Building a Circular Economy for EV Batteries

The Japan Research Institute, Limited

1. Expansion of Battery Market in the EV Era

(1)Global EV Trend

In 2009, Mitsubishi Motors launched "i-MiEV" as the world's first mass-produced EV, and in 2010, Nissan Motor Co., Ltd., also a Japanese company, launched "leaf", which led to the introduction of EVs in the general market. Although the spread of EVs was expected due to their high environmental friendliness, since EVs have lower profit margins than gasoline-powered vehicles, movements of major manufacturers on a global scale have not been active since then, and they did not spread until the mid-2010s.

China was the first country in the world to popularize EVs. Beginning in 2010, China introduced the so-called "10 cities 1000 EVs" policy, which resulted in the introduction of the system in cities across the country. Since 2013, China has provided large-scale subsidies to promote introducing of EVs among a large number of people, including ordinary households. In addition to subsidies, the government is also promoting the development of an environment for the spread of EVs by implementing preferential policies for EVs and other vehicles under license plate regulations and policies to support the development of charging infrastructure. By combining these policies, China accounted for the majority of EV sales in the world in 2018.

In response to the expansion of EVs in the Chinese market, Chinese automakers have been active in the production of new-energy vehicles, and from around 2019, European and American brands, which place particular emphasis on the Chinese market, began to gradually shift to EVs. For example, Volkswagen of Germany declared the production of 22 million EVs by 2028, and 40% of new car sales will be EV by 2030. By 2025, GM of the U.S. will produce all 30 typies of EV, and all new cars will be EV or PHV by 2035. Volvo of Sweden, which is affiliated with Jili Motor, is the most aggressive, and it says that 50% of new cars will be EV by 2025 and 100% by 2030. In this way, each manufacturer is now in a position to set specific numerical targets.

Figure 1: Target of EV introduction in each country

Produced by JRI base on various sources

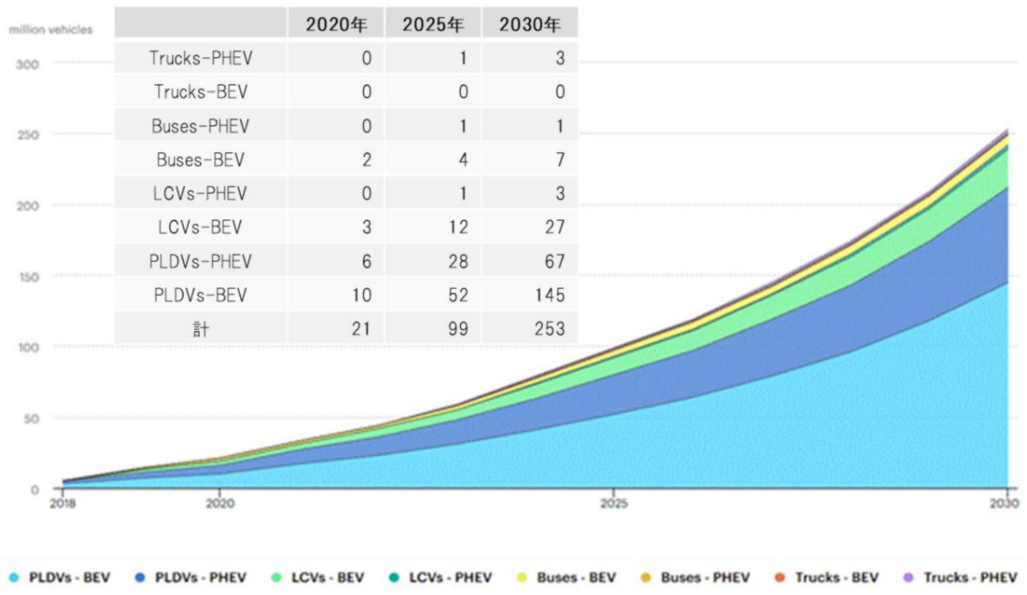
In 2020, European governments began setting targets for the proportion of electric vehicles in their domestic markets. Germany and UK have declared policies of banning the sale of gasoline-powered vehicles (Including diesel vehicles. hereinafter the same) by 2030, Germany will ban the sale of PHVs in 2030 and UK will ban the sale of PHVs in 2035. France will ban the sale of gasoline vehicles in 2040. Norway has the most avant-garde goal, banning the sale of PHVs as well as gasoline-powered vehicles by 2025. Such numerical targets were set by European countries around 2015, but at that time, there were no actual EVs to be sold, so the feasibility of such targets was being tested from the beginning. The target seems to be realistic to a certain extent, partly because manufacturers are making progress in dealing with the problem.

In October 2020, the China Society of Automotive Engineers presented a "Roadmap for New Energy Vehicle Technology" outlining the outlook for future targets in China until 2035. According to the roadmap, hybrid vehicles will be 50% in 2035, and the remaining 50% will be EV or PHV, so it is planned that there will be no gasoline-powered vehicles. The ratio of EVs to PHVs in China is currently around 4: 1, and it is expected that the ratio will remain at this level or increase further in the future.

Based on the policies of the governments of China and European countries as well as the moves of major manufacturers, the IEA (International Energy Agency) has indicated that it expects the spread of new-energy vehicles. According to the report, EVs are expected to increase greatly in the 2020s, and the number of EVs in operation as of 2020 was about 12 million, but will increase to 179 million by 2030.

China is the driving force behind such EV growth, followed by Europe. This picture will remain unchanged throughout the 2020s, and trends in the Chinese market will be important in shaping the EV-related market.

Figure 2: Estimated Number of EVs Introduced in the World



	2020年	2025年	2030年
Trucks-PHEV	0	1	3
Trucks-BEV	0	0	0
Buses-PHEV	0	1	1
Buses-BEV	2	4	7
LCVs-PHEV	0	1	3
LCVs-BEV	3	12	27
PLDVs-PHEV	6	28	67
PLDVs-BEV	10	52	145
計	21	99	253

IEA " Global EV Outlook 2020 "

In 2030, if 179 million EVs run as predicted by the IEA, assuming a replacement period of 5 years, 36 million EVs will be sold globally every year.

On the other hand, new car sales in China are estimated to increase from around 26 million at present to around 30 million in 2030 (Although there is a possibility of further growth, the figure of 30 million units, which is highly feasible, is assumed here.). As mentioned above, 50% of automobile sales are new energy vehicle and 80% of them are EVs, so the number of EVs sold in 2030 will be 12 million. The Chinese market is expected to account for about 1/3 of total global EV sales. Although it will be lower than the current 50%, the Chinese market will be the driving force of EV sales throughout the 2020s.

(2)Large Amount of Used Batteries

As EVs spread on a large scale, the size of on-board batteries will also increase. Major battery manufacturers have been investing heavily in production expansion over the past few years, including CATL, the world's largest manufacturer, which has said it will increase its production capacity from 36 GWh to 115 GWh. It is also expected that the scale of the EV market will expand further in the 2020s.

Some EVs are used as used cars several times before being disposed of after certain period of time. Therefore, when EV is dismantled after disposal, the on-board battery is removed from the vehicle body and becomes a used battery. In the future, automotive batteries are expected to be used in a life cycle that is different from the product life of EVs themselves, as evidenced by the ongoing trend of electric vehicle separation and BaaS mainly in China.

Here, I would like to summarize the capacity scale of the in-vehicle battery that is separated from the EV body and reused. Despite some progress in BaaS, the scale as of 2030 is estimated using a simple model. The capacity scale of reusable batteries is obtained by multiplying the number of used batteries by the capacity per used battery.

First, the number of used batteries. Assuming a simple model (The period until disposal is the same as the replacement period: 5 years, from 2020 to 2030, the market grows linearly), the number of EVs discarded in 2025 is estimated to be 2.52 million globally, 1.36 million in China, and 19.25 million globally and 6.68 million in China 2030.

Next, the capacity per used battery. It is estimated that the capacity of batteries in EVs will become polarized in the future. That is to say, while the battery installed in the vehicles of the category where the cruising range such as the premium brand is required becomes larger, the battery of the vehicles specialized in the driving in the region becomes smaller. At present, batteries with capacity of approximately 40 kWh per EV are installed, but larger batteries will be installed with a capacity of approximately 80 kWh, while smaller batteries will be installed with a capacity of less than 10 kWh. Therefore, the average value is assumed to be 40 kWh. In addition, it is assumed that the storage capacity of a used battery is reduced by about 20% from new battery, and is about 32 kWh per battery.

Based on the above, the estimated capacity of automotive batteries for reuse in 2025 was 80.6 GWh globally and 43.5 GWh in China, and in 2030 it was 616.3 GWh globally and 213.8 GWh in China. Assuming that the market size is 50,000 yen per kWh, the market size in China alone is about 10 trillion yen.

Reusable batteries are especially expected to be used as ESS, and they are expected to last for about five years after being used. Based on this assumption, the cumulative reused battery capacity in 2030 was estimated to be 1742.4 GWh globally and 643.2 GWh in China. This means that China alone has the capacity of about 60 nuclear power plants, when calculated as the power supply capacity when discharging electricity simultaneously from EVs.

There are two types of onboard batteries: lithium-iron phosphate batteries and ternary lithium-ion batteries. In the future, as the ratio of ternary batteries increases, they will be segregated according to the attributes of EVs to be mounted, and it is assumed that both will coexist. The ternary system contains a large amount of rare metals, so there is a tendency to recycle it. However, it is considered reasonable to reuse it in ESS, etc. in any case, if economic value in the life cycle is sought.

Figure 3: Trends in the Size of Reused EV Batteries

EV Sales Volume (10,000unit)

	2020年	2025年	2030年
World	252	1926	3600
China	136	668	1200

Discarded 5 years ago

EV discardes Volume (10,000unit)

	2020年	2025年	2030年
World	60	252	1926
China	33	136	668

×32kWh

Capacity scale of reuse Bettery(GWh)

	2020年	2025年	2030年
World	19.2	80.64	616.32
China	10.6	43.52	213.76

Cumulation of 5 years

Cumulative scale of reuse Bettery(GWh)

	2020年	2025年	2030年
World	—	249.6	1742.4
China	—	135.2	643.2

Produced by JRI based on various materials

2. Reuse and Recycle of EV Batteries

(1)Trends in EV Battery Reuse and Recycly

According to statistics from Chinese industry associations, in 2018 and 2019 China's waste batteries accounted for 6.2 GWh and 15.33 GWh. Before 2016, manyEV used lithium-iron phosphate batteries because of large-scale of buses and distribution vehicles. In the initial stage, most of the reused batteries are lithium-iron phosphate batteries, but the number of ternary lithium-ion batteries will increase in the future.

Since 2009, the Chinese government has been advocating the establishment of system to collect and reuse of batteries, while promoting the dissemination of EV. In 2016, Chinese government announced a policy to expand production responsibility, fully implement the construction of a system for reusing electric vehicle batteries, and clarify the recycling responsibility of automobile manufacturers. Furthermore, in May 2018, Ministry of Industry and Information Technology and other government agencies announced the "Notice of model project for Reuse and Recycle of EV battery", which led to the start of model projects for the collection and reuse of EV battery nationalwide mainly led by local governments.

Since May 2018, 18 areas including Beijing, Tianjin, Hebei Province, Guangdong Province, Shenzhen City, Zhejiang Province, Ganso Province, Jiangsu Province, Henan Province, Hubei Province, Qinghai Province, Fujian Province, Jiangxi Province, Anhui Province, and Shanxi Province have been selected as model project areas.

These regions have developed regional versions of "Implementation plan of model project for Reuse and Recycle of EV battery" and are demonstrating technology and business models in such areas as waste battery collection networks, cascade utilization, and dismantling and recycling, as well as fostering representative companies.

The characteristics of the model project in each region are based on the characteristics of the region or the characteristics of the representative company in the region.

For example, in Beijing, Tianjin, and Hebei provinces, 21 model projects proposed by 18 recycling companies were approved. Of these, three were for collection networks, nine for reuse, three for disassembly, and one for recycling. It can be seen from the fact that reuse is common. A well-balanced selection of recovery networks, reuse, dismantling, and recycling businesses was made.

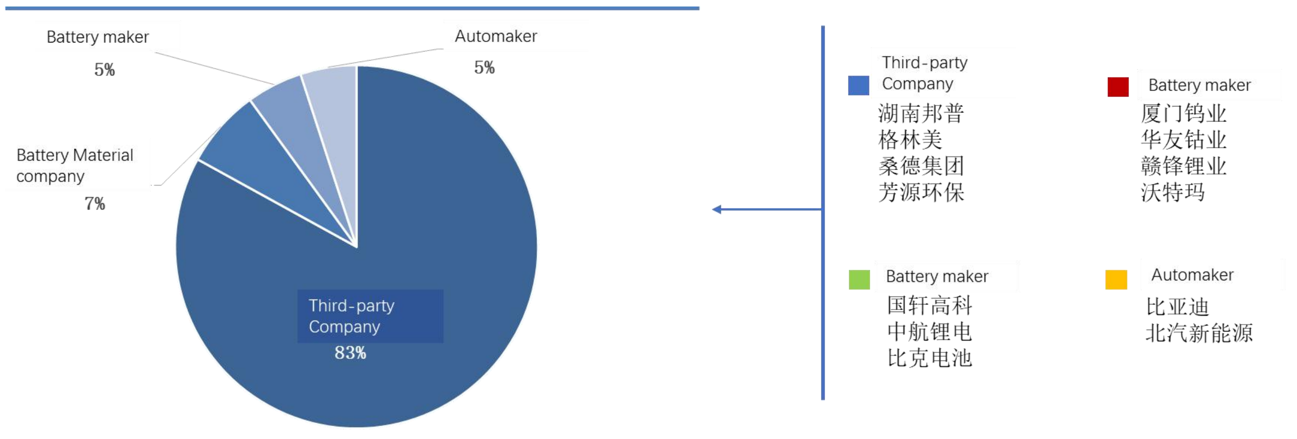
In Hunan province, many recycling businesses were chosen because the main businesses are material recovery companies. Of the 45 model projects that have been approved, 16 have been established as collection networks, 10 have been reused, 15 have been recycled, and 10 have been established as other standards. It is characterized by many recovery network construction and recycling business.

In Zhejiang Province, battery manufacturer and energy storage company are involved in a model project, so the project focusing on the construction of a recovery network and reuse was approved.

The companies involved in the model project are mainly manufacturers of AUTOMAKERS, battery manufacturers, battery material manufacturers, and other third-party companies that collect and reuse batteries. In September 2018, Ministry of Industry and Information Technology announced the "Industry Standard Conditions for Comprehensive Use of Waste Batteries fromEV". Five companies, Cobalt Industry Co., Ltd., Goho Technology Co., Ltd., Kyokurin Bei Co., Ltd., Boppu Circulation Co., Ltd., and Koka Technology Co., Ltd., were selected to fit the these standards. In January 2021, additional 22 companies were selected to fit these standards. In addition, there are many other companies that have been recognized as model enterprises by local governments. On November 12, 2020, the number of companies involved in the reuse of EV batteries in China reached 235, and the number of new companies entering the business has been increasing year by year. It is characterized by a large number of SMEs.

According to the report of EV tanks, an EV related think tank in China, main players involved in the reuse of EV batteries are as following. Currently, main competitors in the reuse/recycle battery market are third-party companies that collect and reuse batteries, with combined share of more than 80% in 2019. In the future, the standards for EV battery reuse policy will be improved, and the competitive advantage of major companies will become clearer, and the degree of industry concentration will be further improved.

Chart 4: Market share of recyclers in China



EV Tank report

The leading third party reuse/recycle companies are Bangpu Circulation Co., Ltd. and Gelinmei Co., Ltd.

Founded in 2005 and headquartered in Foshan, Guangdong Province, the company specializes in battery recycling and vehicle dismantling. There are production bases in Guangdong Province and Hunan Province. CATL became the largest shareholder in October 2016. The processing capacity of the ternary battery is 20,000 tons per year, and the annual production capacity of the business of producing the precursor of the ternary battery from recycled materials is 15000 tons. There are 100 waste battery collection centers in china, and they have formed strategic cooperative relations with domestic and overseas finished car manufacturers to carry out cascade utilization and recycling of new-energy vehicles and power batteries.

Gelinmei, established in 2001 and listed on the Shenzhen Stock Exchange in 2010, is a leading company in the field of waste management and resource recycling in China. The company says it has established cooperative battery collection relationships with more than 180 automakers and battery manufacturers around the world over a series of lifecycle value chains with "Recovery of batteries, remanufacturing of raw materials, remanufacturing of materials, remanufacturing of battery packs, and provision of services forEV". In recent years, the company has been involved in the development of technologies for the recycling of electronic waste, waste vehicles, and storage batteries, has acquired more than 220 patents, and is involved in the development of more than 70 national and industry technical standards. It has an annual EV storage battery processing capacity of 100,000 tons, and can recover waste batteries and waste materials from battery companies to produce 20,000 tons of battery materials, and 8000 tons of nickel sulfate and electrolytic copper annually. In 20 cities in Japan, 20,000 battery recovery centers have been constructed. It is also capable of producing 200 reusable packs per day, and in partnership with BYD, has built 4 solar power generation facilities that make use of reusable batteries.

In recent years, through the implementation of model projects, a nationwide waste battery collection network has been established, and technical capabilities for reuse and recycling have been improved, and the recycling industry of EV batteries in China has made progress. However, the industry as a whole still faces the following challenges.

- The amount collection volume is much less than the amount volume of dispose. Illegal collection and recycling is exist, and it is difficult for authorized collection company to collect batteries due to the problem of profitability.

- There are various types of batteries and the compatibility of recycling treatment is low. Therefore, the amount of battery that can be reused and the reuse rate of lithium are low.
- Although standards and technologies related to reuse and recycling have been developed, there are still insufficient technologies to improve the standard level, evaluation technologies, and efficiency.
- Reduction of costs, control of secondary pollution, and improvement of recycling rate are issues in the process of recovery, reuse, and recycling.
- Exception of large companies operating in all industrial chains from upstream to downstream, companies have a single profit model and tend to depend on the selling price of metals in the market, which affects business stability.

(2)Reuse System As Social Infrastructure

① Establishment of legal regulations and standards

Since 2009, the government departments such as Ministry of Commerce, Ministry of Industry and Information Technology have formulated various policies to promote the use ofEV.

- In the "Energy Conservation and New Energy Vehicle Industry Development Plan (2012 – 2020)" announced by the State Council in July 2012, EV battery Reuse and recycle management methods will be established, and the development of EV battery Reuse and recycle management methods will be submitted to promote the development of specialized battery recovery companies.
- In January, 2016, 5 divisions including the engineering department announced "Technology Policy for Reuse and recycle of EV Batteries". In the Reuse and recycle of batteries, the basic principle was shown that the use of cascade utilization was given priority, and the recycling was applied when cascade utilization was not available.
- In February 2016, Ministry of Industry and Information Technology established the "Temporary management method for new energy vehicle waste battery starting use industry standard" and the "Standard conditions for new energy vehicle waste storage and integrated use industry" to regulate the EV bettery recycling industry.
- In December, the Ministry of Environmental Protection announced "Waste battery pollution prevention technology policy". This paper presents the requirements for pollution prevention of all processes of waste battery classification, collection, transportation, Reuse and recycle, storage and disposal, and technical guidance for environmental management and pollution prevention of waste battery.
- In the "Proposal for promotion of manufacture responsibility expansion system" announced by the State Council in January 2017, it was announced that the producer responsibility expansion system and collection and Reuse and recycle system of EV batteries would be fully promoted, and that AUTOMAKERS, battery companies, cascade utilization companies, and reuse and dismantling companies would be held responsible.
- In March, 2018, the Ministry of Engineering and Communication announced "Trial point implementation plan for reuse and recycle of batteries for EV". For the first time, the company announced a plan for conducting tests on the Reuse and recycle of betteries and clarified the overall goal of recovery. In the "Guidance on strengthening the construction of green data centers" announced in February 2019 by 4 divisions including the

Engineering Department, it was clarified that cascad use battery can be an energy storage for data center based on satisfing reliability requirements.

In addition, regarding the Reuse and recycle of EV batteries, regulations and normative conditions for the entry of companies, and qualification requirements for entrants were established, and requirements related to the distribution of companies and project construction conditions, scale, facilities and technology, integrated use of resources and energy consumption, environmental protection, safety, etc. were presented.

Chart 5: Entry Management Rules and Corporate Standard Conditions for the Reuse and recycle of Lithium Battery Materials

2009.7	◆ New Energy Vehicle Manufacturing Enterprise and Product Entry Management Rules, which require that a complete sales and after-sales service management system should be established, including policies and parts recycling, and the ability to implement
2015.3	◆ The automotive power battery industry regulatory conditions, proposed that battery companies should work with automotive enterprises to study and develop an operable recycling program for the treatment and reuse of used power batteries, in order to further open access, the policy has been repealed in June 2019
2018.9	◆ The new energy vehicle waste power battery comprehensive utilization industry specification conditions", requirements from the enterprise layout, scale, equipment, process, resource utilization, energy consumption and environmental protection and other multi-perspective on the energy vehicle waste power battery comprehensive utilization enterprises have been regulated to strengthen industry management and recycling supervision
2018.9	◆ Announced the first batch of "comprehensive utilization of new energy vehicle waste power battery industry specification conditions" enterprise list
2020.1	◆ The New Energy Vehicle Waste Power Battery Comprehensive Utilization Industry Specification Conditions (2019), which clearly explain and principle requirements for new energy battery enterprises in terms of layout and project location, technical equipment and processes, comprehensive utilization of resources and energy consumption, environmental protection requirements, product quality and vocational education, as well as safety production, personal health and social responsibility

Produced By JRI based on public information

Chart 6: Standard System for Recovery and Utilization of Lithium Battery Materials

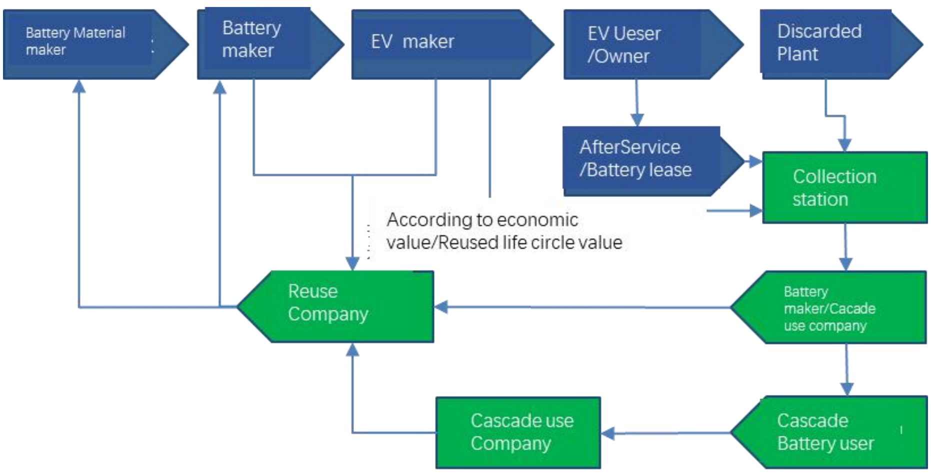
2010. 10	◆ GB/T 33059-2016 Treatment of lithium-ion battery material waste recycling by the National Standards Committee
2017. 5	◆ GeneralAdministration of Quality Supervision, Inspection and Quarantine, National Standards Committee "GB/T 33598-2017 vehicle power battery recycling dismantling specifications
2017.7	General Administration of Quality Supervision, Inspection and Quarantine, National Standards Committee ◆ GB/T34014-2017 Automotive Power Battery Coding Rules ◆ GB/T34015-2017 Power Battery Recycling for Vehicles - Residual Energy Testing ◆ GB/T34013-2017 Power Battery Product Specification Dimensions for Electric Vehicles
2019.3	◆ GB/T 37281-2019 Technical Specification for Waste Lead-Acid Battery Recycling
2019.3	◆ National Automotive Standardization Technical Committee "Automotive Power Battery Recycling Cascade Utilization Product Marking

Produced By JRI based on public information

② market building

As described below, the company is trying to establish a nationwide EV battery reuse and recycle system through the model project starting from 2018.

Figure 7: Lithium Battery Reuse and recycle System



EV Tank Report

③ Development of high-quality Technologies

As mentioned above, the reuse and recycle market for EV batteries in China will continue to expand. In recent years, through the implementation of model projects, technological progress has been made in the cascade utilization and recycling. However, in order to process large-scale batteries efficiently and with less environmental impact, the technological level of the entire industry must be raised.

For reuse, there are no standards for evaluating the safety of batteries, evaluating the remaining amount of waste batteries. Moreover, technologies for measuring the remaining amount of batteries and evaluating residual value are not yet mature. For example, companies currently engaged in reuse business often evaluate reusable batteries based on their own standards and promise the condition of the batteries in a contract with customer. Improvement of these standards and development of diagnostic techniques are required.

Second, we need to increase the automation rate across the industry. For example, there is no standard for EV batteries, and each manufacturer has its own shape and size. Therefore, in the case of reuse, although automated equipment is available, it cannot be applied to all batteries, and the dismantling of battery packs and modules is still often performed manually. There is a need for technology that reduces the safety, efficiency and environmental burden of such work.

For recycle, precious metals have traditionally been removed by wet treatment technology, but this has a high environmental burden and low extraction efficiency. Technologies with low environmental impact and high metal extraction rate are required in the future.

(3)Safety and Reliability Required

EV betteries are made of precious metals such as nickel and cobalt, as well as toxic and harmful substances such as electrolytes and organic solvents, which pose risk of environmental pollution. In order to effectively reuse the battery, it does not discharge completely and the voltage is high, so there is a high risk of electric shock or explosion during transportation, storage and reuse.

Currently, it is said that most of the discarded batteries are handled by small and medium-sized companies. According to an estimate by a Chinese automobile-related research institute, the amount of waste batteries collected through formal compaonies in China was only about 10% in 2019. Most of batteries were collected and disassembled, disposed of by small and medium-sized companies, which are poorly managed, low-cost manual processes. There is a high risk of environmental pollution due to illegal dumping of waste fluids during dismantling.

In May 2020, more than two tons of lead acid batteries were found in a car accident in Xiamen. The aim is to transport the batteries to other cities for sale.

In 2021, a fire broke out by aluminum foil at storage area where EV batteries are dismantled and discarded at Hunan Provincial Circulation Technology Corporation, which causing casualties.

In order to solve the above problems, the government has been making efforts since 2019 to establish industry standards for reuse and a trace system for EV batteries. In particular, it is said that establishing standards for rapid measurement and evaluation of reuse-related residual values is important. In the reuse of EV betteries, it is considered essential to establish regulations and technologies concerning environmental safety, such as avoiding environmental risks and preventing pollution.

3. Functions Required for the Circular Economy of EV Batteries

(1)Social Trends in Circular Economy of EV Batteries

Currently, attention is focused on the realization of a circular economy that properly promotes the reuse and recycling of EV batteries. Reuse and recycling of resources can solve the problems of safety, resource depletion and CO2 emission reduction that we face today.

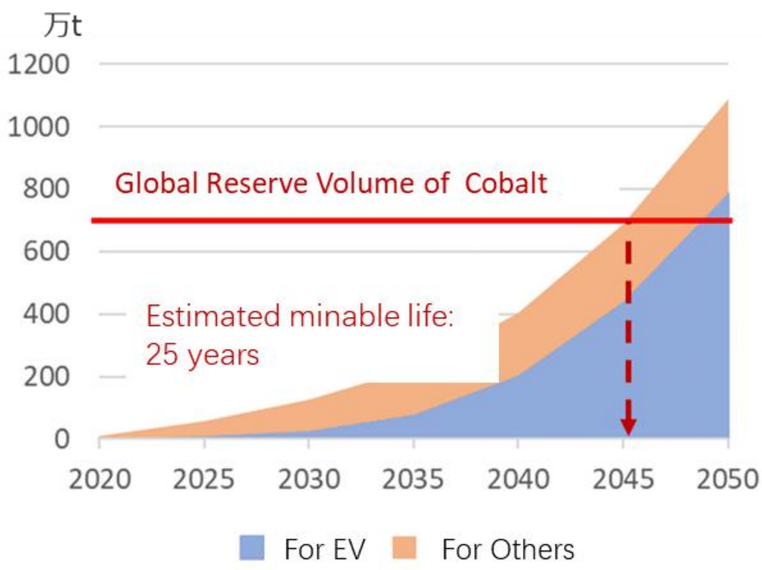
As mentioned in the previous section, the social issues of EVs include ensuring safety and reducing social burdens such as illegal dumping. At present, batteries are installed in the product, and charge/discharge and safety are controlled by the battery control system (BMS), but if batteries are removed from the vehicle and used, there is no means to ensure safety. Therefore, it is necessary to improve the usage environment and to establish and manage an appropriate control system according to the usage of the battery.

In addition, if a large battery is illegally dumped, the carbonate ester, which is a dangerous substance contained in the battery, mainly leaks out of an organic electrolyte. Illegal dumping is caused by improper management of recycling.

As a means to solve these problems, the circular economy is to realize an economically viable battery circulation mechanism.

The second viewpoint is the depletion of resources such as rare metals. With the rapid growth of the EV market, in 2030 the world will consume more than 1 million tons of cobalt per year. In 20 years, the number is expected to increase 25 times. At present, the maximum amount of cobalt resources that can be mined is said to be 7 million tons. Considering the expansion of the EV market, in the 2040s, there will be a crisis of resource depletion, and issues such as rising resource prices will arise. Although the development of cobalt-free batteries is progressing, they will not be released on the market until 2030, and the price will inevitably rise. In order to cope with this situation, circular economy is to recycle resources.

Chart 8: Prediction of cobalt mining trends



Compiled by the Japan Research Institute from the U.S. Geological Survey (2017) and EV Projections, etc.

The third is the viewpoint of CO2 emission reduction. If batteries are reused for a long time and recycled to minimize the extraction of new resources, CO_2 emissions from resource extraction and battery manufacturing can be minimized. In other words, products that are easy to reuse and recycle will be differentiated from products that emit less CO_2 in the future. This will make recycling easier. By establishing a system that actively recycles resources, we can also contribute to the reduction of CO_2 emissions. Benz announced zero-carbon requirement for all parts it procures from 2030s. Products that do not emit CO_2 are expected to become essential requirements for the sale of products after 2030 from the view point of differentiatio . We expect Early realization of circular economy.

From this perspective, the European Commission announced a new battery management rule in December 2020 to create a circular economy for EV batteries. These include important items such as CO_2 emissions at each stage of the battery life cycle, from manufacturing to reuse and recycling, carbon footprints such as certificates from third-party verification organizations, and specification of the amount of recycled materials used. The earliest of these items is scheduled to take effect in 2024. As a result of these regulations, companies that do business with EU countries are now required to manufacture batteries on the assumption that they will be reused or recycled, for example, by indicating the ratio of recycled materials in batteries and ensuring traceability. In the past, it was difficult even to secure traceability, but it is assumed that these rules have been put into practice because the recent use of the IoT has enabled not only traceability but also safety management during vehicle loading and reuse, and highly efficient recycling. In this way, EV batteries have created a new market as a product that forms circular economy.

Chart 9: EU Battery Directive (excerpt)

■In the product design, the following points are required for EV batteries and industrial rechargeable batteries (Article 7 of the draft regulations).

- Declarations of the carbon footprint, including manufacturer and factory information, total carbon dioxide (CO_2) emissions at each stage of the battery's life cycle, and independent third-party verification authority certificates (From July 1, 2024).
- Display of performance categories to facilitate identification of large and small CO_2 emissions throughout the lifecycle (From January 1, 2026).
- Implement cap values for carbon footprint throughout lifecycle (From July 1, 2027).

■For EV batteries, industrial batteries, and automotive storage batteries containing cobalt, lead, lithium, and nickel, the following points will be made mandatory (Article 8 of the same Act).

- Disclosure of the amount of recycled materials used (From January 1, 2027).
- Introduction of a minimum percentage for each type of recycled raw material (From January 1, 2030)

Materials of EU Commission

(2)Reuse Functions Required for Circular Economy of EV Batteries

The most important function in building a circular economy is to maximize the value of available assets. Maximizing the value of an effective asset means appropriately evaluating and distributing the residual value of a product as an asset and making the most effective use of it.

When an industrial product is produced, the manufacturer is responsible for ensuring the quality of the product. On the other hand, it is difficult to objectively define the value of a product that has been used for a certain period of time. Traditionally, the value of the second-hand market has been determined by the user's evaluation. In other words, the current market is an economic system in which the value of a product at the time of production is socially most easily distributed.

On the other hand, in the IoT era, the historical information and performance information of a product can represent the value of the product, and it becomes possible to secure the value and reliability not only when it is sold as an industrial product, but also when it is sold as a used product.

In this way, if the use value of a product is traded instead of the manufacturing value, the value of the carefully used product will increase or the scarcity value will be demonstrated. This will promote the effective use of non-material assets (intangible assets) as well as conventional goods. Data automatically collected by the IoT will form a new foundation of value for society. This transformation of society will change the world's material-oriented society.

In order to respond positively to such changes in the market, it is necessary to construct functions necessary for the reuse market. In other words, it will create an IoT mechanism that replaces the value of industrial products and materials with the value of data. Ensure data authenticity and define value. Data such as how much impact was applied, how many times the temperature rose above the upper limit, and, consequently, how bad the battery is, determine the value of the battery. Since the internal state of a battery cannot be grasped when it is used, reliability and performance must be evaluated by estimating the internal state. However, by collecting a large amount of such indirect data, the probability of the quality of the battery is ensured and reliability can be obtained.

(3)Reuse and Recycly Functions Required for Circular Economy of EV Batteries

Another function is to maximize the value of scarce resources. There is a high possibility that the price of rare resources will rise with the development of EVs in the future. If this is the case, the recycling of resources may proceed naturally. However, this is an optimistic scenario depending on the external environment. In general, discarded resources cannot be easily separated and recycled. This is because resources cannot be efficiently recycled without knowing where, what kinds of rare resources are contained, and to what extent. In the past, however, there was no mechanism to manage such information, so it was difficult to recycle only based on economic principles. For this reason, recycling has caused social problems through global distribution.

This externally dependent economic system may eliminate waste, but recycling will not progress. How can we promote recycling? One policy is to establish a system to ensure recycling costs at the time of manufacture and sale. In Japan, the Automobile Recycling Law was enacted in 2002 to establish a system in which users bear the costs of recycling. As a result, illegal dumping in Japan has been greatly reduced, and recycling of iron, copper and rare metals contained in catalysts has been promoted.

But it's a pre-IoT system. In the past, the cost of each distribution and processing process was high and the added value was low, which made it impossible to manage goods sufficiently. In the IoT era, traceability of goods has become possible at low cost, and it has become possible to improve the efficiency and value of distribution and processing processes according to resource information. If information on materials and appropriate separation methods can be obtained at recycling sites, the business potential of recycling will improve. In the IoT era, the value of materials can be realized by linking data such as product information.

In recent years, as the value of CO_2 emission reduction through resource recycling has been added, further economic improvement of recycling has been expected.

4. Characteristics of Circular Economy of EV Batteries

(1)EV batteries, Representative of Construction of Circular Economy

Expectations for the construction of circular economy for batteries are high. This is because common products often have the same primary and secondary uses, and their secondary use value is often greatly reduced.

However, there are many differences between primary and secondary use of EV batteries. This is because EVs are vehicles that have a need for long-distance travel, and if the distance that can be traveled on a single charge decreases, the product will not meet specifications. Generally, in the case of EV, when the remaining capacity of the battery becomes 70 ~ 80%, it is said to be replacement time. In other words, in the case of self-moving product equipped with battery, such as automobile, decrease in the ratio of the driving energy to the weight of the vehicle, that is, decrease in the energy density becomes a problem directly related to the performance. As the result, even though the residual value remains at 70 ~ 80%, it is required to be exchanged. In this way, EV batteries end their primary use while maintaining high residual value. You can't use it for the same purpose, but you can use it for a long time if you use it for other purposes, especially when it doesn't move.

The representative of the secondary utilization application is the fluctuation absorption of the renewable energy. In Japan, zero-energy houses (ZEH) and zero-energy buildings are widespread. ZEH is a type of housing in which renewable energy, such as solar power generation, can be installed to reduce net energy consumption to zero. In this case, electric water heaters such as EcoCute and storage batteries are used to adjust the imbalance between fluctuating energy such as sunlight and demand. The EcoCute system converts excess solar power into heat source for hot water supply, and stores the remaining power in storage batteries for nighttime use. Consumers tend to invest in long-term facilities for housing that will last for several 10 years. This has created a huge demand for storage batteries.

Mega solar and green hydrogen production equipment will also require large amounts of storage batteries. In order for mega solar power plants to be connected to the grid, they need to supply and demand electricity to prevent sudden voltage fluctuations caused by moving clouds from adversely affecting the grid. Green hydrogen production using photovoltaic power generation will be expanded in the future, and storage batteries are needed to reduce the influence of load fluctuation on hydrogen production equipment and to reduce the maintenance cost of hydrogen production equipment. In addition, there is a growing need for emergency power generation in preparation for future urban disasters.

Batteries will play an important role in expanding applications of renewable energy. In response to these growing needs, there is no alternative but to effectively utilize the power supply capacity equivalent to that of 60 nuclear power plants, which was mentioned in Section 1. These markets are expected to expand the renewable energy market at low cost by actively applying reusable batteries instead of introducing new batteries.

In this way, the demand for storage batteries is high in the market that will expand in both primary and secondary use, and it can be said that they are the best in the circular economy. In the future, EV batteries will be expected to be effectively used for different primary and secondary applications as a leader in the circular economy, and development of batteries suitable for every application will be expected.

(2)Ecosystem Promoting Battery Reuse

In the construction of the circular economy of EV battery, there are features which are greatly different from other electric appliances. This means that it is very dangerous to leave the battery while it is charged, and that it must always be sold, used, and transported under proper control.

This means that the battery and its management system must be used in combination at all times, not as a single object. In other words, batteries are IoT type products, and they do not exert their value by themselves, but as IoT systems. At the same time, this means that those who buy and sell batteries must take into account the connection of data and management systems, and it also suggests the necessity of sharing systems within the ecosystem. When the battery is dismantled, removed from car and transported, even a reusing company that receives and uses the battery must be able to understand the condition of the battery.

The battery cannot be completely decline to zero due to its structure. It will significantly reduce the performance of the battery. In other words, the work such as transportation and disassembly is carried out in a state of being charged to a certain degree. Depending on how much the battery is charged, what kind of temperature environment it was in during transportation, what kind of vibration it was exposed to, and so on, it affects the next task. There is a need for a dynamic IoT information coordination system that manages these kinds of creatures and ensures that the history information is passed on to the next operator. This is more than just tracing the owner of the battery. This means that the IoT ecosystem in which battery users build networks is essential for the battery recycling market.

On the other hand, there is a risk that this will close the market and create a small market in which new renewable energy providers will have difficulty participating. Thus, while the ecosystem itself is not closed, but open and free to enter and leave, it is necessary to build a platform for IoT ecosystem that enables reliable management coordination while participating in the ecosystem.

(3)Challenges in Building Circular Economy

On the other hand, if we look at the current market, the market is open, but many of them are battery manufacturers and automakers. This situation cannot be helped because the circular market has just begun, but this market, which is expected to reach 10 trillion yen in 2030, cannot operate efficiently in closed loop. An open and efficient distribution market is essential for more renewable energy providers and city managers to make effective use.

In such market, the IoT dynamic information distribution platform described in the previous section is required. The absence of such a mechanism has led to a fearful expansion of the market. In building such a system, it is important to (1) secure investments and (2) realize highly reliable operations by relevant parties.

First, the platform system involves a wide range of businesses from dismantling and distribution to reuse and recycling. Moreover, the market is still immature at this point, and only a few companies can invest in large-scale platform systems. On the other hand, it is also difficult for automakers and battery makers to implement the system. In the first place, platform operators are required to have the ability to operate the IoT market by integrating new material assets and intangible assets through integration of goods and information. Because the manufacturing industry has strengths in businesses that seek to improve the quality of goods and reduce costs, there are no human resources who can contribute to improving the value of intangible assets. In order to build a platform system for the whole China and each region, it is necessary to wait for the emergence of new service providers in cooperation with local governments.

Second, market participants can realize highly reliable operations, but the market is still immature and only a limited number of companies can conduct highly reliable operations. In order to expand and grow the market safely and efficiently in such a market, it is necessary to increase the number of business operators carrying out reliable operations and promote growth. A good way to do this is to use these platforms to communicate and visualize work quality. As information on the acceptance of batteries, disposal of batteries, and utilization of battery management systems for safety must be provided to the platform, if work quality is poor, data willl show the results to the next operator. In other words, a business operator whose work quality is low cannot make a deal. In this way, companies that do not improve quality are eliminated from the market.

In addition, it is necessary to establish a system that can detect and solve problems at early stage by checking the quality of batteries at key points of distribution. To measure the quality by SOH or something like of a battery, various techniques exist at present. Conventionally, only technique requiring 10 hours or more to measure 1 battery such as charge/discharge method has been developed, but recently technique capable of performing highly accurate diagnosis in short time has also been developed. If such technologies are used effectively, the reliability of data distribution will be greatly improved. In addition to the charge-discharge method, there are various diagnostic techniques in Japan, such as the characteristic utilization method during discharge, the analysis method using the charge-discharge curve, the AC impedance method, the statistical method, the micro-SOH method, and the CC-CV discharge method. Diagnostic techniques can be broadly divided into methods for analyzing charge/discharge characteristics and methods for measuring internal resistance. In order to utilize the charging/discharging characteristics, there are various methods such as a method of analyzing partial charging characteristics, a method of making a model of a battery by repeating charging/discharging in various patterns, and the like, instead of the conventional method of charging/discharging for 10 hours or more.

In order to confirm the quality of batteries quickly and easily, it is necessary to use diagnostic techniques that match the characteristics of each type of battery. Therefore, it is necessary to select and utilize such techniques appropriately.

5. Proposal For Creation of Circular Economy for EV Batteries

In this paper, we have shown the scale and potential of the EV battery market, which is expected to increase in the future, and the problems and the direction of the solution in forming the circular economy of the EV battery. It is pointed out that the construction of circular economy can only be realized by integrating the traditional market and industrial structure of material assets into IoT model and intangible assets, and that a dynamic information sharing platform that improves reliability is required. Therefore, we propose the following measures to establish such a system.

(1)Forming an Open Market That Does Not Closed between EV Manufacturers

First is the open market. EV batteries are expected to form a great value market for society due to the size of their residual value, the volume of supply due to the expansion of the EV market, and the rapid expansion of the market for renewable energy. These new markets greatly expand the existing used goods market and form new circular economy market. This market is large enough compared to the size of average automobile company which each automobile company takes responsibility for its disposal, it is a market that returns a large value to society that cannot be contained in a closed market.

Therefore, we propose the formation of an open market from a closed market in which automobile manufacturers and battery manufacturers engage in face-to-face transactions. We will build a data linkage platform that will enable companies such as automobile manufacturers, which are responsible for battery management, to entrust the disposal of batteries with peace of mind, and to ensure the recycling of resources toward a recycling-oriented society in the future. The platform is a data linkage system that ensures the reliability and certainty of confidential data with the involvement of local governments, and ensures the transfer of related data and battery control status to operators. Various players are expected to enter these markets in the future. It is necessary for new businesses to be able to dispose of such waste reliably.

(2)Promotion of Quality Control Methods in Cooperation With Japan

The second is cooperation with Japan in quality control and reuse/recycling methods. Japan has been developing various diagnostic technologies to control the quality of batteries. In order to utilize these diagnostic technologies and their data, it is effective to cooperate with Japanese companies that have such technologies.

There are several types of batteries, such as lithium-iron phosphate batteries and ternary batteries, and each company has its own manufacturing method and the size of the battery, so that a single diagnostic technique cannot be applied. Therefore, it is necessary to effectively utilize multiple diagnostic techniques according to the type of battery. In Japan, many diagnostic technology companies, led by the Japan Research Institute (JRI), are working together to develop utilization technologies.

In Japan, a system for detailed reuse and recycling has already been established. One such initiative is a network that uses recycled automobile parts. Although large batteries for EVs have not yet been distributed, nearly 100 companies in the fields of dismantling, reuse, recycling, and distribution cooperate to distribute and sell high-quality used automobile parts. In order to ensure the environmental friendliness of disassembly, parts are carefully removed, and if a product is damaged or faded, information is shared by taking pictures so that the point can be clearly identified. Used parts are different from new parts in that various types of deterioration have occurred. However, if it is not clear where and what kind of deterioration has occurred, recycled parts that occur over a wide area cannot be purchased through a web service. For this reason, the company ensures trust by disclosing as much deterioration information as possible that would be disadvantageous to product sales. In terms of securing trust, since improper disposal by the company selling the product will reduce trust not only in that company but also in the entire network, the company actively responds to the improvement of work quality and the sharing of ideas.

In China, it is expected that diagnostic technologies will be actively used to clarify the quality of such batteries, and a system will be established to promote the use of used batteries by clarifying the quality. However, in the distribution of used parts, it is necessary not only to distribute information, but also to improve the reliability of the companies that produce and distribute the information, and to form a market for recycling EV batteries that increases on the base of trust. IoT information management is essential for diagnosis technologies and methods to improve the reliability of such companies. It is hoped that Japan, which has a good track record in this regard, will work together to foster healthy markets.

(3)Institutional Design for Market Formation

The third is institutional design to create a healthy new market. The circular economy not only forms a market through reuse and recycling, but also serves as social infrastructure that contributes to safety, environmental value, resource conservation, and low carbon society as whole. In this sense, market formation should be promoted with appropriate government support.

Batteries in particular are dangerous goods, and if we rely only on market power, there is a concern that the number of companies that reduce costs in transportation and storage and do not manage them properly will continue to increase. In particular, in view of the future expansion of the EV market, it is necessary to actively foster and expand business operators capable of appropriate disposal. In this case, if management equipment and systems are introduced at early stage, the market will become more efficient, and new market entrants will increase in proportion to the residual value of the battery, and it is expected to develop into a large-scale market. However, it is heavy burden for companies to invest in the development of information management systems in the early stage of the market. Taking these points into consideration, it is expected that the following measures will be implemented as institutional design by the government.

① Strict penalties for illegal dumping, which causes environmental pollution, etc. and distribution management through the construction of a system to ensure its traceability. Illegal dumping, which lies behind illegal dumping, will not disappear unless the government can crack down on the illegal outflow of waste overseas and the distribution of waste on the domestic market at an unreasonably low price. This system already exists as a system, but it is expected to further improve the quality of EV batteries as a system utilizing the information cooperation system in the region.

② As in Japan, there is a method in which the purchaser of automobile purchases the automobile with the automobile recycling fee added, government manages the fee and when the automobile is dismantled and recycled, the fee is paid to each company as the recycling fee. This is based on traceability. If this can be achieved, the outflow of inappropriate waste can be avoided.

③ Subsidies, such as system installation costs, are provided to enterprises that conduct high-quality management at the beginning of the market. In addition, business licenses are granted to enterprises that have introduced IoT information management systems that enable a certain level of quality control, such as proper management of transportation, and the promotion of crackdowns on enterprises that fail to meet standards. The introduction of such a system can contribute to the development of circular markets by ensuring that the number of new entrants increases and that high-quality management can be implemented with policy funds. Such government financial assistance is required at the early stage of market formation, and if a certain number of business operators are fostered, it will be possible to operate business independently without government support in order to improve efficiency and improve business efficiency through market expansion.

Currently, several large companies have grown up and the market is in early days. However, only a few companies have introduced systems for high-quality battery management using highly reliable technologies. In this early stage of the market, new measures are needed to make it a market.

(4)Formation of New Industrial Structure Based on Recycling

Finally, we show the new mechanism created by the recycling market of EV batteries and its effectiveness. As we have seen, the battery circular economy is the starting point for formation of market that combines the intangible economy such as brand value and intellectual property rights with the material economy.

In the circular economy, the quality cannot be equalized as in the conventional monolithic product. This is because it is necessary to distribute products that are the same but have different values. Therefore, information such as the history record, characteristic analysis, and the present state of the product is combined and distributed, and the value is generated in the product meeting the needs of the user. In other words, in the circular economy, not only the value of the primary use, but also the market of the secondary use in which things and information connected to the value of various intangible assets are fused is formed.

Traditionally, products have been produced primarily for their primary use. Secondary use was only additive and a small market outside the industrial structure. However, in the case of products such as EV batteries where the value of secondary use accounts for a large part of the product value, the value of the recycling market will increase, and the product value will not be determined only by the value of primary use. For example, in the case where the battery is reused for adjusting the fluctuation of wind power generation, the battery haing high followability to the fluctuation and uniformity of charging and discharging characteristics is highly evaluated in the secondary use stage. Such batteries have high value for secondary use and are traded at high prices, resulting in phenomenon in which the value of the secondary use of the battery is included in the evaluation of the automobile when the product is manufactured. In other words, batteries will be a product of the combined market of primary use market as automobiles and secondary use market such as renewable energy. In addition, the secondary market is a market in which intangible assets, which combine goods and information and are difficult to handle in the past, are added. In this way, the automobile and renewable energy markets will create a new modular industrial structure in which IoT links multiple markets centered on core components such as batteries.

Historically, after the industrial pyramid structure developed in Detroit in the United States, which centered on conventional automobiles and other final industrial products, the industrial structure of modular ecosystem of single industry flourished, centered on Shenzhen, in the fields of home electronics, smartphones, robots, and so on. This new change in industrial structure will create a multi-industry IoT modular ecosystem centered on components that incorporate the value of intangible assets.

In China, IoT product industries such as the robot industry and smartphones have been successfully established. It is hoped that these findings will be used to the fullest extent to promote the formation of a new industrial structure for the circular economy.