Cross-ministerial Strategic Innovation Promotion Program (SIP)

Energy Systems of an IoE Society

Research and Development Plan

July 25, 2019

Director General for Science, Technology and Innovation

Cabinet Office

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Outline of the Research and Development Plan

1. Significance, goals, etc.

Japan currently mostly relies on importing energy resources from abroad, and it is not possible to realize stable management of energy with control of energy consumption alone. Our earnest wish is to ensure stable energy resources. In the mid- to long-term, there will be major changes in demand structure such as expansion of uses of energy resources including next-generation vehicles powered by electricity, hydrogen, etc. as well as the adoption of co-generation that efficiently uses gas, etc. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that there is no room for doubt about warming of the climate system, and that it is necessary to drastically, continuously decrease greenhouse gas (GHG) in order to mitigate climate change.

At the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) held at the end of fiscal year 2015, there was adoption of the Paris Agreement, a new international framework from 2020 aiming for drastic reduction of anthropogenic GHG emissions, the primary cause of global warming issues. The Paris Agreement mentions initiatives of worldwide long-term goals to limit global average temperature rise to well below 2 degrees Celsius above the pre-industrial level (the 2°C goal), to pursue efforts to limit the temperature increase even further to below 1.5 degrees Celsius the pre-industrial level, to reach global peaking of GHG emissions as soon as possible, and to achieve a balance between the amount of greenhouse gas emissions from anthropogenic sources and their removal by GHG sinks in the second half of this century.

We will not meet the time limit for achieving the Paris Agreement by simply prolonging our current reduction efforts. It is essential to create innovation that realizes drastic GHG emissions reductions worldwide, including unsustainable technologies for reductions thus far.

In order to create innovation in the fields of energy and the environment, in addition to strongly developing and adopting promising technologies for contributing to major GHG emissions reductions, in conjunction with establishing and implementing those separate technologies, it is necessary to optimize all energy systems by networking separate technologies (equipment, facilities, etc.), that is, design energy systems for Society 5.0 that fuses energy and information (IoE society).

In addition, the requirement for this future society is to be smart (S) and digital (D) and have resilience (R), and it is hoped to realize an IoE society that is rich with SDR.

The abbreviation IoE Society for internet of energy means a society that combines energy information and the internet and has mutual management of energy demand through information exchange. It is hoped to formulate a grand design to realize comprehensive energy management that aggregates various systems including electricity, thermal, chemical energy, etc.

We consider it extremely important to maximize synergy through creating further systemization of basic technology systems in the IoE society of Society 5.0 for this subject. We aim to steadily put into practice having a “System of Systems” to realize an IoE society, and implement it in society.

2. Research content

In order to realize IoE energy systems for the Society 5.0 era, this project examines designs for society energy systems where renewable energy is the main energy source, develops common platform technologies needed to implement the designs, and carries out R&D necessary for their actual implementation in society.

Theme (A): Design an energy system for an IoE society

Japan has been a leader in energy management technologies thus far, and has been carrying out both individual and interrelated projects (centered on demonstration projects) including for home energy management system (HEMS), building energy management system (BEMS), smart community (environmentally-friendly cities) projects, and virtual power plant (VPP) projects. As electrification and automated driving see progress in the transport sector, sector coupling of the transportation sector and energy sector is becoming a major theme. Centered on the Energy Management Technical Committee concerning this subject, together with trying to grasp the size of results causing decarbonization, there is specification of bottleneck subjects for effectively conducting energy management. There is also clarification of the results of promotion of further use of renewable energy through the control of the wireless power supply to the batteries of in-motion vehicles and the widespread use of power electronics from the implementation of technologies from (B) and (C) below. In addition, focusing on the cyber layer of energy systems, propose a method for designing energy systems that includes architecture to receive data from different areas.

Theme (B): IoE common platform technology

As common platform technologies that build energy systems combining renewable energies, development is carried out for basic technologies concerning power modules essential for energy conversion and wireless power transmission (WPT) that responds to diversification of energy transmission

(1) In order to develop the Universal Smart Power Module (USPM) with high functionality and general purpose at a low cost that can maximally exhibit the excellent characteristics of the latest power semiconductor switching element, and enables extremely efficient response to variable energy sources such as renewable energy, development is carried out for ① high-speed digital controller for wide bandgap (WBG) semiconductors, ② the power module that operates at high power density and high temperatures, and is capable of responding to the digital controller such as ①, and ③ the metal-oxide-semiconductor field-effect transistor (MOSFET) that realizes low loss at the same level as silicon carbide (SiC) at about the same cost as silicon (Si), as a WBG switching device.

(2) As an energy transmission technology, WPT system basic technology has been developed, enabling flexible energy transmission networks that respond to diverse energy consumption forms. In particular, R&D is carried out for component technologies concerning power devices and circuit systems necessary for implementing WPT systems at a high frequency that enables making equipment smaller, that is, using frequencies from the MHz band to the microwave band. Those functions are demonstrated by building WPT systems.

Theme (C): R&D for application/practical implementation of IoE

Toward the realization of energy management with long-distance, highly efficient, high power, and safety wireless power transmission, highly efficient devices both for the transmitter and receiver and advanced transmission control technology in the WPT system are developed, and demonstration is carried out for ① Indoor WPT (sensors, mobile information equipment, etc.), ② Dynamic WPT for in-motion electric vehicle(EV)s (excluding development and demonstration of energy supply while stationary), and ③ outdoor energy supply to drones (assuming, e.g. maintenance of an operation and maintenance management of the infrastructure). Work is carried out encompassing from R&D of implementation technologies to implementation in society, including R&D of basic component technologies such as devices to R&D of WPT system technologies, ensuring safety, and work toward standardization.

Furthermore, toward implementation in society of WPT systems, there is cooperation with Theme (B) regarding R&D for basic component technologies like devices.

3. Implementation structure

Takao Kashiwagi, Program Director (PD) is in charge of formulation and promotion of the R&D plan. The PD works as Chair and the Secretariat is run by the Cabinet Office, which carry out comprehensive coordination of the promoting committee composed of related ministries, agencies, and experts. The Japan Science and Technology Agency (JST) promotes R&D through the implementation agency selected through a public appeal utilizing a grant, and management of the progress of each subject is carried out by JST management. The technical committee centered on the Sub Program Directors (Sub PDs) and Innovation Strategy Coordinators (Strategy Cs) works on energy management, and the subcommittee centered on the Sub PDs established within the JST effectively promotes R&D regarding other subjects.

4. Intellectual property management

The Intellectual Property Committee is within the JST, and conducts appropriate intellectual property management that ensures incentives for inventors and people who advance industrialization and increases benefits for the public.

5. Evaluation

Before the evaluation at the end of each fiscal year by the Governing Board, there is work on improving the research plan independently through self-inspection by the PD and others as well as implementing a technical, objective peer review by experts.

6. Exit strategies

Theme (A): Design an energy system for an IoE society

The Energy Management Technical Committee was established in FY2018 to identify the bottlenecks to efficient energy management and to collectively announce the grand designs of the energy systems contributing to the optimization of energy use with the technologies described in (B) and (C) below.

Theme (B): IoE common platform technology

With cooperation among industry, academia, and the government, we will construct a consortium-type R&D system in collaboration with business operators and universities, with a view to the exit goal of social implementation. After the completion of the project, there will be implementation of the key power devices at university-started venture companies that were the core of the consortium, as well as swift practical utilization of renewable energy, industrial machines, EVs, home appliances, etc. mainly by participating venture businesses and major private businesses.

Theme (C): R&D for application/practical implementation of IoE

Within the SIP project period, demonstration tests for highly safe, highly-efficient indoor WPT technology in environments where there are humans and others, dynamic WPT technology for in-motion EVs, and WPT technology for in-flight drones will lead to practical use and implementation in society. After completion of SIP, the technologies will be commercialized, primarily by the participating businesses, that will also establish technical standards for those technologies and standardize them internationally in collaboration with a consortium comprising industry, academia, and the national and local governments, based on the results of the R&D.

1. Significance, goals, etc.

(1) Background and situations inside and outside Japan

At COP21 held at the end of fiscal year 2015, there was adoption of the Paris Agreement, a new international framework from 2020 aiming for drastic reduction of anthropogenic GHG emissions, the primary cause of global warming issues. The Paris Agreement mentions initiatives of worldwide long-term goals to limit global average temperature rise to well below 2 degrees Celsius above the pre-industrial level (the 2°C goal), to pursue efforts to limit the temperature increase even further to below 1.5 degrees Celsius the pre-industrial level, to reach global peaking of GHG emissions as soon as possible, and to achieve a balance between the amount of greenhouse gas emissions from anthropogenic sources and their removal by GHG sinks in the second half of this century.

We will not meet the time limit for achieving the Paris Agreement by simply prolonging our current reduction efforts. It is essential to create innovation that realizes drastic GHG emissions reductions worldwide, including unsustainable technologies for reductions thus far.

In order to create innovation in the fields of energy and the environment, in addition to strongly developing and adopting promising technologies for contributing to major GHG emissions reductions, in conjunction with establishing and implementing those separate technologies, it is necessary to optimize all energy systems by networking separate technologies (equipment, facilities, etc.), that is, design energy systems for an IoE society in Society 5.0.

Theme (A): Design an energy system for an IoE society

As shown in the 5th Science and Technology Basic Plan adopted by Cabinet decision in January 2016 as a major wave of the structural reform of society and industry, there will be rapid development and progress of implementation in society in the near future of the Internet of Things (IoT), artificial intelligence (AI), big data analysis technology, information and communications technology (ICT), etc. Cooperation will become easy between different products, technologies, as well as multiple different systems, and through the various value chains created through that, it is hoped that new added values will be offered to society and this will lead to realizing Society 5.0 (super-smart society) that enriches human life.

In the fields of energy and the environment as well, it is important to develop and adopt promising GHG emissions reduction technologies based on that large significance and results. Furthermore, in conjunction with the implementation in society of the different technologies, in order to enable status monitoring and real-time control of various energy equipment and power sources through the IoT, it is necessary to have initiatives that network energy-related equipment and facilities, comprehensively grasp them as energy systems, and optimize them as overall systems. For these initiatives, there is also the important perspective of a response to ensure mobility in Japan’s local regions where there are many senior citizens, a major social issue.

From this perspective, there is examination of specific system architecture while elucidating the results of sector coupling that enables energy system integrated control centered on automated driving and high affinity EV and renewable energy power, which have attracted major interest among initiatives by the government and others thus far. Through this, it is possible to reduce GHG emissions by spreading EVs that are moved by green energy, and additionally provide system compatibility increasing the rate of photovoltaic(PV), etc. variable energy sources enabling reduction of the load on the grid through high-speed control of stored energy equipment made mobile by WPT.

Theme (B): IoE common platform technology

For common platform technologies, technologies will be executed that contribute to innovation for (1) “energy conversion” and (2) “energy transmission.”

In the energy systems of a society that fuses energy and information (IoE society), in addition to energy creation functions and energy storage functions, it will be necessary to have energy transmission technology enabling flexible energy management as well as a power module that takes charge of energy conversion as an interface linking this.

(1) Power modules, which serve as the core energy conversion technology, currently have many custom parts for each application, and it is predicted that the shortage of developers and development performance will worsen against the predicted explosive increase in applications going forward. In addition, the power modules are unfit for instant feedback, predictions, and transmission between power electronics networks responding to irregularly fluctuating power sources because the power module supports analog control. In order to break through these deficiencies, there are high hopes for development of a universal smart power module that allows universal and smart properties to coexist, creates the innovation of energy conversion in an IoE society, and contributes to improving that development efficiency of power electronics products, by freely combining ultra-high speed digital control, core packages and WBG devices that are expected to be low-price.

Currently, Japan’s standards for power module component technologies is at a level leading the world, but initiatives are being advanced in various countries toward R&D and creating products for general-purpose power modules and optimized driving control. There are concerns that Japan will be surpassed unless it advances its initiatives.

(2)As energy transmission technology for an IoE society, it is necessary to have power transmission technology with flexible connectivity and controllability that can respond to the increase in energy demand and the diversification of its consumption forms. WPT technology is being raised as technology to respond to this demand. WPT technology is partially being utilized for charging mobile devices and power supply systems for stationary EVs, but in terms of expanding choices and application fields for WPT technology, and as technology enabling high capacity transmission functions as well as miniaturization of devices, there are hopes for development of WPT technology utilizing MHz bands and microwaves.

Theme (C): R&D for application/practical implementation of IoE

Demands in “Society 5.0” (super-smart society) are including “being able to realize Energy to Everything (E2E) that efficiently and effectively supplies power to everything,” “being able to reduce CO_2 emissions,” and “being able to strengthen power and societal infrastructure and stabilize lifelines,” and so on. There are many solutions through WPT for these demands. For example, by supplying energy with a WPT system to everything, including

EV, automated driving, robots, drones, and IoT sensors utilized in Society 5.0, it is possible to actualize a society that does not need to be conscious of charging and supplying power and also create further innovation. In addition, by building wireless networks that integrate 5G (5th generation mobile communications system) information and electricity, it is possible to implement management systems for leading-edge power control and safe use. Furthermore, with the progress of the spread of EVs due to realizing energy supply to in-motion EVs through WPT, it is possible to use it to stabilize grid power in the case of renewable energy increases and to use it as an emergency power source in the event of a disaster, by using EV storage batteries. As for drones, the implementation of wireless power supplies will enable the reduction of social cost through maintenance innovation and contribute to the construction of a safe and reliable society through swift responses such as providing relief supplies during emergencies. There are major expectations for implementation in society of WPT systems for the above.

Currently, Japan’s elemental technology of WPT system is at a level leading the world, but initiatives are being advanced in various countries toward R&D and creating products for WPT systems. There are concerns that Japan will be surpassed unless it advances its initiatives. In particular, in order to enable ensuring Japan’s competitiveness from the viewpoint of the global market by swiftly resolving subjects necessary for implementation in society such as ensuring safety, R&D will be implemented encompassing basic component technologies to system technologies and practical use technologies, significant for linking this to implementation in society.

(2) Significance and political importance

In order to create innovation in the fields of energy and the environment, in addition to strongly developing and adopting promising technologies for contributing to major GHG emissions reductions while grasping the size of their results for decarbonization, in conjunction with establishing and implementing those separate technologies, it is necessary to optimize energy systems overall by networking separate technologies (equipment, facilities, etc.), that is, design energy systems for Society 5.0 where energy and information are fused (IoE society).

In addition, the requirement for this future society is to be SDR, and it is hoped to realize an IoE society that is rich with SDR.

The abbreviation IoE Society for internet of energy means a society that combines energy information and the internet and has mutual management of energy demand through information exchange. It is hoped to formulate a grand design to realize comprehensive energy management that aggregates various systems including electricity, thermal, chemical energy, etc.

We consider it extremely important to maximize synergy through creating further systemization of basic technology systems in the IoE society of Society 5.0 for this subject. We aim to steadily put into practice having a “System of Systems” to realize an IoE society, and implement it in society.

Theme (A): Design an energy system for an IoE society

In regard to energy management technologies, the Japanese government has taken the central role for conducting all aspects of projects (centered on demonstration projects) including for HEMS, BEMS, smart community (environmentally-friendly cities) projects, and VPP projects. Going forward, it is predicted that in addition to power management, heat and chemical reactions (including green hydrogen production through hydroelectricity, etc.) and energy conversion technology such as heat pumps will become more important. For this subject, centered on the Energy Management Technical Committee, we specify bottleneck issues for efficiently conducting energy management, and announce compilation of the energy system grand design to contribute to optimizing energy use in Theme (B) and Theme (C) below.

Theme (B): IoE common platform technology

In an IoE society, the varieties and number of power supplies and converters will surge, and it is expected that there will be a shortage of developers, designers, and others to respond to this, an increase in development costs and periods, and an increase in investment due to the increase in varieties.

Through the combination of ultra-high speed digital technology with unit modules adopting Japanese high-efficiency WBG semiconductors, the USPM will curtail the above barriers due to full customization and the USPM will simplify the development and design of application engineers. In addition, utilizing ultra-high-speed digital technology, cooperation on energy networks, that is, on cyber space, will become easy and play a role as a component for creating a smart IoE society.

For this, it is necessary to conduct development of USPM with the following capabilities going forward.

① Development of high-speed digital controllers for WBG semiconductor systems (not only optimal design and development of just the power module part, but also maximum utilization of the excellent capabilities of WBG devices through instant feedback control by constantly monitoring the operation conditions of WBG devices and unstable input power source conditions through instant digital driving control technology
② Development of power modules enabling response to digital controllers in ① that enable operation at high power density and high temperatures (Increasing efficiency, functionality, and general purpose, and drastically lowering design costs for the power electronics use equipment itself)
③ Development of the MOSFET that realizes low loss at the SiC at about the same cost as Si, as a WBG semiconductor switching element.

R&D for technology like USPM is advancing in various countries, but it is not established. It can be expected that Japan will acquire global market share by developing, demonstrating the effectiveness of, and establishing the technology for innovative USPM ahead of the world. Furthermore, by resolving the distributed compensation between modules, the cause for instability such as temperature balance fluctuations, through control including real-time autotuning, this will contribute to strengthening Japan's domestic industry foundation by further enhancing power efficiency and long-term reliability such as for server infrastructure, industrial machinery, and EVs.

The places where USPM technology is needed can largely be sorted into the following four categories.

① EVs

Enable shortened development lead times and lower costs for entire systems through USPM at standardized costs.

② Renewable energy power conversion equipment

Enables response through USPM for instable power sources and different power capacities (reduce design support for each individual condition).

③ Next-generation server power sources

Efficiency improvement accompanying smaller sizes and lower loss, simplification of cooling systems, and reduction of design support for each different condition.

④ Next-generation industrial inverters

Enables responding to the electricity shortage due to the increase of industrial robots, environment robots, etc. as well as instability of decentralized power sources with operations in dangerous workplaces and centralized operations at factories, thus making it possible to reduce the effects of noise to other power sources, etc.

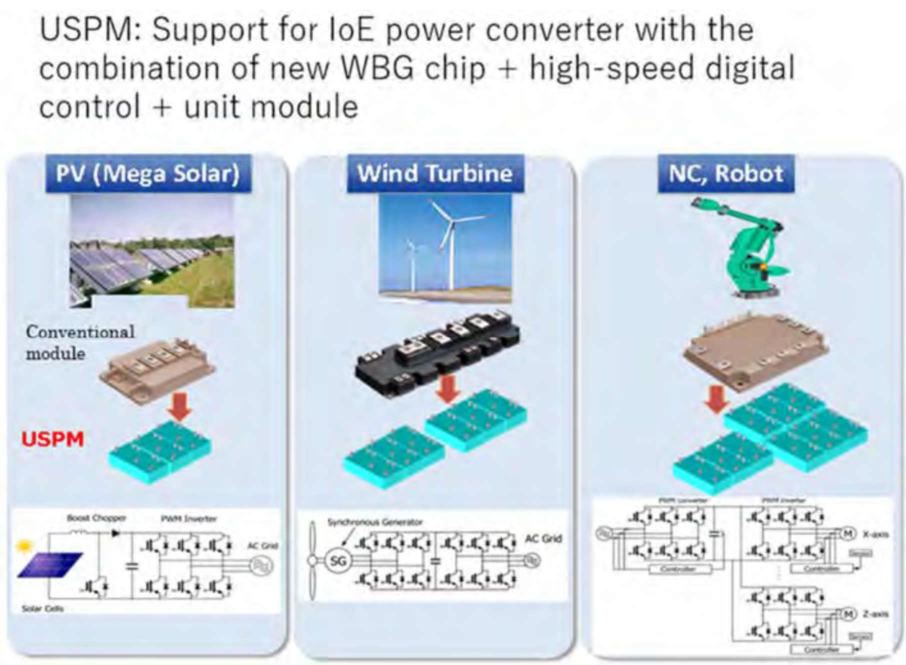


Figure 1-1 Example of combination for USPM of the new WBG chip + high-speed digital control + unit module

In an IoE society with fusion of energy and information where various energy supply and demand information is shared, optimizing energy systems through the diversification of energy transmission techniques such as WPT will be effective for reducing GHG emissions for society as a whole. In particular, WPT technology is essential for flexible, dynamic configuration of energy networks. Additionally, this is a field of important technology enabling contributions to the resolution of social issues that will manifest in Japan and the world going forward, including implementing safe mobility measures combining in-transit power supply through WPT and automated driving technology as well as implementing automation and optimization of infrastructure inspections through drones leading to cost control for various social infrastructure improvement.

Theme (C): R&D for application/practical implementation of IoE

In order to realize a society with the world's top safety, peace of mind, and health in Society 5.0, a society where there is efficient, effective power supply for everything, a society where it is possible to reduce CO_2 emissions, and a society where power and social infrastructure is strengthened and lifelines are stabilized, WPT systems are effective, and it is important for Japan to swiftly advance their implementation in society in places where they are needed indoors (sensors, mobile information equipment, etc.), EVs, and drones (infrastructure improvement, management). For this, with industry-academia-government cooperation, it is important to carry out R&D and demonstrations of WPT system technology and advance their implementation. In addition, active efforts by Japan for international systemization and standardization will lead to acquiring the global market.

For this research subject, R&D for technologies with a method suitable for power supply to various workplaces is conducted, and establishes safe WPT systems that are long-range, highly efficient, and provide a large amount of power. WPT systems consist of high frequency conversion circuits for supplying power, wireless transmission parts, and converter circuits for receiving power, and thus technology development is needed for various parts in the respective frequency bands and method.

In addition, demonstration tests are carried out focusing on adoption of the developed WPT system technology in applications where the technology is needed indoors (sensors, mobile information equipment, etc.), EVs, drones (infrastructure improvement and management), and using the results for feedback in the R&D of WPT system technologies leads to establishment of WPT system technologies. At the same time, efforts are made for subjects concerning related system improvement and we actively participate in international standardization.

The places where WPT system technology is needed can largely be sorted into the following three categories.

① Indoors(sensors, mobile information equipment, etc.)

- In order to meet diverse needs toward realizing Society 5.0, development of sensors, information systems, etc. with a higher level of freedom is necessary.
- To enable establishment without the limitations of cables, contribute to enhancing convenience and productivity by increasing the level of freedom for sensors, information systems, etc.
- In addition, together with enabling safe power transmission through advanced technology detecting humans and wireless systems as well as advanced beam control technology in environments where humans and other wireless systems are located, power transmission with high time efficiency becomes possible in a practical sense, and contributions are made to further increasing convenience for sensors, information systems, etc. as well as further increasing productivity through utilization of them.

② EVs

- The length of charging times accompanying the increase in size of batteries has caused the spread of EVs to be obstructed.

・Increasing voltage of chargers shortens charging times, but operation is difficult for large-scale high voltage chargers.

⇒Increase convenience and contribute to the spread of EVs by enabling wireless charging. Furthermore, contribute to system and load reduction at power supply peak times. In addition, with the progress of the spread of EVs due to realizing in-transit energy supply to EVs, etc., it is possible to expect use for system power stabilization through increasing renewable energy through utilization of EV storage batteries as well as use as emergency power sources during disasters.

③ Drones (infrastructure maintenance and management)

・It is predicted that about one third of the total of about 3.4 million skilled workers in the construction industry will leave their jobs in the next 10 years due to workers aging, etc. This combined with the decreasing population has caused major concerns for a labor shortage.

・There are many aspects that rely on human efforts in the inspection of factories, bridges, and so on. Moreover, there are inherent problems with the difficulty of inspection of places that workers cannot approach easily.

⇒Flying drones can be utilized for long-duration continuous inspection and monitoring of bridges, factories, power systems, etc. for continuous long periods of time. This will contribute to the fundamental reform of social infrastructure maintenance technology, drastically reduce maintenance efforts, and more. Meanwhile, WPT system technology equipped with long-distance, highly efficient, high power, and safety functions in the outdoors is applicable not just to drones but to fundamental technologies such as Space Solar Power Systems (SSPS) in the future.

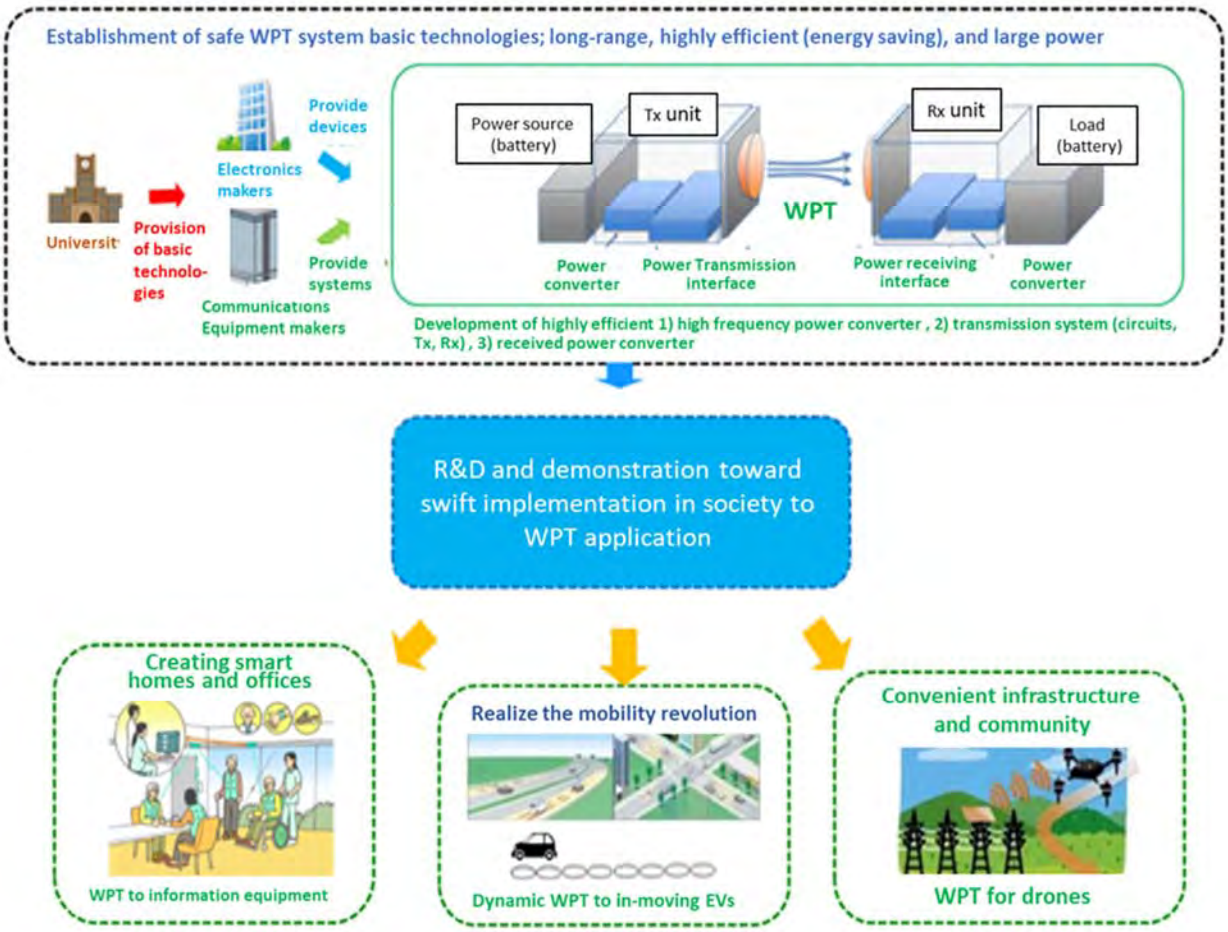


Figure 1-2 WPT systems

(3) Goals and aims

We aim to realize energy systems for an IoE society by overcoming technological issues regarding the following R&D items.

① Toward realizing Society 5.0

As stated above in 1. (2) Significance and political importance, this subject optimally designs a society that fuses energy and information (IoE society) and works on R&D of component technology to realize this. This will enable introduction of large amounts of renewable energy, and contribute to realizing Society 5.0 with its diversifying power consumption needs.

② Goals for society

- Show specific ideas for IoE society energy systems.
- Show it is possible to respond to hundreds of power modules that combine basic units, the characteristic of USPM.

- In order to avoid the mistakes of concerns about the effects of radio waves on the human body when spreading mobile technology, measures will be taken for explaining the effects and safety on human bodies of WPT before implementation in society.

③ Goals for industry

- IoE energy systems are like an energy OS or data platform. From the perspective of optimizing use of energy (electricity, thermal, chemical, etc.), the forms of efficient energy systems for implementation in society are worked out, and we contribute to R&D concerning this field in various industries and advancing implementation in society.
- Contribute to creating low-cost, versatile power electronics application devices by integrating power modules capable of operating at high power density and high temperatures, high-speed digital driving control technology, and low-cost, high-functionality MOSFET. In addition, contribute to strengthening Japan's domestic industry foundation by further increasing power efficiency and long-term reliability of server infrastructure, industrial machinery, vehicles, etc. by resolving the distributed compensation between modules through control with real-time autotuning, etc.
- Contribute to drastic increasing of productivity at construction, manufacturing, distribution and other sites by implementing WPT systems for robots and sensors at automated factories, general electric vehicles excluding buses and trucks, drones, etc.

④ Goals for technology

- Design architecture for IoE society energy systems.
- Establish component technologies and integrated design technologies necessary for high voltage USPM that is highly functional at a low cost.
- Commercialize MOSFET at a low cost at the Si level with low loss at the SiC level.
- Formulation of standards and international standardization of WPT technologies.
- Establish WPT systems for sensor networks and mobile equipment under test systems.
- Establish WPT systems for in-transit EVs.
- Establish remote WPT systems for drones equipped with WPT systems.

⑤ Goals for the system, etc.

- Based on the R&D results, implement initiatives toward technology standards formulation and international standardization while cooperating with the consortium, municipalities, etc. participating from industry, academia, and the government.
- Establish the Working Group for System Improvement and Standardization, build systems for implementation in society, select subjects, conduct consideration for resolving them, and implement initiatives based on the results.

⑥ Global benchmarks

Theme (A): Design an energy system for an IoE society

Energy digitalization is rapidly progressing as there is an increase in distributed models centered on variable renewable energy, that are being added to the centralized model of power sources through now for power source organization. (According to *Digitalization & Energy* by the International Energy Agency (IEA), by 2040 we are headed toward a power system where there is interconnection of one billion households and 11 billion smart consumer electronics and they can alter their power consumption behavior. Energy management through demand response would provide 185 GW of flexibility, which would lead to saving USD 270 billion of investment in new electricity infrastructure.) Although sector coupling is being aimed for with the transportation field in Europe, efforts are not being conducted for grasping the effects and for practical use. On the other hand, although Japan has been working on development of component technologies for energy management systems centered on electricity through now, it has not been working on building energy systems that leverage the IoT and cooperate with the transportation field.

Based on this situation, from the perspective of optimizing new energy systems centered on renewable energy and EVs, we aim to create forms of economically feasible energy systems that can be implemented in society.

Theme (B): IoE common platform technology

USPM R&D is being advanced actively in various foreign countries, and it is predicted that R&D will accelerate toward establishment of the technology. We aim to lead formulation of technology standards and international standardization through valid demonstrations and technology establishment of our world-leading USPM by leveraging our competitiveness in component technologies.

WPT technologies using MHz bands will lead to smaller WPT systems, and there are high hopes for in-transit power supply to EVs and rapid charging of drones desired for making power transmission equipment smaller and lighter. High-speed switching-enabled gate driving circuits above MHz level and synchronous rectifier technology are necessary for implementing this technology, but there are no precedents for developing technologies needed for high capacity, high-speed controllability targeting kW class power transmission. In addition, although there has long been consideration concerning radiation-type WPT using microwaves, there is a high degree of difficulty for making it high capacity, and would just be research for limited applications. Thus, there are no development examples of practical rectifier components and power receiving circuits including antennae optimized for high capacity uses. Because this R&D implements WPT systems using frequencies from the MHz band to the microwave band as new energy transmission technology for the IoE society, it aims to ensure Japan’s international competitiveness by establishing basic technology ahead of others.

Theme (C): R&D for application/practical implementation of IoE

Demonstration tests are being conducted at the demo level in the United States and other countries concerning indoor power supply to sensors and mobile information equipment, and there is some advancement of implementation. However, the systems in various other countries only have limited usage in environments where there are humans and other wireless systems, and cannot provide sufficient power supply. In our research for this, R&D is conducted toward realizing systems with high time efficiency that can be used safely and with peace of mind in environments where there are humans and other wireless systems. In addition, it is necessary to work on standardization for WPT systems that have not been built yet.

Projects have been launched concerning power supply to in-motion EVs in the United States, Europe, China, and others, and R&D is carried out at the basic level for power transmission. However, the initiatives by various foreign countries still have many issues related to achieving high-efficiency, reducing interference, miniaturizing and reducing costs, infrastructure economic feasibility, etc. for power transmission. This research is being undertaken to resolve such issues ahead of various foreign countries. It is also important to quickly expand the research results to discussions on international standardization.

Regarding the WPT systems for drones, the development status is still to the extent of basic experiments in Canada and some other countries. This research aims to develop a transmission method that can supply enough power with the small-sized and lightweight devices required for application in industry. Furthermore, it is important to undertake system development ahead of the world, such as transmission and receiving power management and power and beam control indispensable for the implementation in society.

Within the above circumstances, we will pioneer implementation of new wireless power transmission products using our advanced technical capabilities, and aim to acquire not only the domestic market but the global market as well.

⑦ Cooperation with municipalities, etc.

We will cooperate with not only companies but also municipalities, etc. as necessary when conducting indoor tests at locations where WPT systems are effective and needed (indoor power supply (sensors, information systems, etc.), EVs, and drones (operation and maintenance and management of infrastructure)).

2. Research and development content

Together with conducting the energy system concept design contributing to energy supply and demand optimization for realizing an IoE society, developing the common platform technology for this, and conducting R&D for applications and practical use (wireless power transmission systems), as well as enabling universal energy supply to EVs and IoT sensors expected to spread going forward by advancing system improvement, standardization, and implementation in society, this project contributes to realizing a society where diverse energy conversion equipment is connected, including renewable energy power source cooperation and EV charging and discharging. Furthermore, development is conducted while having mutual cooperation between Themes (A) through (C).

Theme (A): Design an energy system for an IoE society

R&D period:

FY2018-FY2022

Sub-Program Director (Sub-PD):

Hiroshi Asano (Associate Vice President, Central Research Institute of Electric Power Industry)

Innovation Strategy Coordinator (Strategy C):

Bunro Shiozawa (Senior Associate, Sumitomo Chemical)

Energy Management Technical Committee members:

Private companies, universities, National Research and Development Agency

Related ministries and agencies:

Cabinet Office; Ministry of Internal Affairs and Communications; Ministry of Education, Culture, Sports, Science and Technology (MEXT); Ministry of Agriculture, Forestry and Fisheries; Ministry of Economy, Trade and Industry (METI); Ministry of Land, Infrastructure, Transport and Tourism; Ministry of the Environment

R&D content:

Carries out the concept design for energy systems in a society where energy and information are integrated through Society 5.0. The work status of each ministry and agency is grasped, interviews are conducted with information system architecture designers, and work is conducted on the design of an IoE society related to fusion of energy networks and transportation management, including energy conversion, storage, and transmission technologies.

Structure:

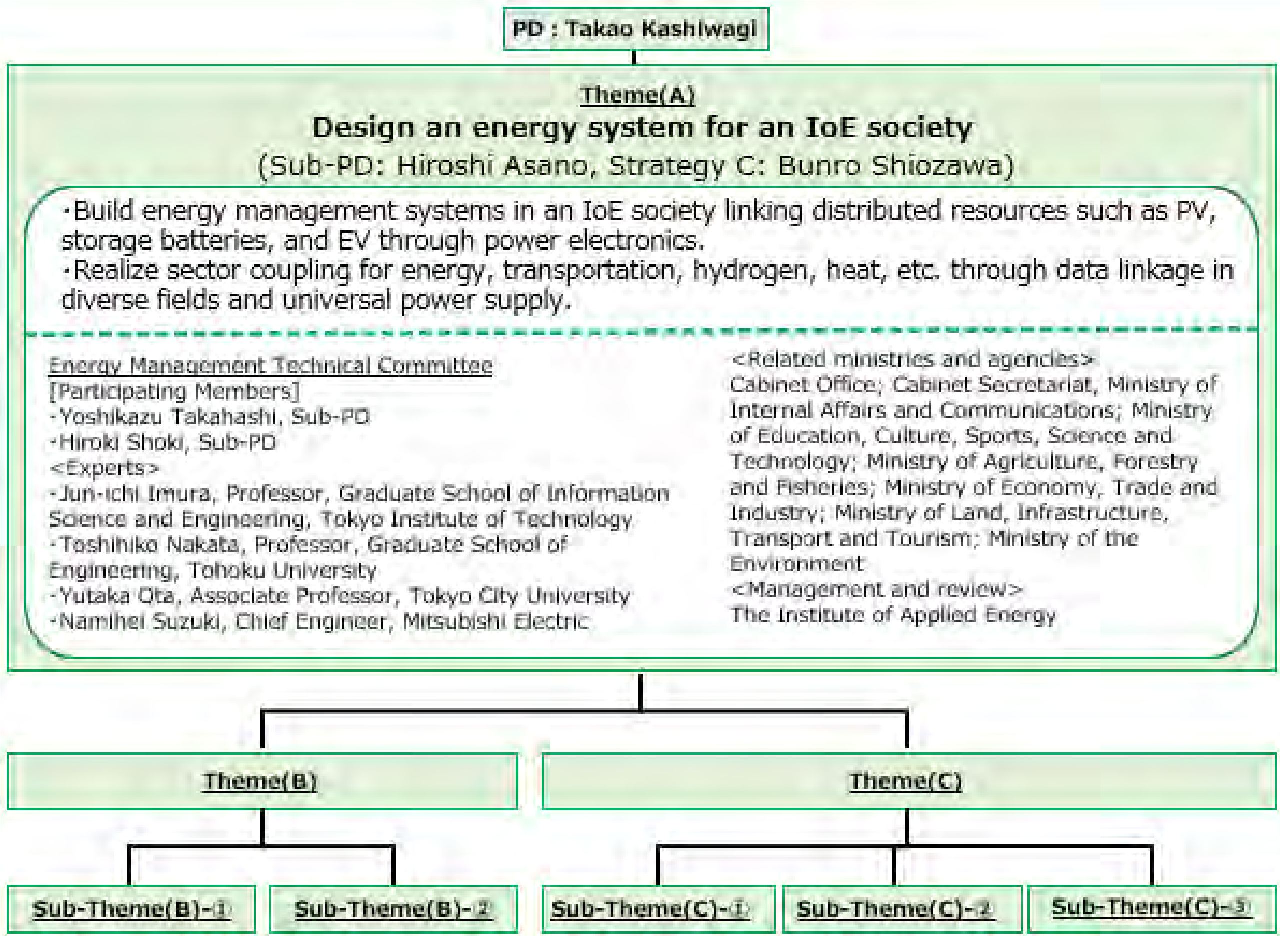


Figure 2-1 Theme (A) promotion system

Theme (B): IoE common platform technology

R&D period:

FY2018-FY2022

Sub-Program Director (Sub-PD):

Yoshikazu Takahashi (Professor, Center for Innovative Integrated Electronic Systems, Tohoku University)

(B)-①: IoE common platform technologies focusing on applications for energy devices

Representative:

Junichi Itoh (Professor, Faculty of Engineering, Nagaoka University of Technology)

Research outline:

Aim to decrease the total cost for power systems by developing the USPM that enables response to diverse input power sources including renewable energy. Also, develop USPM that enables high-speed switching utilizing materials science progress.

<USPM specific functions>

(1) Universal: Uses high-speed digital driving control with the core power module, fully leverages excellent characteristics of WBG devices, and supports many different power electronics applications and varieties.

(2) Smart: Enables optimal control according to load conditions and differences in characteristics between units through digital control.

(3) Low cost: Standardizes the core power modules and minimizes individual designs.

<Main technical points of development>

(1) Development of high-speed digital controllers for WBG semiconductor systems

(Always monitor the operation conditions and unstable input power source conditions for WBG devices through instant digital drive control technology without relying on optimal design and development of just the power module part, and fully leverage the excellent characteristics of WBG devices through instant feedback control)

① Development of technology that reduces delay time for sensing information

② Acceleration of digital control operation for power supply high-speed switching

③ Inclusion of real-time autotuning function

(2) Development of power module enabling response to the digital controller in (1) that can operate at high power density and high temperatures (high efficiency, high functionality, versatility, drastic reduction in design cost of power electronics application equipment,

① Over 1200V breakdown voltage

② High temperature operation of 200° C or higher

③ High power density

(3) Realize low loss at the level of SiC and costs at the level of Si as a WBG semiconductor switching element

MOSFET development

(Realizes Si replacement in mid-voltage areas such as industrial machinery, EVs, and consumer electronics, excluding high-voltage areas such as railroads where SiC is predominant)

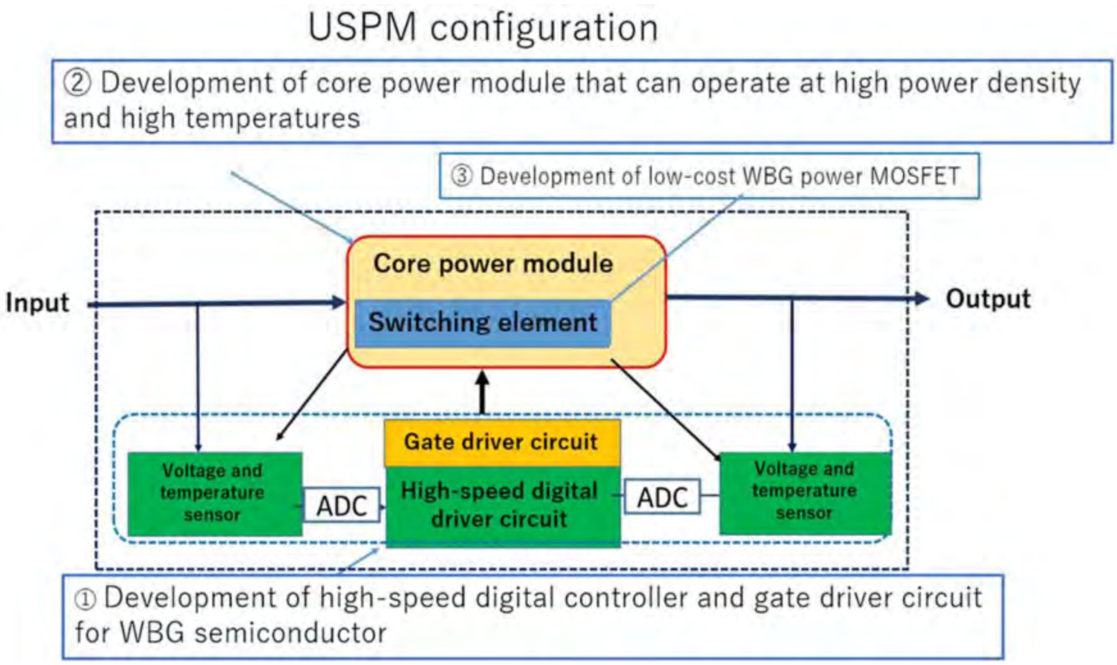


Figure 2-2 USPM structure

Structure:

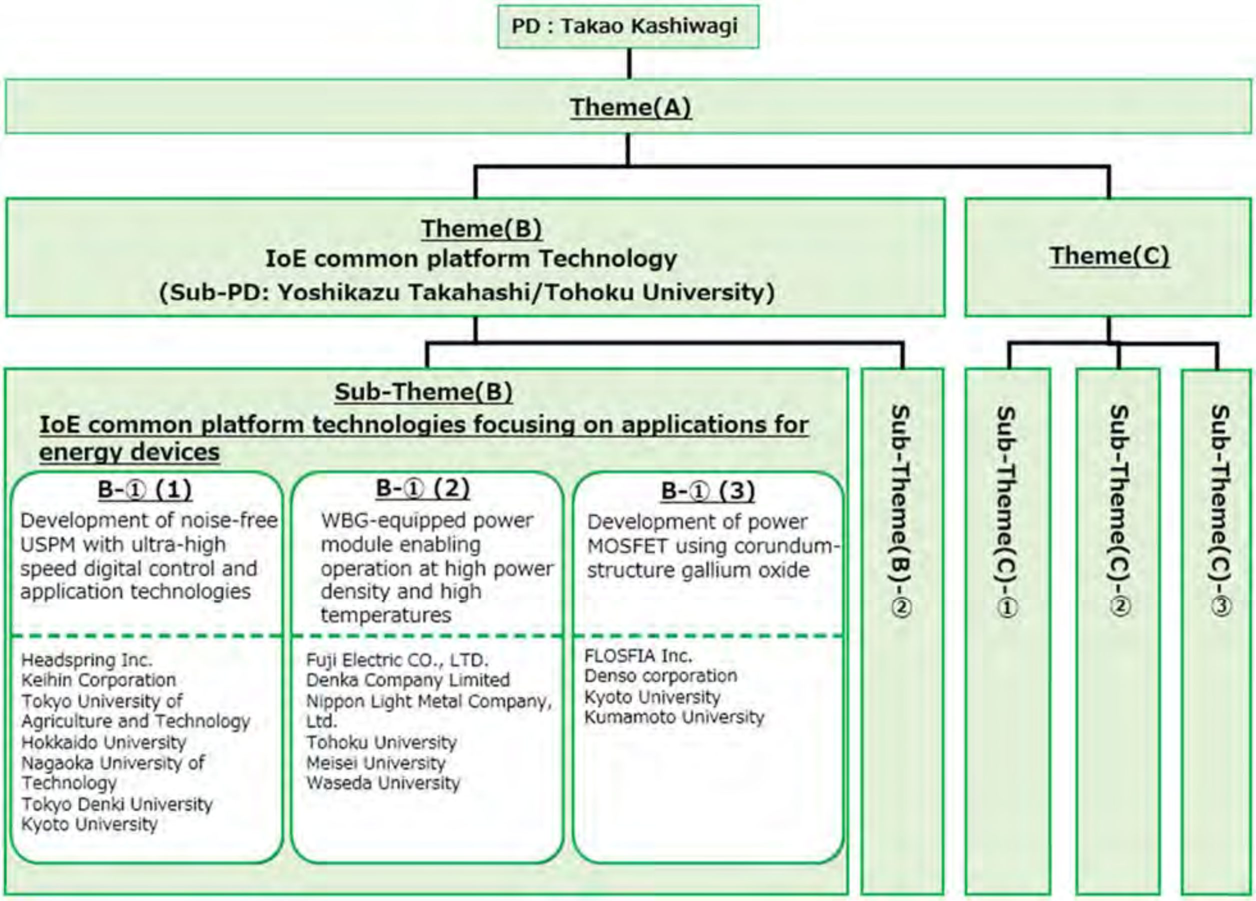


Figure 2-3 Sub-theme (B)-① promotion system

B-① (1): Development of noise-free USPM with ultra-high speed digital control and application technologies

Research supervisor:

Junichi Itoh (Professor, Faculty of Engineering Nagaoka University of Technology)

Participating organizations:

Tokyo University of Agriculture and Technology, Headspring Inc., Hokkaido University, Nagaoka University of Technology, Tokyo Denki University, Kyoto University, Keihin Corporation

Related ministries and agencies:

Cabinet Office; MEXT; METI

R&D content:

With the goal of rapidly expanding energy conservation and renewable energy use introduction to make it easy for even makers without knowhow of design technology for power electronics equipment to enter the market, create new value by offering new power converter system configuration through USPM that is easy for everyone to use. The following four items are developed aiming for changes through integration in the power electronics field.

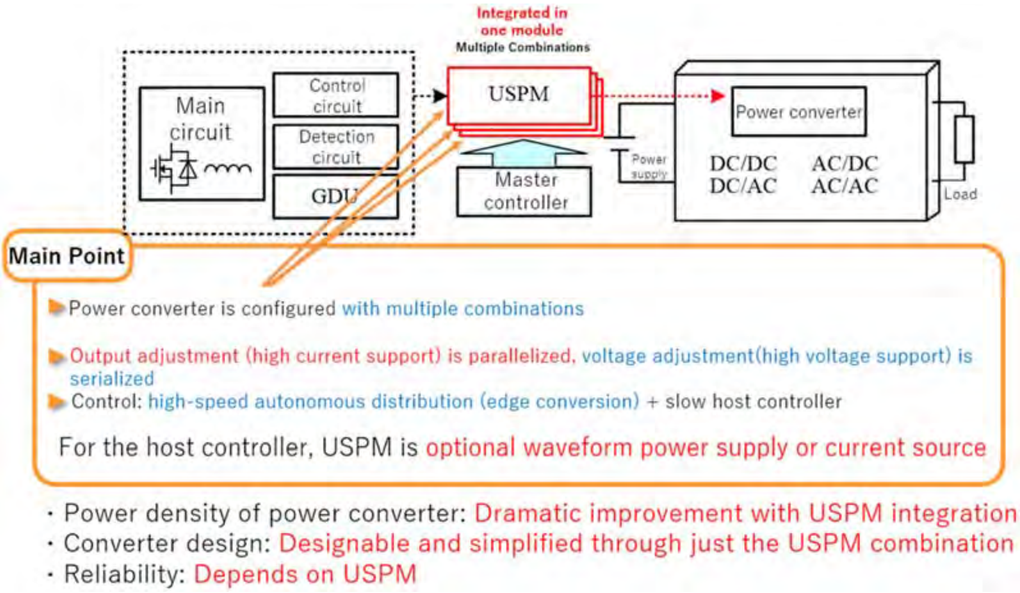


Figure 2-4 Outline of Sub-theme B-① (1)

<Development theme 1> Noise-free electro magnetic interference (EMC) filter development (layer 2)

Participating organizations:

Hokkaido University, Nagaoka University of Technology

R&D content:

Analysis of USPM noise Development of normal mode, common mode filter and active filter

<Development theme 2> Active gate driver development (layer 3)

Participating organizations:

Tokyo University of Agriculture and Technology, Headspring Inc.

R&D content:

Development of gate drive circuits that can control dv/dt, di/dt of WBG device as USPM basic technology

<Development theme 3> Instant digital driver control technique and hardware development (layer 4)

Participating organizations:

Tokyo Denki University, Kyoto University, Headspring Inc.

R&D content:

Development of hardware and control method that can realize digital control for USPM

<Development theme 4> Master controller and system application technology development (layer 5)

Participating organizations:

Nagaoka University of Technology, Hokkaido University, Keihin Corporation

R&D content:

Development of application technology for systems using USPM

Structure:

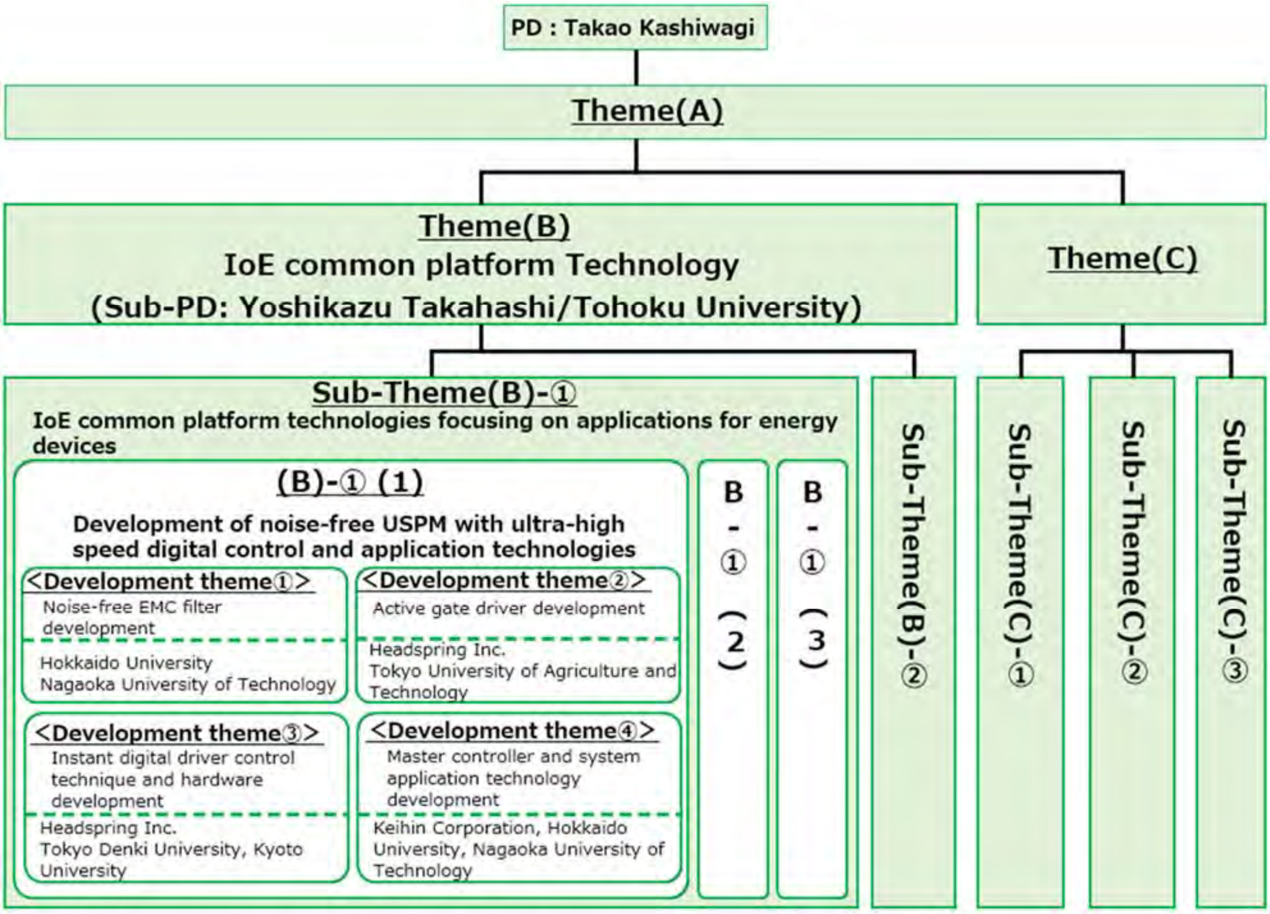


Figure 2-5 Sub-theme (B)-① (1) promotion system

Goals:

【Goals for the fiscal year】(at the end of fiscal year 2019)

<Development theme 1>

- Implement an automatic current control (ACC) basic design enabling drastic noise reduction for the switching frequency component surrounded by low frequency field, and enabling response for uses at high voltage above 400 V.
- Implement theoretical consideration regarding filter design methods for optimizing capacity and weight.

<Development theme 2>

- Start switching test equipment of power device
- Implement evaluation test of the current detection technology in main circuit developed in the previous fiscal year.
- Implement switching operation test through the dv/dt, di/dt closed-loop control, benchmark evaluation and subject extraction.

<Development theme 3>

・Design the high-speed digital driving-capable gate driver as a power level digital conversion circuit based on the gallium nitride(GaN) high electron mobility transistor(HEMT) high-speed gate driver, and confirm the operation characteristics through a simulation.

・Manufacture the designed gate array circuit as a discreet element, and have digital driving of the 1200V class SiC-MOSFET.

・Demonstrate the surge control during SiC-MOSFET high-speed switching through the active gate driver circuit design.

・Design and prototype the USPM digital controller, and implement an operation verification of its basic functions.

・Develop the USPM control software, and implement operation verification with the prototype controller.

<Development theme 4>

・Design and prototype the presumed 4 in 1 and 6 in 1 modular multi-level converter for USPM application, and confirm the basic operation by testing on existing equipment. In addition, examine the application of USPM for fluctuating voltage universal matrix converter.

・Examine performance requirements for in-vehicle use, with the goal of expanding the application scope of USPM.

【Mid-term goals】(At the end of fiscal year FY2020)

<Development theme 1>

・Acquire outlook for under half the conventional volume.

・Acquire decrease effect of over -6 dB.

*Conventional: General Si inverter with switching frequency of about 10 kHz.

<Development theme 2>

・Operation at about 50 kHz switching frequency

<Development theme 3>

・Finish prototype board operation verification

・Finish field programmable gate array(FPGA) implementation verification

・Over 5 kHz current response with about 50 kHz switching

<Development theme 4>

・Implement function module verification of experimental basic verification Bidirectional 2-phase Universal Matrix Converter (B2UMC) concerning USPM module parallel (under 5% input distortion rate)

【Final goals】(At the end of fiscal year FY2022)

<Development theme 1>

・Basic verification of the high frequency active noise canceller (aim to establish active canceller technology that responds to 2 MHz switching frequency in the end)

<Development theme 2>

・Basic benchmarking of prototype design board (operation at about 2 MHz switching frequency)

<Development theme 3>

・Finish development of the controller responding to the basic module configuration, and systemize software and FPGA (over 100 kHz current response)

<Development theme 4>

・Finish optimization of USPM functions for solar power conditioning system(PCS) (acquire outlook for half loss compared to conventionally)

・Establish technology including basic verification of medium-voltage (6.6 kV) server power supply through input series output parallel(ISOP) method

B-① (2)： WBG-equipped power module enabling operation at high power density and high temperatures

Research manager:

Yoshinari Ikeda (Section Manager, First Development Section, Packaging Development Division, Electronic Devices Headquarters, Fuji Electric CO., LTD.)

Participating organizations:

Fuji Electric CO., LTD., Denka Company Limited, Nippon Light Metal Company, Ltd., Tohoku University, Meisei University, Waseda University

Related ministries and agencies:

Cabinet Office, MEXT, METI

R&D content:

Development is needed for low-cost, highly functional, versatile USPM that can fully leverage the excellent characteristics of new WBG chips and can respond extremely efficiently to variable power sources such as renewable energy. For this, development is conducted for the following component technologies.

1）Development of fine bonding and three-dimensional wiring mounting technology for low inductance

2）Development of heat resistance reduction and heat dissipation cooling technology for higher power density

3）Development of compatibility technology with the gate drive unit(GDU) and digital controller

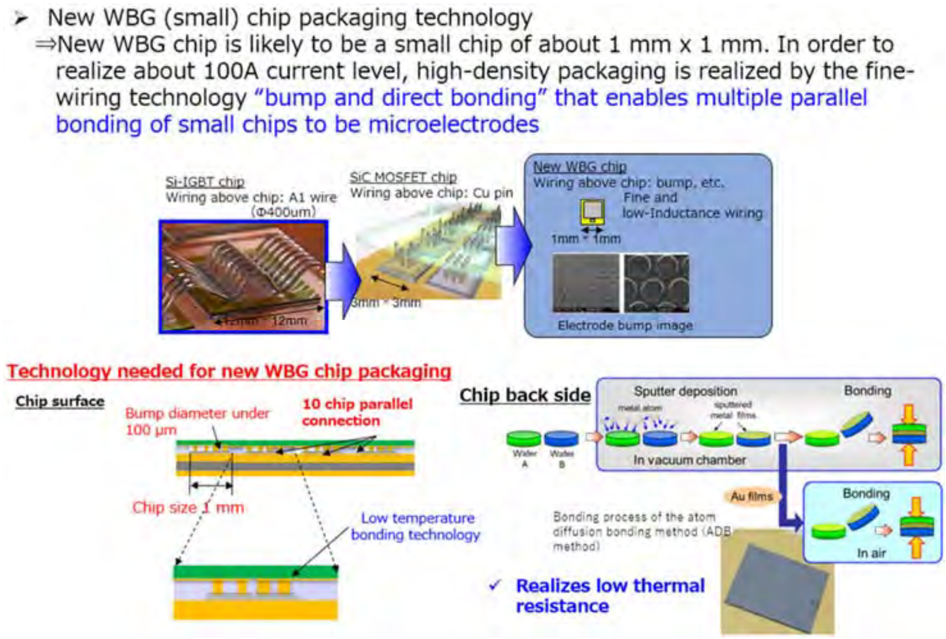


Figure 2-6 Sub-theme B-① (2) outline

<Development theme 1> Development of the core power module

Participating organizations:

Fuji Electric CO., LTD.

R&D content:

Development of a module that responds to Tj 200°C and achieves 150% higher power density compared to conventionally through fully leveraging the excellent characteristics of WBG devices, by applying technologies built in each theme

<Development theme 2> Development of ultra-high thermal conductivity and highly reliable circuit board

Participating organizations:

Denka Company Limited

R&D content:

Development of ultra-high thermal conductivity and highly reliable insulating circuit board based on insulating heat dissipation materials (high thermal conductivity silicon nitride substrate, aluminum nitride multilayer substrate, high thermal conductivity resin insulation layer

<Development theme 3> R&D for ultra-high heat dissipation cooling system

Participating organizations:

Nippon Light Metal Company, Ltd.

R&D content:

Development of cooling equipment that realizes low heat resistance through ideas such as a fin shape

<Development theme 4> Development of chip direct bonding technology

Participating organizations:

Tohoku University

R&D content:

Development of direct bonding technology without use of a bonding material below the chip

<Development theme 5> Development of chip surface electrode technology

Participating organizations:

Meisei University

R&D content:

Development of fine bonding and three-dimensional wiring mounting technology with bump diameter of about 100µm that responds to small chips

<Development theme 6> Development of module/cooling equipment joining technology and optimized design technology

Participating organizations:

Waseda University

R&D content:

Development of joining technology below 200°C through liquid phase sintered material, etc.

<Development theme 7> Development of GDU/digital controller connection compatibility technology

Participating organizations:

Waseda University

R&D content:

Development of wiring technology that realizes low inductance using optimized design techniques

Structure:

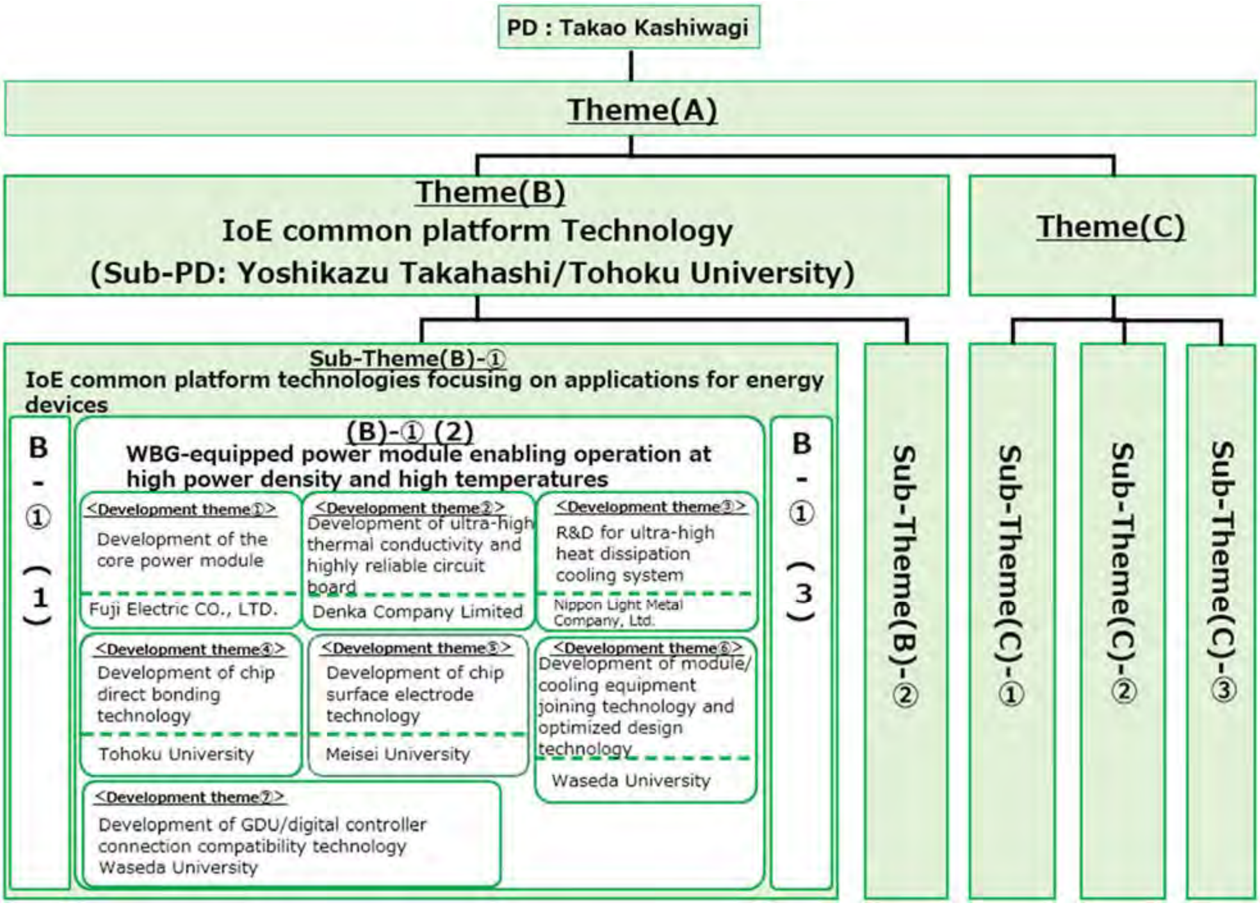


Figure 2-7 Sub-theme (B)-① (2) promotion system

Goals:

【Goals for the fiscal year】(At the end of fiscal year FY2019)

<Development theme 1>

・Create simple module prototype applying the SiC chip in order to study the effects when combined with various component technologies, and evaluate and verify the electrical characteristics and heat characteristics with the simple module unit.

<Development theme 2>

・In addition to evaluating the manufacturing and fundamental physical properties of the circuit board that can achieve the mid-term goals, conduct preliminary examination of evaluation of the reliability of the circuit board unit.

<Development theme 3>

・Create prototype and implement evaluation of the cooling fin, and confirm the cooler performance enhancement through improvement of the heat transfer rate with the fin atmosphere.

・Create prototype and implement evaluation of the cooler applying high heat transmission materials scattered efficiently on the base part, and confirm the results.

<Development theme 4>

・Together with defining thin film material suitable for bonding using the atom diffusion bonding method with substrates with high heat conductivity and large rough surfaces, develop low temperature bonding technology to bond chips with surface roughness of about 2 nm and mirror polished metals.

<Development theme 5>

・For the electrode structure, to consider possibilities of fine bump and copper posts, verify application for fine electrode structure technology and copper post through the dispenser.

<Development theme 6>

・For the low temperature, low thermal resistance connection, examine bonding increased to 10-20 mm angles for the bonding area.

・Conduct design development leveraging the thermal fluid simulation of the cooling internal structure (fin shape, etc.), and implement adjustment of the device and calculation module that match analysis results and measurement results.

<Development theme 7>

・Implement design of examination system for circuit shape and form through optimized technology.

【Mid-term goals】（At the end of fiscal year FY2020）

<Development theme 1>

・Operation at high temperatures: Tj 200°C response (no problem in initial evaluation)

・Power density: over 130% (compared to conventionally)

<Development theme 2>

・Insulator voltage: over 600V (board unit)

・Heat cycle resistance: 500 cyc. (board unit)

・High heat dissipation of insulated circuit board : thermal resistance, 50% lower than conventionally (board unit)

<Development theme 3>

・High heat dissipation of cooling system: thermal resistance 18% lower than conventionally

<Development theme 4>

・Bonding technology development / low thermal resistance of the bonding below the chip

:High strength bonding of the semiconductor chip to the metal surface of about 5 nm surface roughness

<Development theme 5>

・Establish wiring above chip technology: multiple chip parallel connection (chip size: 3 mm x 3 mm, bump connection)

<Development theme 6>

・Low heat resistance between module/cooling equipment: thermal resistance, 18% lower than conventionally

・Bonding temperature: under 230°C

・Heat cycle resistance: 300 cyc.

<Development theme 7>

・Optimization of internal wiring inductance (through plan optimizing machine characteristics and electrical characteristics): under 15nH

【Final goals】(At the end of fiscal year FY2022)

<Development theme 1>

- Operation at high temperatures: Tj 200°C response (no problem during the reliability evaluation)
- Power density: over 150% (compared to conventionally)

<Development theme 2>

- Insulator voltage: over 1200 V
- Heat cycle resistance: 500 cyc.
- High heat dissipation of insulated circuit board: heat resistance, 70% lower than before

<Development theme 3>

- High heat dissipation of cooling system: 35% lower than conventionally

<Development theme 4>

- Bonding technology development: operation at high temperatures of 200°C
- Low heat resistance of bonding part under chip: thermal resistance, 90% lower than conventionally

<Development theme 5>

- Establishment of wiring above chip technology: 10 chip parallel connection (chip size: 1 mm x 1 mm, bump diameter: under 100 μm)

<Development theme 6>

- Low heat resistance between module/cooling device: thermal resistance, 35% lower than conventionally
- Bonding temperature: under 200°C
- Heat cycle resistance : 500 cyc.

<Development theme 7>

- Optimization of internal wiring inductance (through plan optimizing machine characteristics and electrical characteristics): under 10nH

B-① (3) : Development of power MOSFET using corundum-structure gallium oxide

Research supervisor:

Takashi Shinohe (CTO, FLOSFIA Inc.)

Participating organizations:

FLOSFIA Inc., Kyoto University, Kumamoto University, Denso corporation

Related ministries and agencies:

Cabinet Office, MEXT, METI

R&D content:

Develop power MOSFET with over 1,200 V voltage using corundum-structure gallium oxide $\alpha-Ga_2O_3$

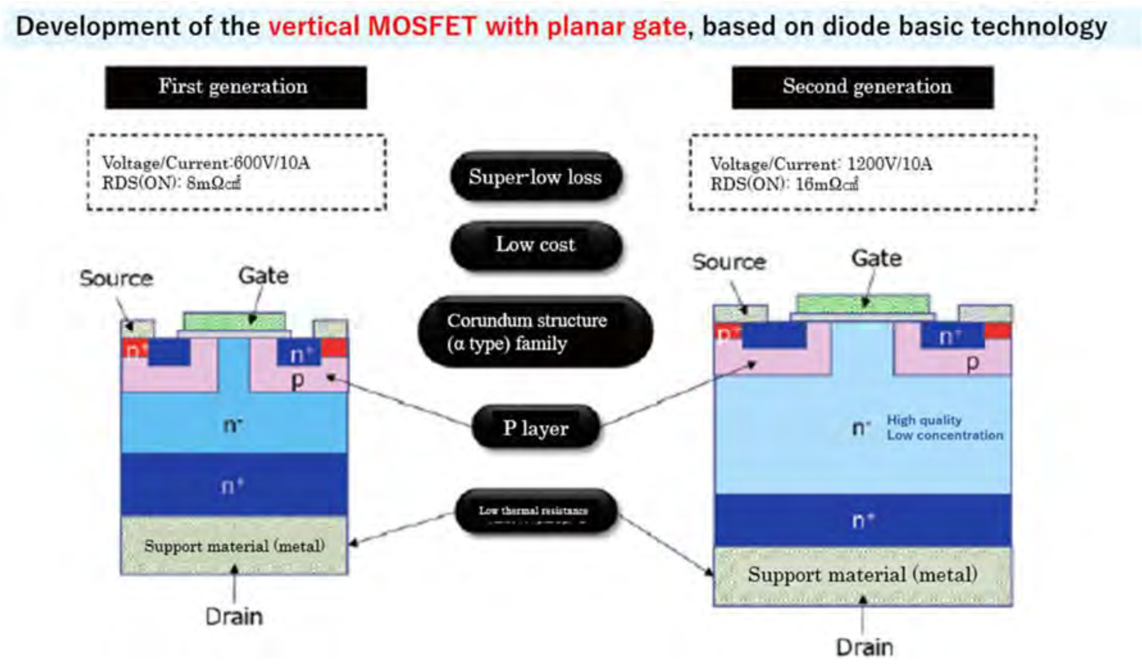


Figure 2-8　Sub-theme B-① (3) outline

<Development theme 1> Component technology development

Participating organizations:

FLOSFIA Inc., Kyoto University, Denso corporation, Kumamoto University

R&D content:

(i) Develop p -well layer

(ii) Analysis and control of electronic properties

(iii) Analysis and characterization of crystal structure

(iv) Develop gate insulating film

(v) Understand the correlation between crystal defect types and electricity characteristics

(vi) Develop MOS interface control technology

(vii) Evaluate MOS interface

(viii) Develop ohmic electrode

(ix) Development of process component technology

<Development theme 2>　MOSFET prototype and evaluation

Participating organizations:

FLOSFIA Inc.

R&D content:

(i) Prototype and evaluate 600 V voltage planar gate structure

(ii) Prototype and evaluate 1,200 V voltage trench gate structure

<Development theme 3>　Application basic evaluation

Participating organizations:

FLOSFIA Inc.

R&D content:

(i) Develop device simulation technology

(ii) Evaluate dynamic characteristics

(iii) Test combination

Structure:

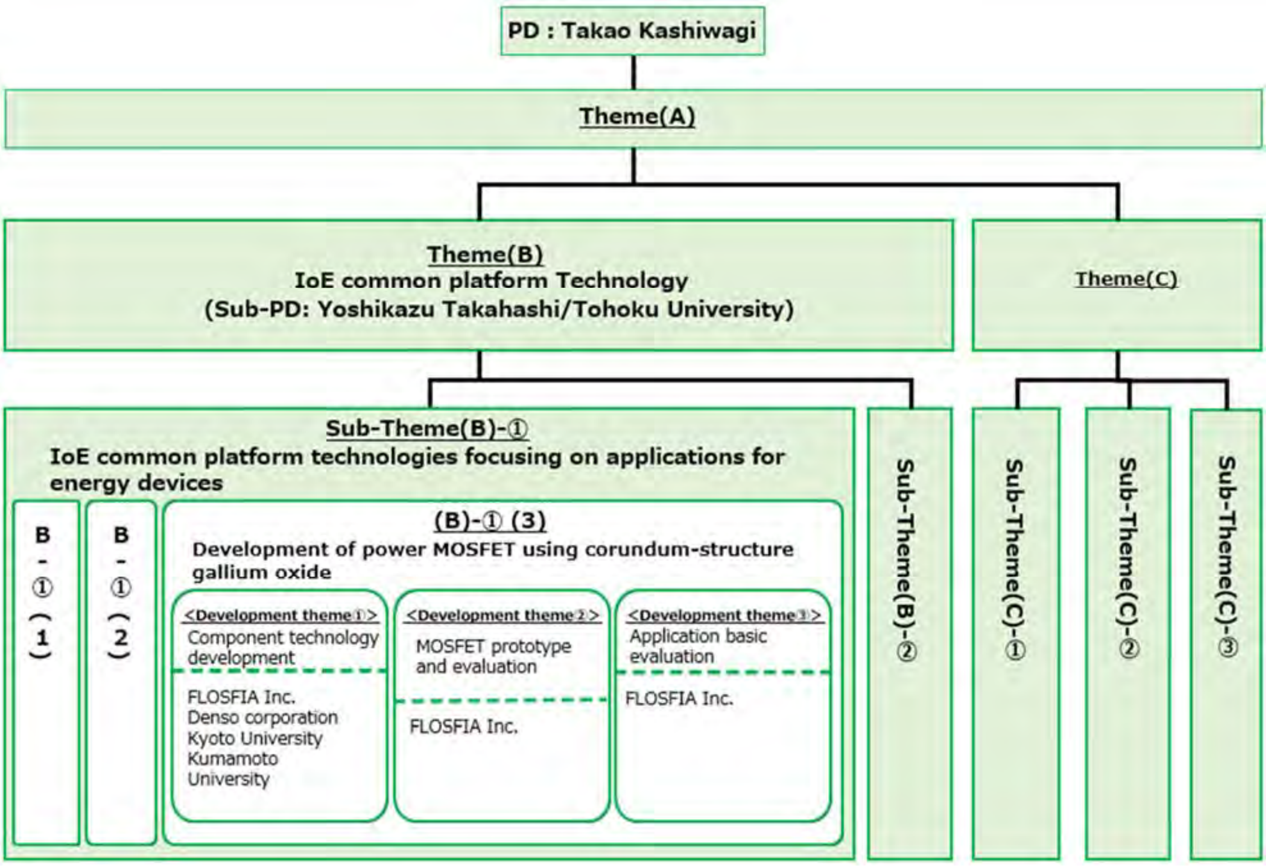


Figure 2-9 Sub-theme (B)-① (3) promotion system

Goals:

【Goals for the fiscal year】(At the end of fiscal year FY2019)

Propose the unit cell that achieves voltage of 1,200 V, ON resistance of 16mΩcm^2, and junction terminal structure.

【Mid-term goals】(At the end of fiscal year FY2020)

Achieve the following goals for vertical power MOSFET with planar gate structure.

- Voltage: 600 V
- Current capacity: 10A
- ON-resistance: 20mΩcm^2

【Final goals】(At the end of fiscal year FY2022)

Achieve the following goals for vertical power MOSFET with planar gate structure.

- Voltage: 1,200 V
- Current capacity: 10A
- ON-resistance: 16mΩcm

(B)-② ： IoE common platform technologies focusing on application in WPT systems

Representative:

Hiroshi Amano (Professor, Center for Integrated Research of Future Electronics, Institute of Materials and Systems for Sustainability, Nagoya University)

Participating organizations:

Nagoya University, Fuji Electric CO., LTD., Furukawa Electric Co., Ltd., Nagaoka University of Technology, Shibaura Institute of Technology, DAIHEN Corporation, Pony Electric Co., Ltd., Sharp Corporation, National Institute of Advanced Industrial Science and Technology (AIST), Nagoya Institute of Technology, Mitsubishi Electric Corporation, Kanazawa Institute of Technology

Related ministries and agencies:

Cabinet Secretariat, Cabinet Office, Ministry of Internal Affairs and Communications, MEXT, METI

R&D content:

Develop basic technologies for electro-magnetic coupling type WPT systems using MHz bands and radiation-type WPT systems using microwaves which are desired to be new power supply systems. Implement R&D for devices and circuits suitable for making various WPT systems smaller, more efficient, and have higher power capacity, and conduct proof of concept as WPT systems with 13.56 MHz bands and 5.8 GHz bands. Through these R&D results, together with responding to diversifying power consumption needs in an IoT society, contribute to optimization and decarbonization of energy management throughout society.

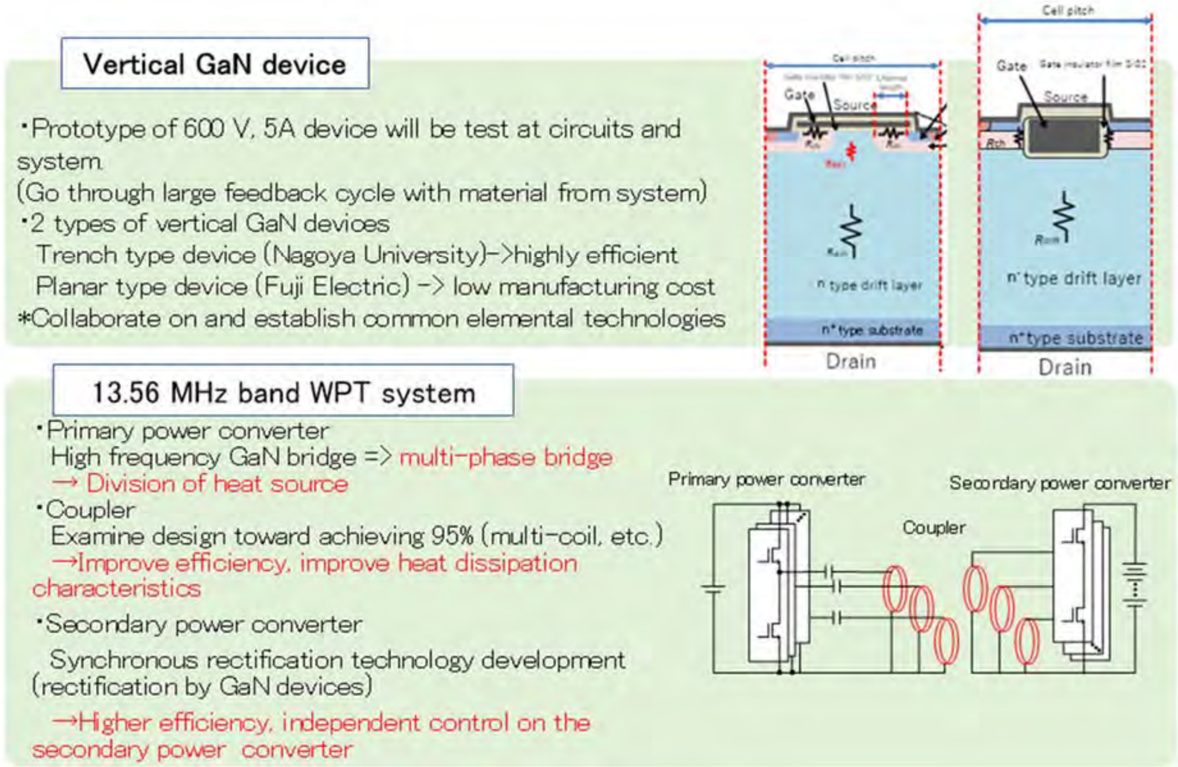


Figure 2-10 Main points of MHz band power transmission system R&D

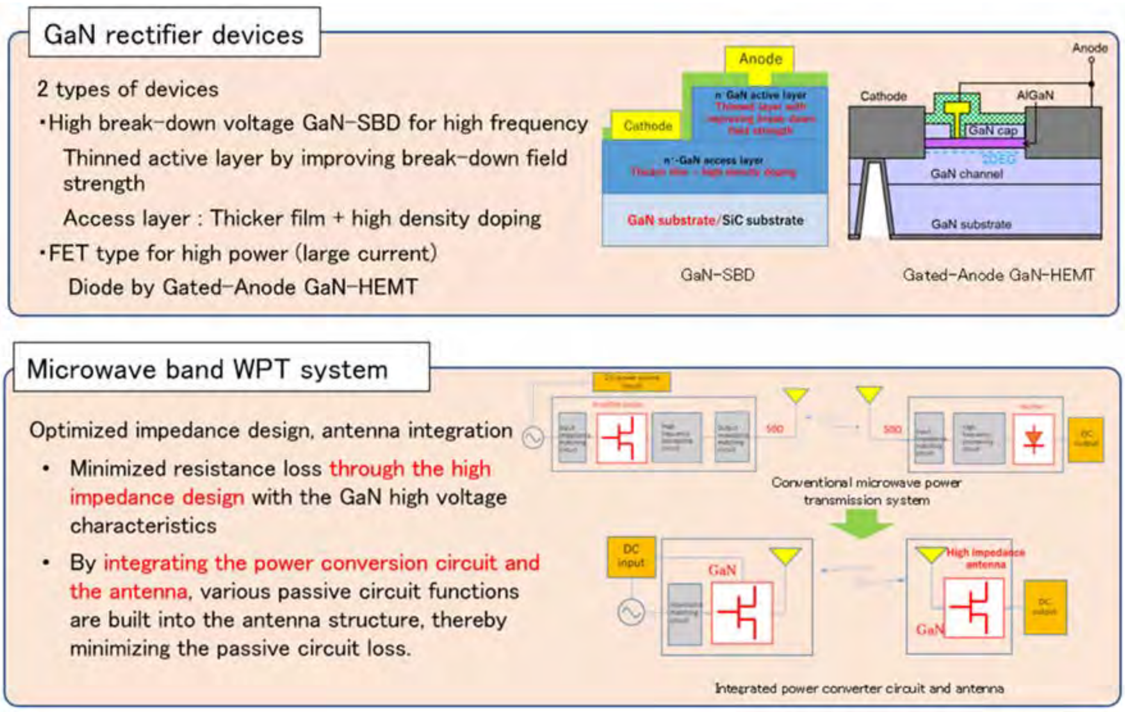


Figure 2-11 Main points of microwave power transmission system R&D

<Development theme 1> Development of WPT system using a high-speed switching device

Participating organizations:

Nagoya University, Fuji Electric

R&D content:

(i) Development of crystal growth technology and equipment for high-quality vertical GaN device

(ii) Examine device structure through device simulation and device prototype

(iii) Examine practical manufacturing process for vertical GaN switching device

<Development theme 2> Development of MHz band WPT system basic technologies

Participating organizations:

Nagoya University, Furukawa Electric Group, Nagaoka University of Technology, Shibaura Institute of Technology, DAIHEN Corporation, Pony Electric Corporation, Sharp Corporation, AIST

R&D content:

(i) Develop MHz band WPT common platform technologies

(ii) Develop high-capacity MHz band WPT system

(iii) Develop basic technologies enabling WPT with dozens of MHz and verify the technology

<Development theme 3> Development of high frequency device for WPT system

Participating organizations:

Nagoya Institute of Technology, Nagoya University, Mitsubishi Electric Corporation

R&D content:

(i) Develop epitaxial layer (crystal) growth technology and equipment for GaN diode

(ii) Develop manufacturing and evaluation technology of microwave band GaN diode

(iii) Examine practical manufacturing process of microwave band GaN diode

<Development theme 4> Development of microwave WPT system

Participating organizations:

Nagoya University, Nagoya Institute of Technology, Kanazawa Institute of Technology

R&D content:

(i) Cooperative design of antenna matching GaN element characteristics, design and make a prototype of high output receiving rectenna circuits

(ii) Design optimal impedance realizing highly efficient circuits, design and make a prototype of lightweight antenna

(iii) Design and make a prototype of highly-efficient power amplification circuit through high voltage and optimal impedance design

(iv) Develop highly efficient microwave band WPT function verification system using GaN device

(v) Understand issues toward realizing power receiver over 10 W with power receiving rectenna using GaN device

Structure:

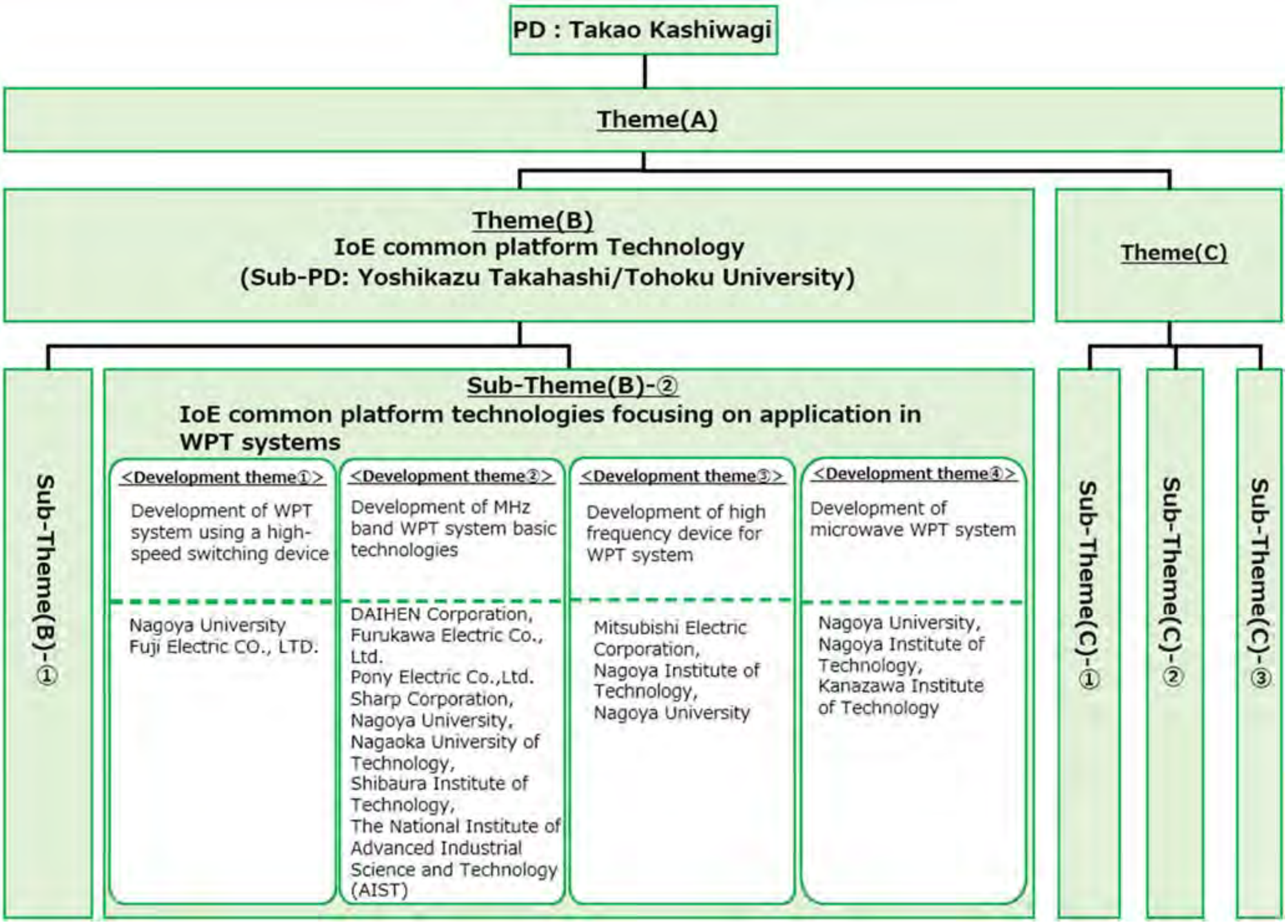


Figure 2-12 Sub-theme (B)-② promotion system

Goals:

【Goals for the fiscal year】(At the end of fiscal year FY2019)

<Development theme 1>

- Complete structure concept formulation for the 600 V voltage, low gate capacity high-speed switching device
- Complete component process verification necessary for realizing the device, implement initial prototype of the switching device

<Development theme 2>

- Complete initial prototype and evaluation of the high-speed gate driving IC component circuit, implement design of the next prototype IC
- Implement power transmission test for 6.78 MHz band

<Development theme 3>

- Complete prototype and evaluation of GaN basic device for rectification, extraction of guidelines for increasing power consumption

・Complete basic epitaxial structure design for the GaN device for microwave power receiving rectification

<Development theme 4>

・Complete designs for antenna for the 5.8 GHz, 1 W microwave band power transmission system, power receiving rectenna, and power amplifier

【Mid-term goals】(At the end of fiscal year FY2020)

<Development theme 1>

・Realize low gate capacity (vs. SiC1/2) MOS(600 V/1A)

<Development theme 2>

・13.56MHz gate driving IC rise, fall time of <2ns (500pF load, 0-5V 20%-80%)

・13.56MHz coupler 3.7kW, coupler efficiency 88%

<Development theme 3>

・Provide GaN device for microwave power receiving rectification for <Development theme 4>

<Development theme 4>

・Demonstrate power transmission function using power receiving rectenna (5.8GHz/1W level)

【Final goals】(At the end of fiscal year FY2022)

<Development theme 1>

・Realize low gate capacity MOS (600V/5A)

<Development theme 2>

・Demonstrate functions through MHz band power transmission system (13.56MHz, 7.7kW)

<Development theme 3>

・Establish epitaxial formation layer technology for power receiving element

・Implement GaN device for 10W-capable WPT systems

<Development theme 4>

・Demonstrate functions through microwave band power transmission system (5.8GHz, 10W level)

Theme (C): R&D for application/practical implementation of IoE

R&D period:

FY2018-FY2022

Sub-Program Director (Sub-PD):

Hiroki Shoki (Senior Expert, Toshiba Corporation)

Toward realizing energy management using long-range, highly efficient, high power and safe WPT, while utilizing high frequency devices with high voltage and low resistance based on next-generation semiconductor technology, which are Japan's strength and are expected to have major energy conservation results, develop advanced transmission control technology that optimizes the transmitters and receivers of WPT systems while utilizing existing R&D results.

We set goals that surpass the world in anticipation of international benchmarks, and establish technologies that enable high-efficiency transmitters and receivers in WPT systems, and transmission over long distances and high power transmission on the WPT system.

Furthermore, the developed WPT system technology will be demonstrated for the following use cases based on the needs of industry.

1. Indoor power supply (sensors, mobile information equipment, etc.)
2. Outdoor power supply (maintenance and management of infrastructure)
3. Dynamic WPT(Wireless Power Transfer) for in-motion EVs

Goals of this theme:

○Within five years, establish long-range, highly efficient, high power, safe WPT system technology, and demonstrate it for various equipment and workplaces. When the project is complete, serve as an intermediary to bring the results to industry and conduct commercialization.

C-① : WPT systems for sensor networks and mobile equipment

Research supervisor:

Shoichi Kajiwara (Head Engineer, Manufacturing Innovation Division, Panasonic Corporation)

Participating organizations:

Panasonic Corporation, Denki Kogyo Company, Limited, Niigata University, Chiba University, Shinshu University, Omron Corporation, Toshiba Corporation, Iwate University

Related ministries and agencies:

Cabinet Secretariat, Cabinet Office, Ministry of Internal Affairs and Communications, MEXT, METI

R&D content:

For WPT systems, conduct R&D on two power supply methods and common matters between them. Upon realizing this, offer the new concept of intelligent Time-Area-Frequency control (iTAF-WPT) that reduces effects on the human body and other systems from the three dimensions of time, area, and frequency, and implement high power supply efficiency by realizing this. The goals are the following two points.

(1) Cooperative beam control method through distributed antennas: This method aims for wide-area electricity supply at the μW - mW level in order to realize battery-less and wireless environment sensors, distribution sensors, and biological sensors placed in greats numbers in indoor spaces such as homes, factories, and nursing homes.

(2) Advanced beam forming method: This method aims for electricity supply at the level of several mW in order to realize electricity supply for mobile sensors, IoT sensors, information device charging, and sensors that move such as in factories.

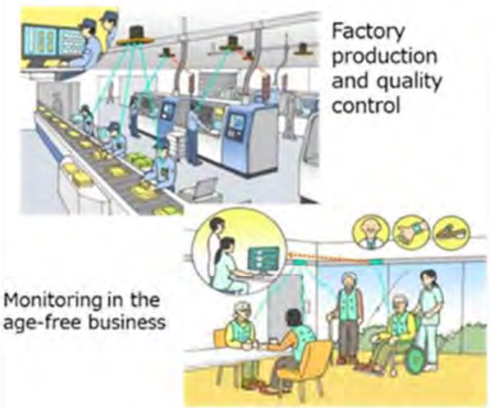
Method	Coordinate beam control with distributed antennas	Advanced beamforming
Peculiarity	Small power supply to a wide area of sensors	Medium power supply for sensors and mobile devices.
Technical Point	High-efficiency power synthesis with low-cost, ultra-precision synchronization	Highly accurate detection and avoidance of human body and interfered system
Main use case		
Target	Sensor of Environment and Person	← + Mobile device
Received Power	Hundreds μW ～ Several mW	Several mW ～ Several W

Figure 2-13 Sub-theme C-① outline

<Development theme 1> Development of the distributed antenna cooperative beam control method

Participating organizations:

Panasonic Corporation, Denki Kogyo Company, Limited, Niigata University, Chiba University, Shinshu University

R&D content:

Install several low equivalent isotopically radiated power (EIRP) WPT transmitters, provide power supply to a wide indoor area, and build sensor networks.

<Development theme 2> Development of the advanced beam forming method (920 MHz band,・5.7 GHz band)

Participating organizations:

Omron Corporation (920 MHz band), Toshiba Corporation (5.7 GHz band), Iwate University (5.7 GHz band), Niigata University (5.7GHz band), Denki Kogyo Company, Limited, Chiba University, Shinshu University

R&D content:

Provide power supply to sensors and mobile devices by arranging advanced EIRP WPT transmitters indoors.

Structure:

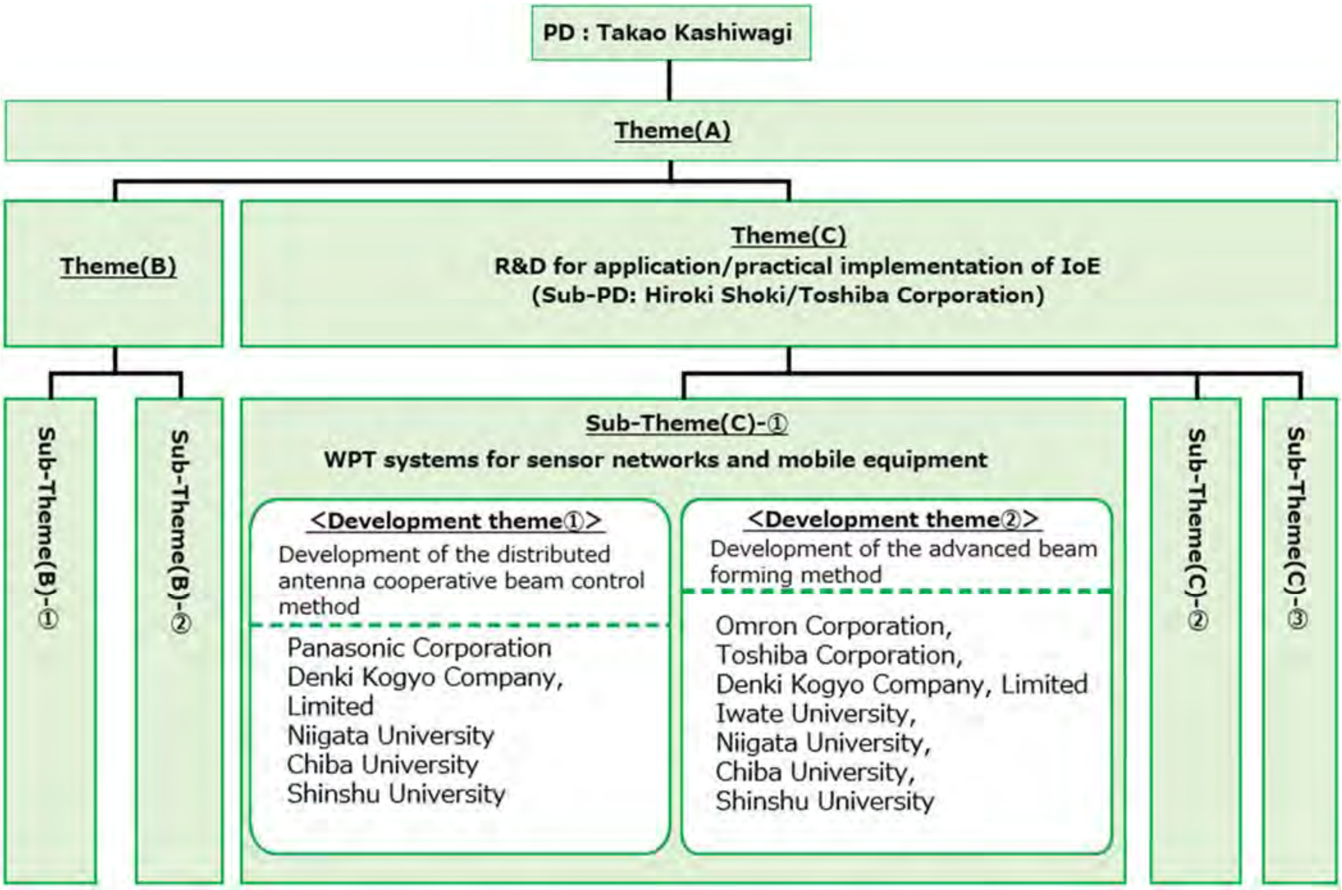


Figure 2-14 Sub-theme (C)-① promotion system

Goals:

【Goals for the fiscal year】(At the end of fiscal year FY2019)

<Development theme 1>

・Verification by examining and analyzing central power algorithm, analysis with receiving terminal detection method and verification with the actual equipment

<Development theme 2>

・Anti-interference wave detection, confirmation of beam forming theory model through detecting humans, and confirmation of results of null control interference avoidance through incoming wave direction estimation technology

【Mid-term goals】(At the end of fiscal year FY2020)

<Development theme 1>

・Achievement of 0.5 mW power supply to terminals and 20% WPT power supply time efficiency with prototype system

<Development theme 2>

・Implementation and verification of advanced beam formation function and human detection function of the prototype system

【Final goals】(At the end of fiscal year FY2022)

<Development theme 1>

・Development of demonstration system

・Implementation of power supply at several hundred μW-mW level and up to 50% WPT power supply time efficiency to the terminals

<Development theme 2>

・Development of demonstration system

・Implementation of power supply from mW level to about 1W level and up to 50% WPT power supply time efficiency

C-② : Dynamic WPT for in-motion EV

Research supervisor:

Hiroshi Iwano (Executive Director, Japan Automobile Research Institute)

Participating organizations:

Japan Automobile Research Institute, Toyota Motor Corporation, Nissan Motor Co., Ltd., IHI Corporation, Honda R&D Co., Ltd., University of Tokyo, Tokyo University of Science, DAIHEN Corporation, NSK Ltd.

Related ministries and agencies:

Cabinet Secretariat, Cabinet Office, Ministry of Internal Affairs and Communications, MEXT, METI

R&D content:

Reducing vehicle CO_2 emissions is an urgent matter for realizing a carbon-free society, and EV are a leading solution method. However, there are issues with convenience in terms of cruising range and charging wait times. For this, there are high expectations for realizing dynamic WPT by wirelessly supplying energy while the vehicle is in motion. This research works on the following three development themes: ① Establishment of WPT interoperability and Foreign Object Detection method, ② Establishment of high-efficiency dynamic WPT technology capable of high-speed driving, and ③ Consideration of economic feasibility. ① shows design limitation conditions necessary for ensuring interoperability between different manufacturers, proposes the safety matter of the Foreign Object Detection method, and carries out verification through testing.

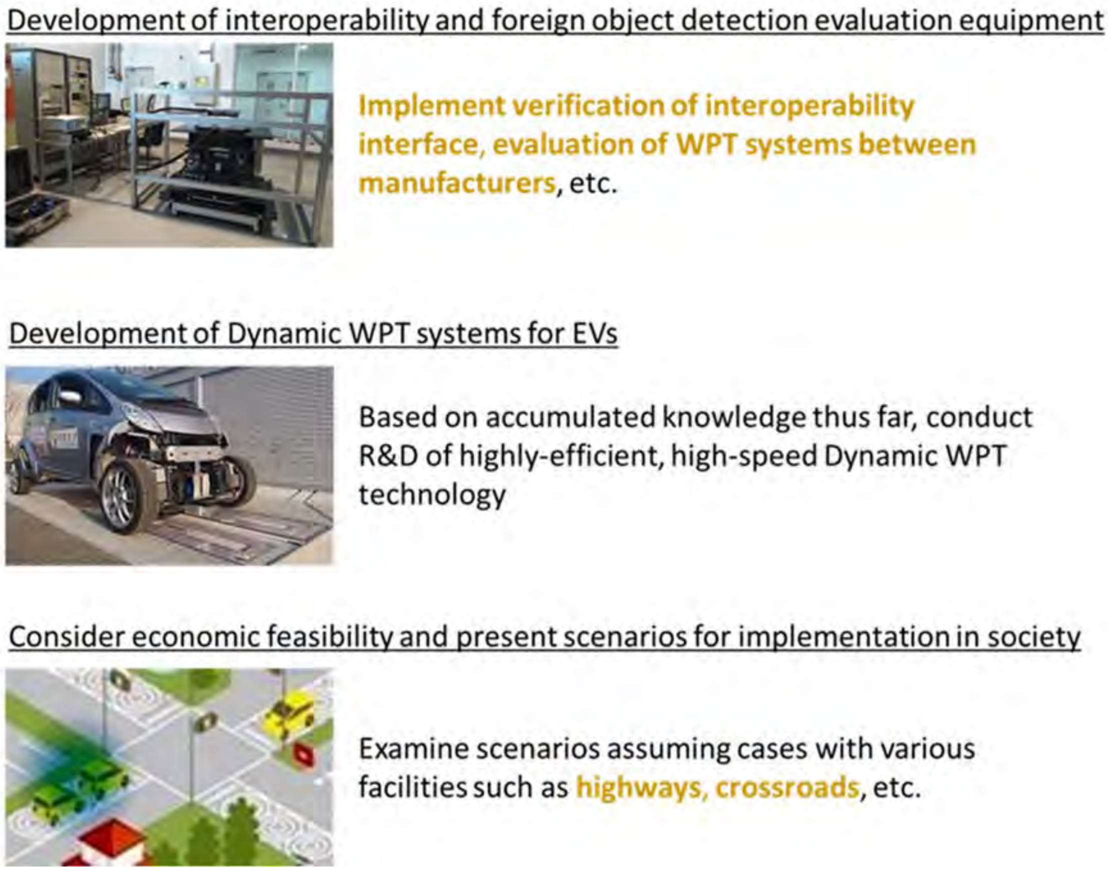


Figure 2-15 Sub-theme C-② outline

<Development theme 1> Establishment of WPT interoperability and Foreign Object Detection method

Participating organizations:

Japan Automobile Research Institute, Toyota Motor Corporation, Nissan Motor Co., Ltd., IHI Corporation, Honda R&D Co., Ltd., University of Tokyo

R&D content:

OEMs and suppliers will present the target performance (detected foreign object, use-cases, etc.), and universities and research institute will examine detection methods and evaluate them using prototypes to satisfy the target performance. The method for which the effectiveness has been confirmed is prototyped through detailed design by the supplier, and the performance is verified in the assumed use-case.

<Development theme 2> Establishment of high-efficiency dynamic WPT technology capable of high-speed driving

Participating organizations:

University of Tokyo, DAIHEN Corporation, NSK Ltd., Japan Automobile Research Institute

R&D content:

Develop wireless in-wheel motor supporting high-speed, high-efficiency power supply, and equip it in an experimental EV of the University of Tokyo Group to conduct dynamic WPT tests at a speed of about 15 km/h on the low-speed dynamic WPT street in the Kashiwa campus of the University of Tokyo. In the second half of the SIP period, together with conducting tests such as measuring power supply efficiency with experimental equipment simulating dynamic WPT, also demonstrate it with real vehicles at speeds of over 60 km/h on a high-speed power supply test course.

<Development theme 3> Consideration of economic feasibility

Participating organizations:

Japan Automobile Research Institute, Toyota Motor Corporation, Nissan Motor Co., Ltd., IHI Corporation, Honda R&D Co., Ltd., DAIHEN Corporation, NSK Ltd., University of Tokyo

R&D content:

Implements installation cost estimates for dynamic WPT infrastructure that was at Mitsubishi Research Institute in the past. For example, for 100% construction of two single vehicle lanes along both directions of the roughly 350 km highway between Tokyo and Nagoya, the practical estimate for the cities was 81.5 billion yen for equipment, 73.8 billion yen for the civil engineering cost, and 4.2 billion for construction of power facilities. As the starting point for the examination results, the estimate was calculated based on environmental changes such as the technology development situation.

Structure:

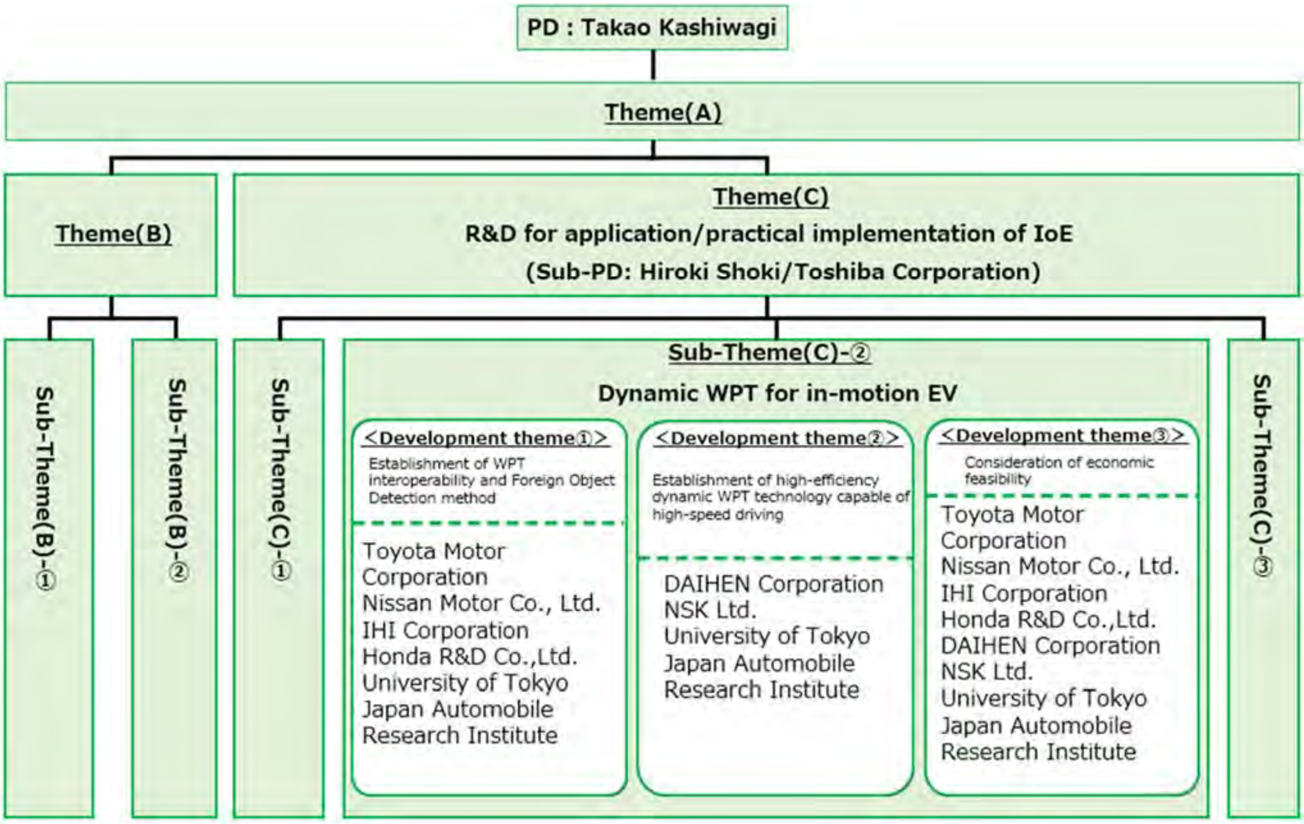


Figure 2-16 Sub-theme (C)-② promotion system

Goals :

【Goals for the fiscal year】(At the end of fiscal year FY2019)

<Development theme 1>

・Complete the establishment of experimental facilities for performance evaluation and verification tests of interoperability and safety

・Conduct simulation of the interoperability interface design method, and clarify the technical issues for implementation.

・Clarify the merits and demerits through desk study of the Foreign Object Detection methods.

<Development theme 2>

・Complete manufacturing of experimental vehicles enabling dynamic WPT at 60 km/h

・Complete manufacturing of prototypes of above-ground facilities, in-vehicle equipment, and wheel side power receiving coil.

<Development theme 3>

・Complete study concerning cost estimate prerequisites

・Complete examination of arrangement of merits of related people toward the effect estimate as well as quantitative presentation method

・Complete rough estimate of the costs and effects concerning implementation in society of dynamic WPT (at about a maximum of three stages (limited areas such as highways, main general roads, taxi pools, etc.)

【Mid-term goals】(At the end of fiscal year FY2020)

<Development theme 1>

- Establish the experimental facilities for testing interoperability, safety evaluation and verification tests
- Design the interoperable interface design method and start verification testing
- Research on detection methods that satisfy target performance and start evaluation with prototypes・

<Development theme 2>

・Achieve 24 kW (conversion for 1 EV) power supply and 90% efficiency in the test bench

<Development theme 3>

・Estimate the costs and effects concerning implementation in society of dynamic WPT, embodying introduced scenarios

・Elucidate the merits for road managers assumed to be the introduction stakeholders and for vehicle owners who will shoulder the costs

・Formulate business model drafts enabling sustainable use of in-transit power supply systems

【Final goals】(At the end of fiscal year FY2022)

<Development theme 1>

・Achieve over 70% rated output for all combinations for equipment interoperability

・Establish Foreign Object Detection method

<Development theme 2>

・Develop the dynamic WPT demonstration system, and achieve 90% power transmission efficiency for 30 kW power supply for vehicles going 60 km/h

<Development theme 3>

・Implement estimate for costs and effects for scenarios in the case of maintenance in limited areas such as highways, taxi pools, etc.

・Examine quantitative merits of dynamic WPT

・Examination toward implementation in society

C-③ : Drone WPT systems

Research supervisor:

Hiroshi Hamada (Area Leader and Section Chief, Grid Transformation & Integration Division, R&D Department, TEPCO Research Institute, Tokyo Electric Power Company Holdings, Inc.)

Participating organizations:

Tokyo Electric Power Company Holdings, Inc., Kyoto University, Toshiba Corporation, Toshiba Energy Systems & Solutions Corporation, Mitsubishi Electric Corporation, PRODRONE Co. Ltd., Toyohashi University of Technology, DENSO Corporation.

Related ministries and agencies:

Cabinet Secretariat, Cabinet Office, Ministry of Internal Affairs and Communications, MEXT, METI

R&D content:

As the population declines in Japan, it has become difficult to secure human resources engaging in maintenance and management of infrastructure, and therefore expectations are rising for drones, robots, etc. as an alternative method. In order to apply drones in actual fields, stabilized operation for long duration times is required and WPT systems are an important technology to support this. The research aims to develop a stationary short-range high power WPT system as well as an in-flight power supply control WPT system for drones. In addition to the developments of the highly efficient devices both for the transmitter and receiver, advanced transmission technology and equipment interference avoidance technology are the main issues for WPT systems. The receiver is also developed with the small-sized, lightweight, and high durability for installation in drones.

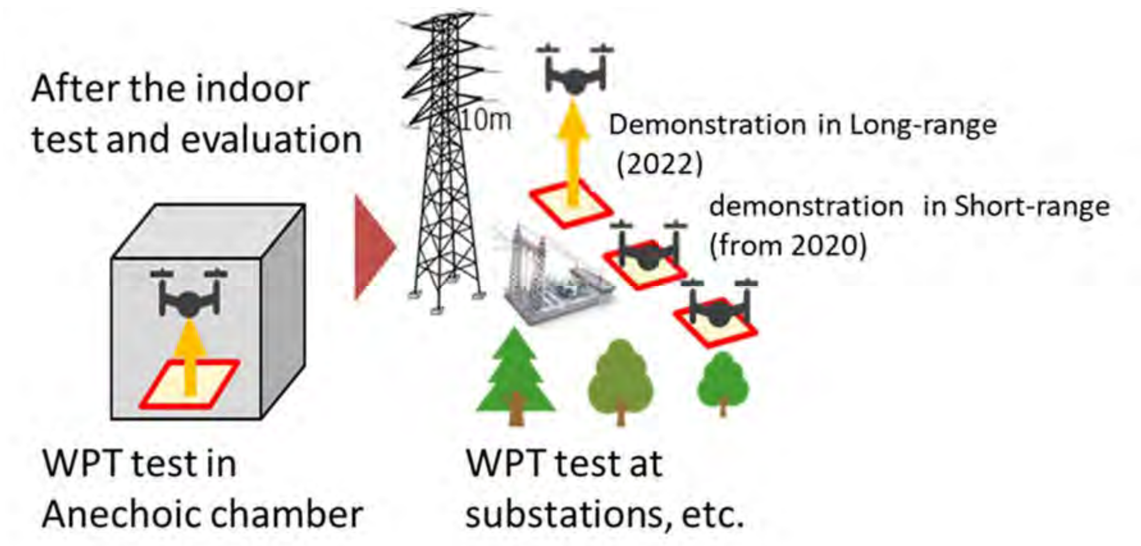


Figure 2-17 Sub-theme C-③ outline

<Development theme 1> Short-range, high power WPT systems when stationary

Participating organizations:

Tokyo Electric Power Company Holdings, Inc., Kyoto University, Toshiba Corporation, Toshiba Energy Systems & Solutions Corporation, PRODRONE Co., Ltd., Toyohashi University of Technology, DENSO Corporation.

R&D content:

Development of short-range, high power WPT systems for when drones are stationary.

<Development theme 2> In-flight long-range, power supply control WPT system

Participating organizations:

Tokyo Electric Power Company Holdings, Inc., Kyoto University、Mitsubishi Electric Corporation, PRODRONE Co., Ltd.

R&D content:

R&D and demonstration of long-range, power supply technology control for when drones are in-flight

Structure:

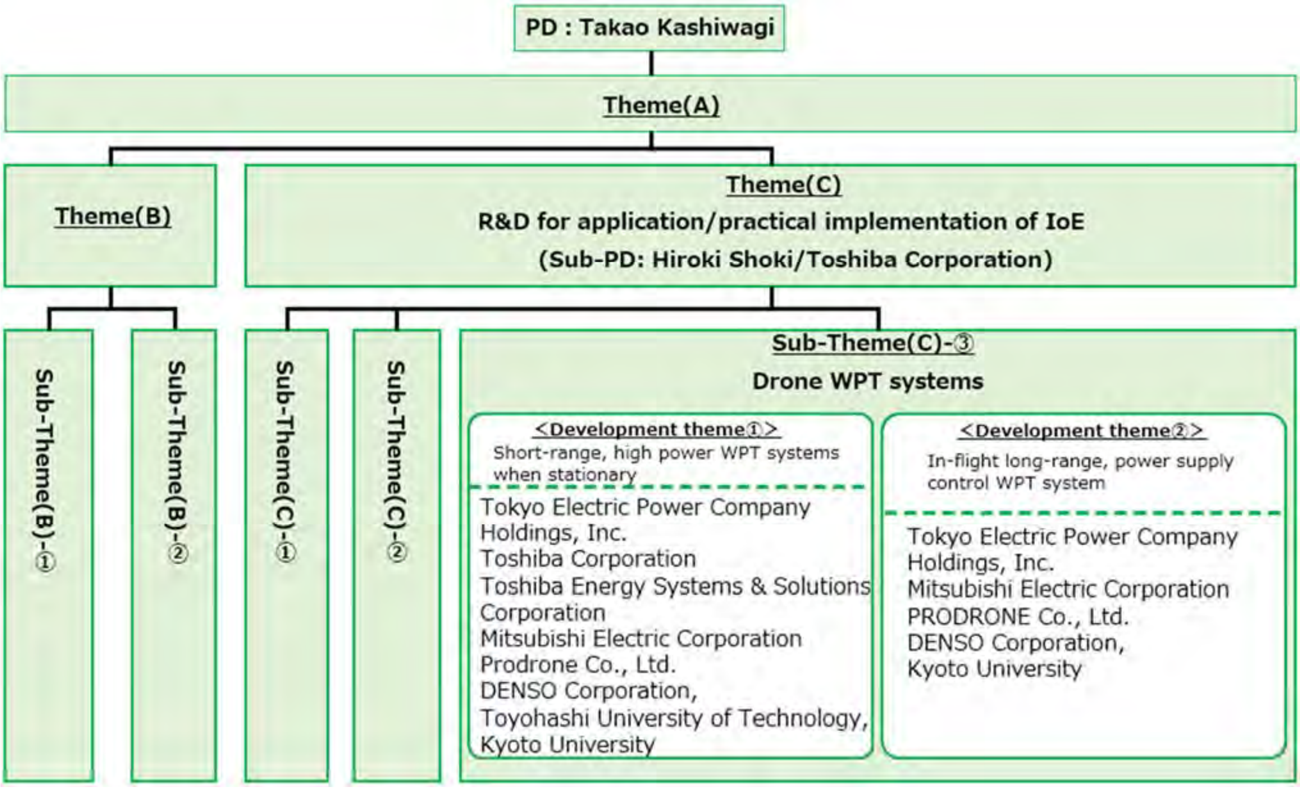


Figure 2-18 Sub-theme (C)-③ promotion system

Goals:

【Goals for the fiscal year】(At the end of fiscal year FY2019)

<Development theme 1>

・Regarding the WPT system of the electric field coupling method, examine and develop the transmitter and receiver parts at a level that could achieve the values of mid-term goals, and then complete the first prototype.

・Regarding the WPT system of the magnetic field coupling method, focusing on the mid-term and final goals, formulate the specifications for the power circuits and coils both of the transmitter and receiver and control system including the communication method for control. Then, produce the prototype for function verification. In addition, conduct implementation for part of the receiving devices for drones.

<Development theme 2>

・Regarding the WPT system of the microwave method, establish the specifications of system and interface.

【Mid-term goals】(At the end of fiscal year FY2020)

<Development theme 1>

・A drone equipped with WPT system can achieve the following procedure; (1) land on the charging port produced for demonstration, (2) charge a battery with receiving power of 360 W or more, and then (3) normally take off and fly.

・Power receiver part weight: Less than the conventional weight of other companies (2 kg or less)

・System efficiency: 75% or more.

<Development theme 2>

・Complete compatibility evaluation based on the study results of the element design technology for the receiver antenna and rectifier.

【Final goals】(At the end of fiscal year FY2022)

<Development theme 1>

・A drone equipped with WPT system can achieve the following procedure: (1) land on the charging port produced for demonstration, (2) charge a battery with receiving power of 750 W or more, and then (3) normally take off and fly.

・Power receiver part weight: 1.4 kg or less.

・System efficiency: 80% or more.

<Development theme 2>

・A drone equipped with a WPT system, in the state of demonstrating power supplying and charging in-flight, can achieve the following: supply power of about 25 W from the transmitter side and receive several W with an efficiency of about 70% at the receiver side at a transmission distance of up to dozens of cm.

3. Implementation structure

Program Director Takao Kashiwagi is in charge of compiling the R&D plans for the issues concerned among other responsibilities.

The promoting committee, with the PD serving as Chair, the Cabinet Office serving as Secretariat, and the participation of related ministries and agencies, the funding (management) agency, experts, and others, is placed in the Cabinet office, and conducts necessary adjustment for formulation, implementation, etc. of the R&D plans for the issues concerned among other activities.

The PD selects the Sub-PDs, who assist the PD regarding strategy formulation and R&D promotion. In addition, in order to promote strategies toward practical use and commercialization, the PD establishes Strategy C for obtaining details regarding industrial trends and policies.

(1) Utilization of the JST

This project is implemented with the structure shown in Figure 3-1 utilizing management expenses grants for the JST. In accordance with this R&D plan and the decisions of the PD and promoting committee, the JST conducts public appeals soliciting research supervisors, concludes contracts, manages funds, manages R&D progress implemented by the research supervisors, implements self-inspections and peer reviews from technical perspectives, publicizes and provides information on results and other matters, studies and analyzes matters related to intellectual property such as the intellectual property committee, and the employment of people necessary for supporting the execution of matters from the PD, and carries out other matters deemed necessary by the PD and Cabinet Office in order to promote matters that are taken charge of.

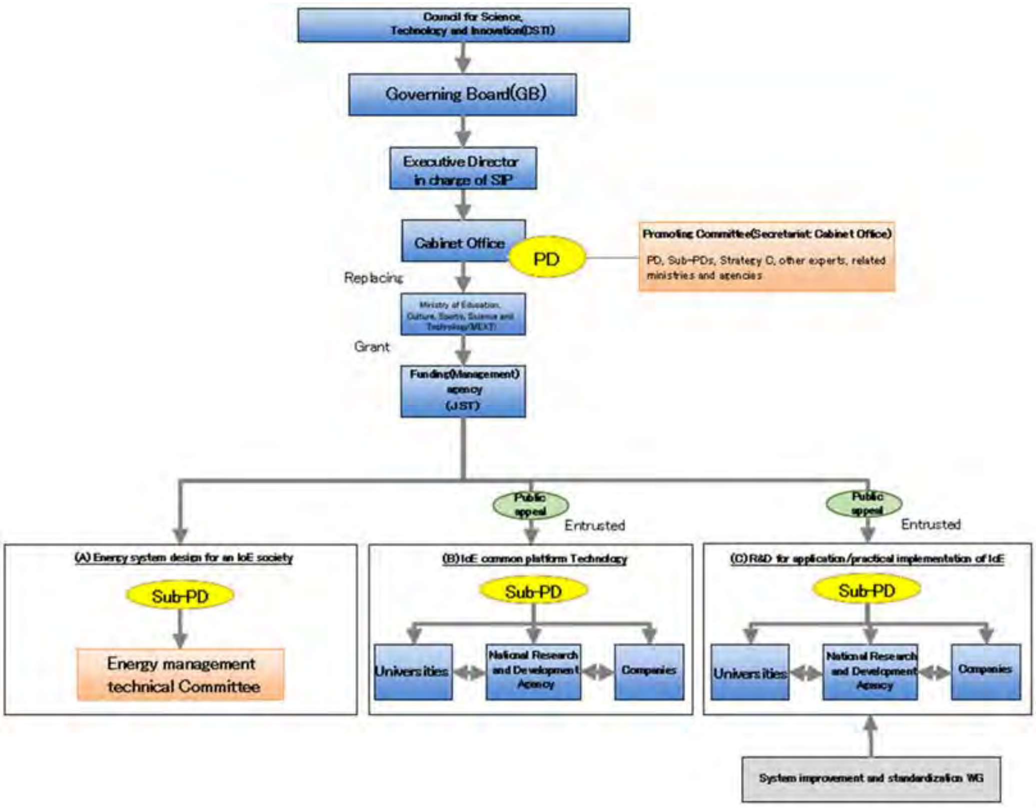


Figure 3-1 Implementation system

(2) Selection of research supervisors

Based on the R&D plan, the JST selects research supervisors via public appeals, etc. However, if there are reasonable grounds, it is possible for selection not to be through public appeals, etc. when that is specified in the R&D plan.

The JST consults with the Cabinet Office to determine the judging procedure such as judging criteria.

Stakeholders including research supervisors, people expected to conduct collaborative research of research supervisors, people expected to be commissioned work from the research supervisors (re-commissioning from the perspective of the JST), and other such people (hereafter, research supervisors, etc.) do not participate in the judging of the research supervisors concerned. The definition of stakeholders conforms with the regulations established by the JST, etc., and the PD consults with the Cabinet Office to change them if necessary.
The selection results are decided with the approval of the PD and the Cabinet Office.
After the research supervisors are decided after public appeals, etc., this R&D plan is revised with the research supervisor names, etc.

(3) Optimization schemes for the research structure

Centered on the Sub-PDs in charge, the sectional committee composed of related ministries and agencies, universities, national research and development agencies, companies, etc., is established within the JST, and promotes the R&D results.
Furthermore, in order to implement the R&D results in society, in addition to development of separate component technologies, in accordance with the states of progress of research tasks and changes in societal conditions, it is necessary to respond by flexibly changing the research systems. Thus, the Sub-PDs and Strategy C consider changing, supplementing, eliminating, etc. suitable research tasks in consultation with the PD and others while considering external views such as of the Governing Board.
In addition, schemes to optimize the research systems for various tasks are as follows.

Theme (A): Design an energy system for an IoE society

Establish the Energy Management Technical Committee composed of related ministries and agencies, universities, national research and development agencies, companies, etc. in the JST, and implement study, analysis, etc. as necessary.

Theme (B): IoE common platform technology

With cooperation among industry, academia, and the government, we will construct a consortium-type R&D system in collaboration with business operators and universities, with the goal of implementation in society. After the completion of the project, swift practical utilization will be realized in industrial machines, EVs, and home appliances, mainly by business operators.

Theme (C): R&D for application/practical implementation of IoE

Leads to promotion and practical use with cooperation between related ministries and agencies and others. It also implements efforts toward standardization including international standardization. In regard to development of long-range, highly efficient, high power WPT system technologies, R&D is conducted centered on academia, and demonstrations are carried out centered on industry. There is close cooperation in order to swiftly conduct comprehensive mediation for academia and industry. In addition, the system improvement and standardization WG will be established, a system will be built toward implementation in society, and consideration will be conducted toward extracting and resolving issues.

(4) Cooperation with ministries and agencies

There is cooperation with related ministries and agencies for each theme (referencing R&D content).

(5) Contributions from industry

Contributions (including personnel and in-kind contributions) from industry going forward are expected to be about 20-35% of the total R&D cost (total of contributions from the government and industry).

4. Items concerning intellectual property

(1) Intellectual Property Committee

○Establish the intellectual property committee within the JST.

○In addition to deciding on the policies for applications, maintenance, etc. of paper presentations, patents, etc. (hereafter, “intellectual property rights”) concerning R&D results shouldered by the established organizations, as well as other activities, the intellectual property committee conducts adjustment, etc. concerning license agreements for intellectual property rights as necessary.

○The intellectual property committee is in principle composed of the PD or the PD’s proxy, the main people concerned, experts, and others.

○The detailed management methods, etc. of the intellectual property committee are determined by the JST.

(2) Agreements concerning intellectual property

○The JST determines handling, etc. of confidentiality, background intellectual property rights (intellectual property rights held by the research supervisors, their affiliated institutions, etc. prior to participating in the program, and intellectual property rights acquired regardless of SIP costs after participation in the program), and foreground intellectual property rights (intellectual property rights occurring from the SIP project costs during the program) in advance in contracts, etc. with commissioned parties.

(3) Licenses for background intellectual property rights

○License agreements for background intellectual property rights for other program participants can be licensed by the intellectual property holders in accordance with the conditions determined by the intellectual property rights holders or the agreement between program participants.

○In cases in which the response to intellectual property rights holders such as for corresponding conditions could impede SIP’s promotion (including not only R&D but also practical use and commercialization of the results), there is adjustment by the intellectual property committee and a rational solution is acquired.

(4) Handling of foreground intellectual property rights

○Foreground intellectual property rights are in principle in accordance with Article 19, Paragraph 1 of the Industrial Technology Enhancement Act, and belong to the research supervisors' affiliated institutions (commissioned parties) who are the inventers.

○When intellectual property rights are made to belong to recommissioned parties, etc. when the recommissioned parties invent something, consent is required from the intellectual property committee. For this, the intellectual property committee can add conditions.

○In the case of insufficient motivation for commercialization by intellectual property rights holders, the intellectual property committee will recommend possession of intellectual property rights and establishing licensing rights for people who actively aim for commercialization.

○In regard to people who withdraw from the program during the period of participation, it is possible for the JST to cause uncompensated transfer or establishment of licensing rights at the time of withdrawal for all or part of results (all of the results from the start of participation in the case of participation over multiple years) acquired through SIP project costs during the corresponding period of participation.

○The costs incurred for application, maintaining, etc. of intellectual property rights are in principle borne by the intellectual property rights holder. In the case of joint applications, the share ratio and cost burden will be decided by consultation among the joint applicants.

(5) Licenses of foreground intellectual property rights

○It is possible for intellectual property rights holders to consent to licenses of foreground intellectual property rights to other program participants, in accordance with conditions determined by the intellectual property rights holder or an agreement between the program participants.

○It is possible for intellectual property rights holders to consent to licenses of foreground intellectual property rights to third parties, in accordance with conditions determined by the intellectual property rights holders within the scope of this not providing more advantageous conditions compared to program participants.

○In the case of concerns that the response of intellectual property rights holders for corresponding conditions, etc. could impede promotion of SIP (including not only R&D but also practical use and commercialization of results), there is adjustment by the intellectual property committee and a rational solution is acquired.

(6) Transfer of foreground intellectual property rights, and establishment and approval for transfer of exclusive rights

○Based on Article 17, Paragraph 1 (iv) of the Industrial Technology Enhancement Act, regarding transfer of foreground intellectual property rights as well as establishment and approval for transfer of exclusive rights, excluding cases of transfers due to mergers or divisions, cases of transfer of intellectual property rights to subsidiaries or parent companies or establishment or transfer of exclusive rights, and other cases (hereafter, "cases such as transfer of intellectual property rights accompanying mergers, etc."), the approval of the JST is required.

○In cases such as of transfers of intellectual property rights accompanying mergers, etc., the approval of the JST is required based on the contract between the intellectual property rights holder and the JST.

○Even after the transfer, etc. of intellectual property rights accompanying mergers, etc., it is possible for the JST to hold the license with sub-license rights for applicable intellectual property rights. In the case that the applicable conditions are not accepted, the transfer will not be approved.

(7) Handling of intellectual property rights at time of expiration

○When the R&D ends, there will be discussions on the response in the intellectual property committee (renunciation or succession by the JST) for intellectual property rights, etc. which no one wants to hold.

(8) Participation in organizations outside Japan (foreign-registered companies, universities, researchers, etc.)

○In the case that participation by related foreign institutions, etc. is necessary for promoting issues, then participation is possible.

○From the perspective of proper execution control, in principle the point of contact for paperwork concerning R&D commission, etc. and proxies will be located in Japan.

○In regard to foreign institutions, etc., intellectual property rights will be shared by the JST and the foreign institution, etc.

5. Items concerning evaluation

(1) Evaluation subjects

Referring to the report on the results of the self-inspections conducted by the PD, the JST, and others and the peer reviews, the Governing Board will invite external experts, etc. For this, the Governing Board can hold this for each field or subject.

(2) Implementation period

○Advance evaluations, evaluations at the end of each fiscal year, and final evaluations will be conducted.

○After the end, following the passage of a certain amount of time (three years in principle), tracking evaluation will be conducted if necessary.

○In addition to the above, it is possible to conduct evaluations during the fiscal year, etc. as necessary.

(3) Evaluation items and evaluation standards

Based on the National Guidelines for Evaluating Government Funded R&D (December 21, 2016, decision of the Prime Minister), from the perspective of evaluating necessity, efficiency, validity, etc., the evaluation items and evaluation standards shall be as follows. The evaluation does not end with simply judging whether the goals have been achieved or not, but also propose analysis and improvement measures for the origins, causes, etc.

a) Importance of significance, and integrity with the goals of the SIP.

b) Validity of the goals (especially outcome goals), and the level of achievement for the work schedule toward achieving the goals.

c) Whether appropriate management is being carried out. In particular, how results of cooperation with ministries and agencies are being shown.

d) Strategy and level of achievement of practical use and commercialization.

e) For final evaluations, the anticipated goals and ripple effects. Have the follow-up methods, etc. for after the project been appropriately and clearly set.

f) Status of achievement of the requirements* set for subject examination.

g) Status of achievement of Technology Readiness Levels (TRL) for each subject research theme.

*Subject requirements

① Aiming to realize Society 5.0.

② Placing importance on fields necessary for the productivity revolution.

③ Rather than simply R&D, bringing about changes in society.

④ Important fields for resolving social issues and for Japan's economy and industrial competitive strength

⑤ Clear exit strategies toward commercialization, practical use, and implementation in society (clear content for commercialization five years later, etc.)

⑥ Having exit goals for system aspects of intellectual property strategies, international standardization, regulatory reform, etc.

⑦ Being cross-sectoral initiatives necessitating cooperation of ministries and agencies.

⑧ Comprehensive R&D focusing on commercialization and practical use from basic research.

⑨ Promotion by setting "cooperation areas" and clearly distinguishing them from "competitive areas" (having an open/close strategy).

⑩ Building industry-academia-government cooperative systems, and participating companies having built-in components for structure and matching funds leading to practical use and commercialization of the R&D results.

(4) Reflection method for evaluation results

○The advance evaluations will be carried out regarding the plan for from the next fiscal year, and be reflected in the plans from the next fiscal year.

○The evaluations at the end of each fiscal year will narrow down or add subjects and research themes as necessary.

○The evaluations at the end of the fiscal year will be carried out regarding the achievements through the corresponding fiscal year, the plans from the next fiscal year, etc., and be reflected in the plans from the next fiscal year, etc.

○The final evaluations will be carried out regarding the achievements through the final fiscal year, and be reflected in the follow-up, etc. after the project.

○The tracking evaluations will be held regarding practical use and commercialization progress for results of the various subjects, and propose improvement measures, etc.

(5) Announcement of results

○The evaluation results will in principle be announced.

○The Governing Board that carries out the evaluations will also handle confidential R&D information, etc., and will keep it confidential.

(6) Self-inspection

○Self-inspections by research supervisors, self-inspections by the PD, and self-inspections utilizing peer reviews from technical perspectives by the JST and others will be implemented, and the results will be reported to the Governing Board.

① Self-inspection by research supervisors

The PD will select the research supervisors who carry out the self-inspection (in principle, selection of the main researchers and institutions for each research item).

The selected research supervisors will apply the evaluation items and evaluation standards from 5.(3), conduction inspection regarding both the achievements following the previous evaluation and the future plan, and include not only judgment of what was achieved and not achieved, but also analysis of the origin, causes, etc. and improvement measures, etc.

② Self-inspection by the PD

While viewing the results of the self-inspections by the research supervisors and referencing the views of third parties and experts as necessary, the PD will apply the evaluation items and evaluation standards of 5.(3), conduct inspection regarding both the achievements of the PD himself or herself, the JST, and research supervisors as well as the future plan, and incorporate not only judgment of what was achieved and not achieved, but also analysis of the origin, causes, etc. and improvement measures, etc. Together with deciding the pros and cons for continuing the research of each research entity, etc. with the results, the PD will provide necessary advice to the research supervisors, etc. Through this, it is a system enabling autonomous improvement.

Based on these results, the PD will draw up materials for the Governing Board with the support of the JST.

③ Self-inspection by implementation agency

The self-inspection by the JST will be carried out regarding whether the administrative procedures were suitably implemented for executing the budget, etc.

6. Exit strategies

Toward the implementation in society of this field of "energy systems of an IoE society," it is important to specify concrete exit strategies by clarifying the bottlenecks for realizing each separate subject as shown below. Amidst strong cooperation with SIP themes of other ministries and agencies and in other fields (such as "disaster prevention and reduction," "health and medical care," "distribution," "automated driving," "security," and other fields), inherent synergy will be created, making it possible to quickly achieve realization of Society 5.0 around the world.

(1) Exit-oriented research promotion

Theme (A): Design an energy system for an IoE society

Grasp the situation of initiatives by ministries and agencies concerning innovative energy systems, conduct interviews with information system architecture designers, and work on the design of an IoE society concerning fusion of energy networks and transportation management including various energy conversion, storage, and transport technologies. Connect this to demonstration of district energy systems enabling implementation in society in accordance with energy and transportation regional characteristics.

Theme (B): IoE common platform technology

With industry-academia-government cooperation and focusing on exits for implementation in society, construct a consortium-type R&D system in collaboration with business operators and universities, and, after completion of the SIP project period, connect this to swift practical use in renewable energy, industrial machinery, EVs, consumer electronics, etc. fields centered on businesses.

Theme (C): R&D for application/practical implementation of IoE

Within the SIP project period, implement demonstration tests including for highly-safe, highly-efficient indoor wireless power supply technology in environments where there are people, etc., in-transit power supply technology for EVs, outdoor wireless power supply for drones, etc., and have this lead to practical use and implementation in society.

After SIP has finished, together with commercialization centered on the participating companies, based on the R&D results, while cooperating with the industry-academia-government consortium, municipalities, etc., implement initiatives toward formulating technical standards and international standardization.

(2) Policies for spreading

Theme (A): Design an energy system for an IoE society

Based on the demonstration tests of the energy systems worked on by the various ministries, agencies, and municipal governments, denote the guidelines concerning district energy system designs leading to economically feasible solutions to regional social issues. In addition, implement work toward creating rules on data linkage enabling realization of sector coupling.

Theme (B): IoE common platform technology

Leverage Japan's mastery of component technologies, and implement initiatives toward formulating technical standards and international standards through validity demonstrations and establishment of technologies of USPM ahead of the world.

Theme (C): R&D for application/practical implementation of IoE

Based on the R&D results, while cooperating with the consortium with industry-academia-government participation, municipal governments, etc., implement initiatives toward formulating technical standards and international standards.

7. Other important items

(1) Basic laws, etc.

This project is implemented based on Article 4, Paragraph 3 (vii)(3) of the Cabinet Office Establishment Act (Act no. 89 of 1999), the Basic Policy on Costs for Science, Technology, and Innovation Promotion (revised on February 27, 2019, Council for Science, Technology and Innovation), the implementation plan (March 29, 2018, Council for Science, Technology and Innovation) for the 2nd period (part of the FY2017 supplementary budget) of the SIP, and the Guidelines for the Cross-ministerial Strategic Innovation Promotion Program (revised on March 28, 2019, Council for Science, Technology and Innovation Governing Board).

(2) Flexible plan amendments

From the perspective of having the fastest, optimized results, this plan will be reviewed according to the circumstances. Furthermore, based on the indicated items of the Governing Board on February 28, 2019, the name of this subject was changed from “energy systems toward a decarbonized society” to “energy systems of an IoE society,” and the systems and plan were greatly reviewed. In addition, accompanying this, it was decided to withdraw the former Theme (C) Innovative technologies for low-emission carbon use.

(3) Background of the PD and personnel

<u>Takao Kashiwagi (from April 2018)</u>

Distinguished Professor and Professor Emeritus, Tokyo Tech

Chairman, Advanced Cogeneration and Energy Utilization Center JAPAN

②Counselors in charge（Officers）

Shizuko Ota
（April 2018 – July 2019）

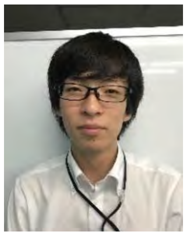
Eiichi Umekita
（April 2018 – July 2019）

Tetsuya Takazawa
（From July 2019）

③ In charge

Tamaki Matsubara
（April-December 2018）

Hiroki Kikuchi
（April-May 2018）



Shinnosuke Kojima
（June 2018 – May 2019）

Hideki Yamasaki
（From January 2019）

Attachment: Funding plan and estimates (unit: 1,000 yen)

FY2018 total: 2,500,000

（Breakdown）

1. Research costs, etc. (including general management costs and indirect costs)	**2,305,000**
（Breakdown for each R&D item）	
（Ａ） Energy management	**49,000**
（Ｂ） WPT systems	**1,333,000**
（Ｃ） Innovative technologies for low-emission carbon use	**528,000**
（Ｄ） Universal smart power module (USPM)	**395,000**
2. Project promotion costs (personnel costs, evaluation costs, meeting costs, etc.)	**195,000**
Total	**2,500,000**

FY2019 total: 1,370,000

（Breakdown）

1. Research costs, etc. (including general management costs and indirect costs)	**1,310,000**
（Breakdown for each R&D item）	
（A） Design an energy system for an IoE society	**40,000**
（B） IoE common platform technology	**817,000**
（C） R&D for application/practical implementation of IoE	**453,000**
2. Project promotion costs (personnel costs, evaluation costs, meeting costs, etc.)	**60,000**
Total	**1,370,000**