavelengths. We combine solar radiation spectrum data for inclined and flat surfaces in five locations, Hokkaido (Naganuma-cho), Ibaraki Prefecture (Tsukuba City), Gifu Prefecture (Gifu City), Saga Prefecture (Tosu City), and Kagoshima Prefecture (Okinoerabu Island), with weather data and make the database available for display through the website.

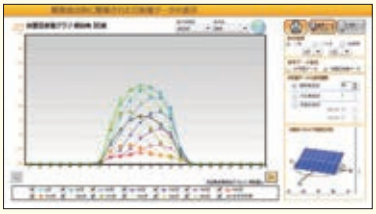
This database provides the spectral sensitivity, the ratio between the intensity of incident light for a specific wavelength and the output current value of a solar cell, for each location taking into account the weather conditions in Japan. Therefore, it can be used in high-precision predictions of power generation amounts, or the research and development of new types of solar cells, to determine the special characteristics of solar cells using new materials and multijunction cells combining multiple materials.

Please visit the website at:
http://app0_2.infoc.nedo.go.jp
The user manual can be found at:
http://www.nedo.go.jp/content/100778070.pdf

Solar Radiation Database for the Asian Region

Understand the amount of solar radiation across Asia

Top page of the Asian map of solar radiation



A screenshot showing inclined surface data from the "Solar Radiation Data at Each Station". Choose the country and location from the regions in Asia, and various weather information will be displayed.

Based on solar radiation data from NEDO projects and the WRDC (World Radiation Data Centre), NEDO has created a databases of calculated average monthly and hourly solar radiation levels for the Asian region, and you can view the data via our website. You can choose from "Map of Solar Radiation" or "Solar Radiation Data at Each Station" at the top of the page.

This database can be displayed in either Japanese or English. This helps you to understand solar radiation across Asia and you can use them to evaluate your business activities and promote solar power in Asia.

Please visit the website at:
http://app0_1.infoc.nedo.go.jp
The user manual can be found at:
http://www.nedo.go.jp/content/100778072.pdf

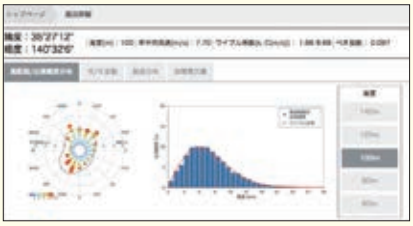
Wind Power Generation

Offshore Wind Conditions Map (Demo Version)

The first resource in Japan to unify the various information needed to plan offshore wind power generation

In addition to the previous wind condition map, NEDO has released a demo version of Offshore Wind Conditions Map which incorporates environmental and port area information as well as wind condition for certain marine area (off the coast of Choshi).

A screenshot of an enlarged view of the Choshi coast from the larger map. By using the bar on the left and the cursor, you can zoom in or out and move between locations on the map.



A screenshot displaying detailed wind conditions. It can also display monthly or annual wind speed fluctuation and the vertical distribution of wind speeds.

In FY2015, based on weather and sea condition information collected from NEDO's offshore wind condition observation system proving research off the coast of Choshi and Kitakyushu, NEDO started to develop a new "Offshore Wind Conditions Map", which unifies information needed to plan offshore wind power generation including information on wind conditions, the environment, and the social environment. Now NEDO is releasing the "Offshore Wind Conditions Map (Demo Version)" with incorporating wind condition information for a limited area (off the coast of Choshi).

For the first time in Japan, we have unified the various data points needed to plan offshore wind power generation, including wind conditions based on highly accurate mathematical simulations, environmental information such as water depth and marine geology, and social environment information such as port areas and major marine routes. NEDO is planning to finalize the "Offshore Wind Conditions Map" by the end of the FY2016 in an effort to let it be utilized in various situations, including not only as basic information for evaluating projects by offshore wind power generation businesses but also finance and insurance businesses.

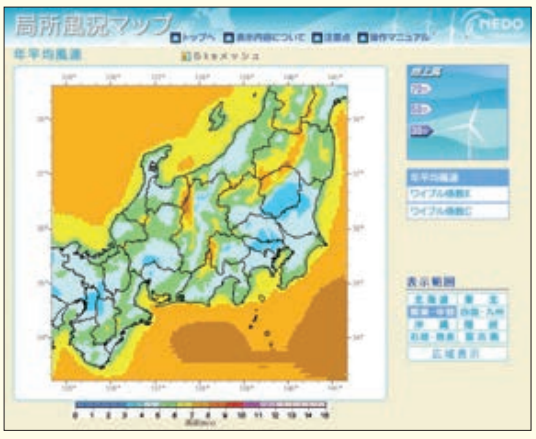
How to access

Offshore Wind Conditions Map | Search

Please visit the website at:
http://dcm04.gis.survey.ne.jp/Nedo_Webgis

Wind Conditions Map (FY2006 updated version)

Shows wind conditions around the country and is helpful for evaluating wind power project locations



5-kilometer mesh display of Kanto/Chubu region. By clicking the map, it zooms in and displays one level finer mesh.

Based on the "wind condition data" collected by the Japanese Meteorological Agency as well as mathematical models for predicting the weather, the map displays the distribution of wind conditions on a map of Japan based on a 5km, 1km, or 500m mesh grid suitable for comparing wind conditions over a wide area. It displays a "wind rose" to show the average annual wind speed, the typical direction of wind and frequency of wind speeds that occur at a height of 30-, 50-, and 70-meters above ground.

How to access

Wind Conditions Map | Search

Please visit the website at:
http://app8.infoc.nedo.go.jp/nedo/

Understand Better! News Release Commentary

A special feature that aims to make news releases full of jargon, technical terms and difficult technologies easier to understand by focusing in on the important points.
This conveys NEDO's state-of-the-art technological achievements and activities with an easy-to-understand explanation.

News Release
28th of March 2016
Development of Basic Technology for Innovative Batteries to Surpass Lithium-Ion Batteries.

News Release

Development of Basic Technology for Innovative Batteries to Surpass Lithium-Ion Batteries

- Researchers to Present Results from the RISING Project -

<Summary>

To extend the driving range of plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV), it is crucial to develop innovative storage batteries with an energy density that surpasses the performance of conventional lithium ion batteries (LIB).

Lithium-ion batteries exchange lithium-ions (as an insertion-type battery) among containers that house ions (host materials) during charging and discharging, and although there is the advantage in terms of the superior repeated charge/discharge characteristics (cycle characteristics) of lithium-ion batteries there is a limit to the energy density that can be achieved because of increases in the weight and volume of the host materials. By eliminating these containers and using the metals themselves as electrodes, the energy density of this new concept of rechargeable batteries (reservoir storage batteries) is significantly increased, but it may cause major problems with regards to cycle characteristics depending on the electrode materials. In particular, when electrode reaction products don't dissolve in the electrolytic solution completely and become inactive, or they dissolve excessively in the electrolytic solution and dissipate, it is hard to use them as a rechargeable battery because the cycle characteristics does not appear.

So, through a NEDO project, a research group including Kyoto University and the National Institute of Advanced Industrial Science and Technology (AIST) looked at creating an environment that allowed for the moderate dissolution of electrode reactants in an electrolytic solution, and through the introduction of additives (anion receptor), immobilization of highly soluble electrode materials, and control of the electrode-electrolyte interface at the nano-level, they succeeded in improving the cycle characteristics and charge/discharge characteristics of a variety of materials.

From this point researchers will work on further enhancements to performance required for use as vehicle-mounted storage batteries including power output and safety characteristics, which is expected to lead to early commercialization.

March 28 News Release
http://www.nedo.go.jp/news/press/AA5_100543.html (in Japanese)
http://www.nedo.go.jp/english/news/AA5en_100054.html (in English)

Glossary

RISING project
Short name for the "Research & Development Initiative for Scientific Innovation of New Generation Batteries" project. The project is backed by an all-Japan consortium involving 13 universities, 4 research institutes, and 13 companies, and was promoted as a NEDO project from FY2009 to FY2015.

To extend the driving range
NEDO aims to extend the driving range to 500 kilometers by 2030 in line with gasoline powered cars.

Energy density
The amount of electric charge that can be stored per kilogram. Expressed as Wh/kg.

Repeated charge/discharge characteristics (Cycle characteristics)
The degree to which the performance of a battery declines over the course of use.

Anion receptor
A material that couples with negative ions in a solution, stabilizing the state of the ions.

Featured Technology

Post Lithium-Ion Batteries:
Innovative Storage Batteries

To make plug-in hybrid electric vehicles (PHEV) or electric vehicles (EV) with the driving range of gasoline-powered vehicles - this technology is said to hold the key.

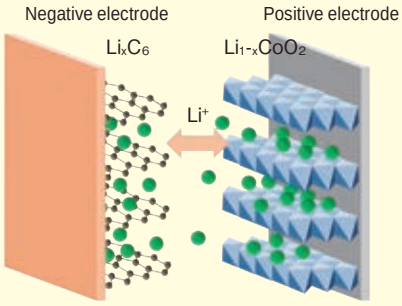
Here are the key points!

- **Focus on a new type of "reservoir-type" batteries**
  Conventional lithium-ion batteries are "insertion-type" batteries.
- **Energy density is significantly improved compared to conventional lithium-ion batteries**
  Three kinds of batteries (zinc-air, nano interface, and sulfide) achieved an improvement in energy density from 100 Wh/kg to 300 Wh/kg.
- **Successfully made significant improvements to charge/discharge cycle characteristics, a major challenge for "reservoir-type" rechargeable batteries**
  Electrodes are activated by the addition of anion receptors as additives.
- **Successfully developed technology to control the transfer of ions across the electrode-electrolyte interface at the nano-level**

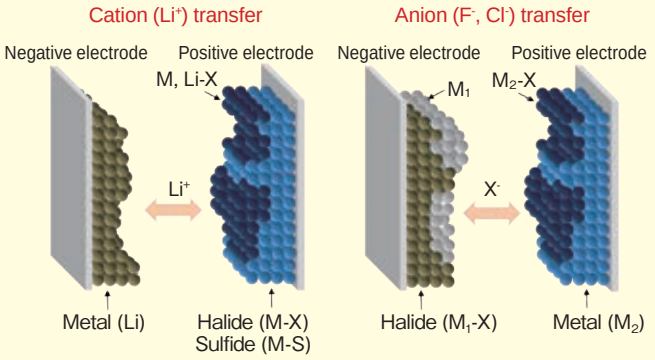
◆ Commentary

Differences between "Insertion-type" and "Reservoir-type" Batteries

Lithium-ion Battery (Insertion Type)



Innovative Storage Battery (Reservoir-type)



Lithium-ion batteries are called insertion-type and repeatedly charge and discharge electricity by having positive ions of lithium move back and force in between the negative electrode and positive electrode. However, each electrode has a container to send and receive ions so they have to be heavier and bigger.

On the other hand, in reservoir-type batteries ions are pulled directly from electrodes so it can achieve a compact form with high energy density. Reservoir-type has two types of ion transfer, one involving positive ions moving back and forth (cation (Li^+) transfer) and the other one involving negative ions moving back and forth (anion (F^-, Cl^-) transfer).

◆ Outlook for the Future

Battery Manufacturers, Automobile Manufacturers, and Universities Work Together to Aim for Commercialization by 2030

To further develop the outcomes from the RISING project to achieve commercialization by 2030, NEDO has launched "Research and Development Initiative for Scientific Innovation of New Generation Batteries II (RISING II)" (FY2016-FY2020). While developing and using the world's best and state-of-the-art analysis technology, NEDO will work on developing the common basic technologies for innovative batteries that have the capabilities needed as on-board batteries for vehicles, including not only improved energy density but also durability and safety.

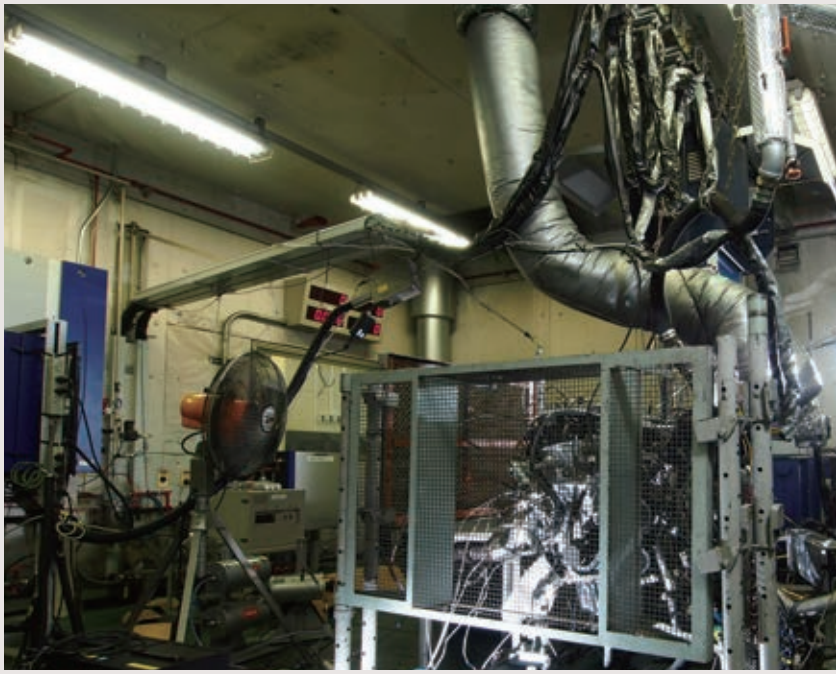
After Project Follow Up! Playback History

NEDO PROJECT SUCCESS STORIES Vol 1.

Comprehensive Technology Development Project for the Innovative Low-Emissions Next Generation Vehicle

Clean Diesel Engine with the World's Best Fuel Economy and Environmental Performance

The results of NEDO projects are utilized in manufacturing processes used by companies and final products available for consumers. In this series we look at untold stories of how technology development projects scaled the high, difficult wall to successful commercialization and what came after, summarizing past articles in "NEDO Project Success Stories".



What is the "Comprehensive Technology Development Project for the Innovative Low-Emissions Next Generation Vehicle"?

Around the time the project began in 2004, as concerns about global warming and environmental issues were increasing, there was an urgent need to address the environmental issues caused by automobiles. Then in FY2009, Japan enacted the world's strictest automobile emission regulations (the Post New Long Term Emission Standards), and in light of the fuel economy goals scheduled to go in effect in FY2015, NEDO promoted a five-year project under an industry-academia-government collaborative framework based around solving difficult problems that automobile manufacturer could not solve on their own.

The "SKYACTIV-D" engine is both more fuel efficient and cleaner in terms of exhaust emissions. In addition, the engine can reach the same revolutions per minute as a gasoline engine. (Credit: MAZDA Motor Corporation)

MAZDA Motor Corporation, one of the companies involved in the "Comprehensive Technology Development Project for the Innovative Low-Emissions Next Generation Vehicle", implemented a collaborative research project with Hiroshima University to work on the development of a new combustion technology that maintains the high thermal efficiency of a diesel engine along with development of an innovative catalytic technology. Then, based on the outcome of the research, the company commercialized the technology and created a low-fuel consumption, clean exhaust diesel engine called "SKYACTIV-D" in 2012 and completely changed the image of diesel engines in society. This engine continues to remain a driving force behind Mazda cars.

The Potential of Diesel Engines to Balance Fuel Economy and Environmental Performance

It is well known that diesel engines, which make use of diesel fuel, have a better fuel efficiency than gasoline engines. However, at the time the project was launched diesel engines had high levels of pollutant emissions, and it was absolutely necessary to have a large, expensive after-treatment device to clean up the exhaust gas and achieve environmental performance equivalent to gasoline engines.

Originally, because of the mechanism of how diesel engines take air into the cylinder and then compress it with a piston until it reaches a high temperature and then inject the fuel (diesel fuel) to achieve spontaneous ignition, it was common sense to use a "high compression ratio" in diesel engines. But a high compression ratio leads to incomplete combustion, which can become a cause of environmental pollutants.

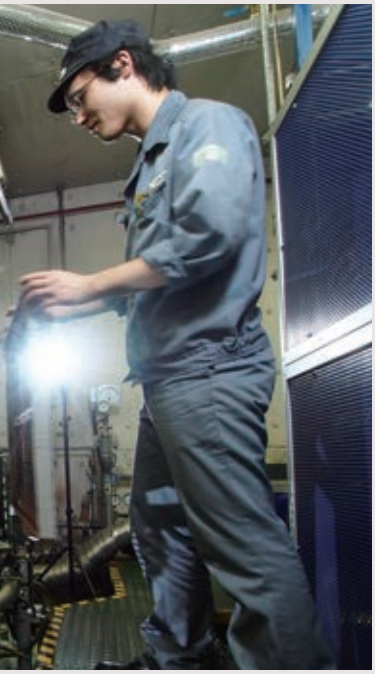
Regarding the potential of diesel engines, Deputy General Manager Akihide Takami of the Technical Research Center at MAZDA Motor Corporation said, "Certainly, conventional diesel engines had problems with high nitrogen oxide (NOx) and particulate matter (PM). In addition, they also had the disadvantage of not being able to achieve the same high rotational speed range of gasoline engines. But diesel engines have greater torque and higher fuel economy, and CO_2 emission per kilometer is approximately 30% lower than gasoline engines. In addition, the emitted during the diesel fuel refining process is about half the amount compared to gasoline refining. All told, diesel engines have an eco-friendly dimension."

To solve the problems with diesel, Mazda worked on a detailed analysis of the diesel combustion mechanism using their conventional engines to figure out the "ideal combustion range" that produced no NOx emissions, soot, or incomplete combustion. Then Mazda focused on the "mixing fuel and air thoroughly to achieve complete combustion" challenge, and they came to the conclusion that it is definitely possible to improve both fuel economy and environmental performance if they achieve combustion within the "ideal combustion range".

Producing Highly Accurate Combustion Simulations in Collaboration with Hiroshima University

What significantly contributed to figuring out the combustion mechanism was a measurement system and simulation technology developed in collaboration with Hiroshima University. Professor Keiya Nishida of

An experiment aiming to further improve engine cleanness.



the Department of Mechanical System Engineering at Hiroshima University's Graduate School of Engineering, who specializes in fluid engineering, developed the "LAS Measurement System". Using a "high-temperature, high-pressure vessel" to reproduce the state inside the engine cylinder, they measured the mixture and concentration of the injected fuel by laser. Also, they made it possible to visualize the state of the fuel after injection, using the experimental apparatus that captures the spray mixture formation within the combustion chamber in 2D.

"It was a significant help to have Professor Nishida of Hiroshima University, whose strong point is measurement technology, to work on advanced measurements which were difficult for us to do internally. The measurement data we collected at that time enabled us to do highly accurate combustion simulations, and clearly showed us the direction for SKYACTIV-D to aim for," said Mr. Motoshi Kataoka, Staff Manager of Powertrain Technology Development Department in the Powertrain Development Division at Mazda.

To Realize "Ideal Combustion", Rethink Common Sense and Arrive at "Low Compression Ratio"

In order to "mix fuel and air thoroughly to achieve complete combustion" in the "ideal combustion range" revealed through the collaborative research with Hiroshima University, the first thing Mazda looked at wasn't actually the "compression ratio" but the "intake air temperature". It would be possible to reduce the NOx emission if the fuel is combusted at as low a temperature as possible. However, it became clear that wasn't possible because they encountered a lot of new issues, such as the difficulty of mass-producing the essential EGR (exhaust gas recirculation) device for diesel engines when the intake air temperature is lowered to 40ºC.

So they reviewed the common logic of "diesel = high compression ratio", and came around to the idea of lowering the compression ratio. When the compression ratio is lowered, compression temperature and pressure at "top dead center" get lowered. So, it takes longer to get ignited after the injection of fuel, which gives the chance for fuel and air to mix well before combustion, significantly reducing NOx emissions and soot generation (see Figure 1). Also, to take advantage of the lower combustion pressure resulting from the lower compression ratio, they made rotating parts including pistons and crankshafts lighter and lower in rigidity. As a result, fuel economy is improved due to reduced mechanical friction, the engine runs smoothly from low to high speeds, and they dramatically challenged the prevailing dogma that diesel engines are "heavy and not suitable for high engine speeds".

To realize the commercialization of such low compression ratio clean diesel engines, it was necessary to create a way for fuel to be injected by the fuel injector and mixed uniformly with the air while retaining its kinetic energy. An "egg-shaped combustion chamber" was developed for just that purpose (see Figure 2). The head of the "SKYACTIV-D" piston has a unique shape with a bulging center and a concave periphery. When the piston is pushed up, the fuel gets injected toward the dent, then the combustion and explosion follow to generate power. That is how they lowered the compression ratio inside of the cylinder to "14.0" for the first time in the world while generating the same power as a high compression engine despite the lower combustion pressure.

20% Improvement in Fuel Consumption and No Need for a NOx After-Treatment Device A Clean Diesel Vehicle You Can Enjoy Driving

Based on the results of a NEDO project that spanned basic research through mass production technology development, Mazda was able to further enhance the combustion efficiency that is the strength of diesel engines while commercializing a new generation diesel engine called "SKYACTIV-D" that can clear international emissions regulations without the need for an NOx after-treatment device in 2012. "SKYACTIV-D" has been installed in Mazda vehicles including the "CX-5", the "Mazda-6", and the "Mazda-2", and the number of vehicles with the technology sold by the end of December 2015 has exceeded 220,000 units (Japan sales only), greatly contributing to the diffusion and expansion of diesel engine vehicles contributing to reducing greenhouse gas emissions.

"Mazda-6" with "SKYACTIV-D" on board displayed in the showroom at MAZDA headquarters.

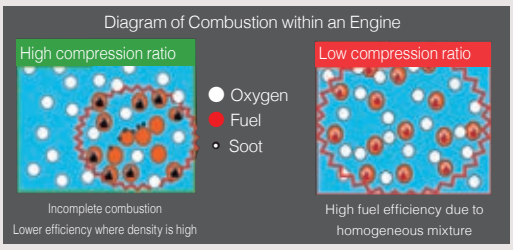


Figure 1

Figure 1
By lowering the compression ratio, combusts after mixing thoroughly with air, not only improving the combustion efficiency but also reducing the creation of NOx and soot emissions.

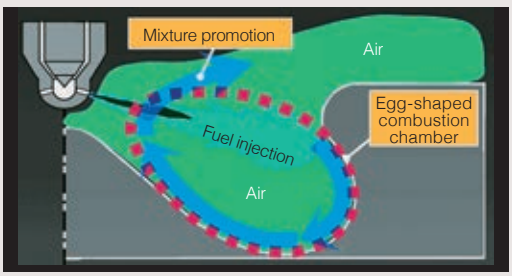


Figure 2

Figure 2
The egg-shaped combustion chamber. By making the combustion chamber where fuel is injected egg-shaped, the air flows along the curved surface, mixing thoroughly with the fuel to achieve clean combustion.

This article is from the "NEDO PROJECT SUCCESS STORIES" previously covered and being introduced as a summarized version with some updated information. The original story has a lot more episodes from the technology development so please visit the website.

NEDO PROJECT SUCCESS STORIES Search

Domestic Offices

Head Office
MUZA Kawasaki Central Tower, 16F-20F
1310 Omiya-cho, Saiwai-ku
Kawasaki City, Kanagawa 212-8554 Japan
Tel: +81-44-520-5100
Fax: +81-44-520-5103

Kansai Branch Office
Umeda Dai Building, 6F, 3-3-10
Umeda, Kita-ku
Osaka 530-0001 Japan
Tel: +81-6-6341-5403
Fax: +81-6-6341-5405

Overseas Offices

Washington, D.C.
1901 L Street, N.W., Suite 720
Washington, D.C. 20036 U.S.A.
Tel: +1-202-822-9298
Fax: +1-202-822-9259

Silicon Valley
3945 Freedom Circle, Suite 790
Santa Clara, CA 95054 U.S.A.
Tel: +1-408-567-8033
Fax: +1-408-567-9831

Europe
10, rue de la Paix 75002
Paris, France
Tel: +33-1-4450-1828
Fax: +33-1-4450-1829

New Delhi
9th Floor, Hotel Le Meridien
Commercial Tower, Raisina Road
New Delhi 110 001, India
Tel: +91-11-4351-0101
Fax: +91-11-4351-0102

Beijing
2001 Chang Fu Gong Office Building
Jia-26, Jian Guo Men Wai Street
Beijing 100022, P.R. China
Tel: +86-10-6526-3510
Fax: +86-10-6526-3513

Bangkok
8th Floor, Sindhorn Building Tower 2
130-132 Wittayu Road, Lumphini
Pathumwan
Bangkok 10330, Thailand
Tel: +66-2-256-6725
Fax: +66-2-256-6727

New Energy and Industrial Technology Development Organization
MUZA Kawasaki Central Tower, 1310 Omiya-cho, Saiwai-ku
Kawasaki City, Kanagawa 212-8554 Japan
Tel: +81-44-520-5100 Fax: +81-44-520-5103
URL: http://www.nedo.go.jp/english/index.html

September 2016 (1st Edition)