JEITA

Report of Investigative Research into Green Benefits Enabled by the Utilization of IoT

-- First Report: Logistics and Agriculture --

March 2017

Green CPS/IoT Review Working Group

Green IT Committee

Japan Electronics and Information Technology Industries Association

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Introduction

The Green IT Committee of the Japan Electronics and Information Technology Industries Association (JEITA) is engaged in activities aimed at promoting the introduction of IT products (devices, solutions, and services) that help improve energy efficiencies in society as a way of fulfilling both environmental and economic needs.

Existing IT products have been put to use in specific operations, industries, and sectors, to the benefit of the environment in various ways. Meanwhile, we are beginning to see the utilization of novel technologies such as IoT and AI in recent years. Because of society's use of IoT, target areas have expanded worldwide over the Internet and a diverse range of data is being consolidated as big data. With AI, new values are being created and provided beyond the frameworks of any single industry or sector.

Based on this background, the Green IT Committee established the "Green CPS/IoT Review Working Group" in 2015 to begin assessing the various benefits that are enabled by IoT. Because IoT is expanding into a variety of areas of society, the Working Group decided to conduct its initial evaluations of the environmental benefits of IoT and did reviews specifically in the areas of agriculture and logistics between 2015 and 2016. This report is a summary of the results of these trial evaluations.

Moving forward, we expect to see the integration of big data through IoT, further advancements in the utilization of AI as well as other technologies, and ongoing growth in the scope and volume of benefits from IT products that utilize these technologies. With the aim of satisfying both environmental and economic needs, the Green IT Committee is committed to promoting the development and use of IT products that can bring benefit to society. We greatly appreciate your support and input.

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Green IT Committee
March 2017

1. From IT to IoT

Thanks to technological advancements in recent years, traditional IT solutions are evolving into solutions that utilize the "Internet of things" (IoT). While computers and other IT devices were the primary devices traditionally connected to the Internet, in IoT, electronic devices such as sensors and control devices that are widely used in manufacturing, offices, and private residents will be connected to the Internet (Fig. 1).
As a result of IoT utilization, we can now improve efficiencies and create novel values in a much wider scope of areas than with traditional IT solutions, as new solutions are being developed in a variety of areas such as manufacturing, logistics, agriculture, infrastructure, and healthcare (Fig. 2). These innovations were first coined "Industry 4.0" mainly in European countries, and discussions primarily focused on their introduction in the area of manufacturing/production. However, we believe that technological innovations such as IoT, big data, robotics, and artificial intelligence (AI) will come together as the "Fourth Industrial Revolution [1] " to the benefit of a broad swath of industry, and will not be confined to manufacturing/production alone. Additionally, from the demand side perspective, expectations have been raised for an "Ultra-Smart Society" (Society 5.0) as a future society where cyber space and physical space (the real world) are highly integrated with each other, products and services are fine-tuned to address diverse and latent needs, and both economic growth and solutions to societal issues are achieved [2].
Expectations are being raised that, as a result of this increase in the number of areas that utilize IoT, the number of areas that benefit from environmental improvements (CO_2 emissions reductions, etc.) that are enabled by IoT-based solutions (hereafter "**<u>IoT solutions</u>**") will continue to grow.

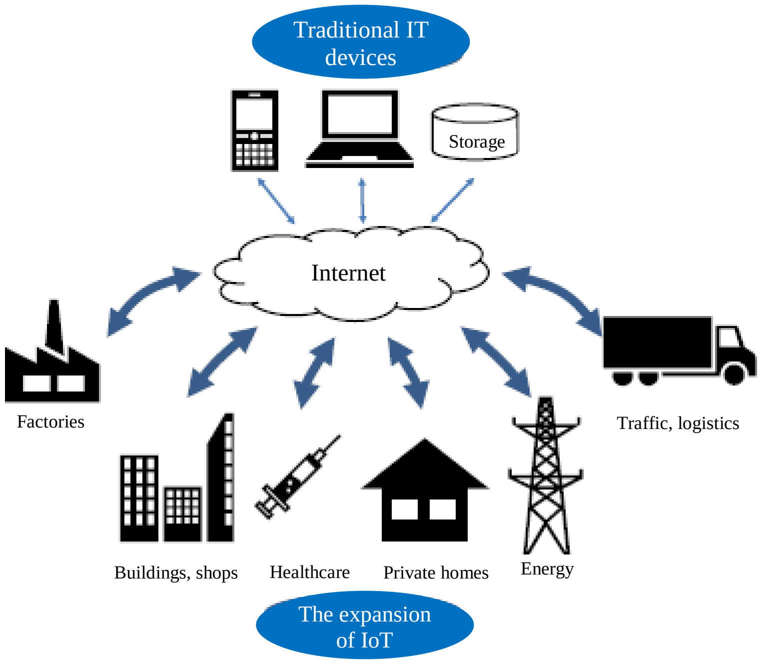

Fig. 1: "Things" are increasingly becoming connected to the Internet

[1] Vision for New Industrial Structures -- Japan's Strategy for Leading the Fourth Industrial Revolution -- Interim Summary (Ministry of Economy, Trade and Industry)
http://www.meti.go.jp/committee/sankoushin/shin_sangyoukouzou/pdf/ch_01.pdf
[2] Basic Plan for Science and Technologies for the Fifth Term (Cabinet Office)
http://www8.cao.go.jp/cstp/kihonkeikaku/index5.html

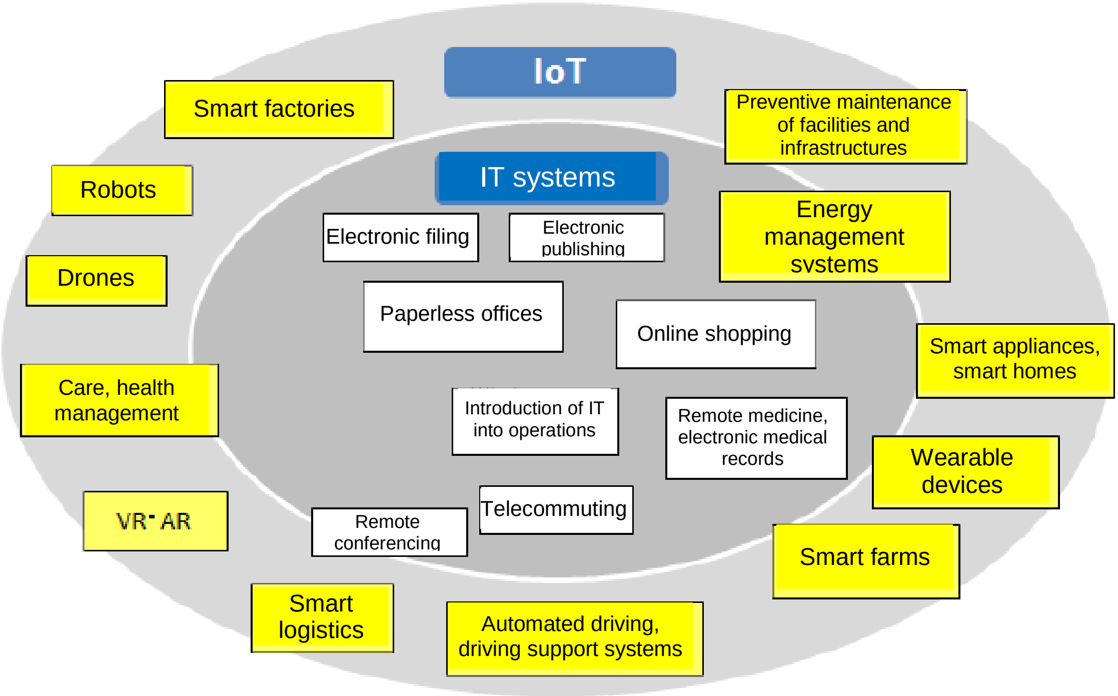

Fig. 2: Increasing number of IoT-based solutions

The former Green IT Promotion Council and JEITA Green IT Committee have reviewed the possibility of visibly representing the amounts of CO2 emissions reduced using traditional IT solutions, and believe that the introduction of IoT will lead to even more reductions and new benefits to the environment.
Through our investigations into a number of examples of IoT utilization in logistics and agriculture, we have identified, and listed in Table 1, examples from the perspective of social benefits to the environment. While these results may be achievable to some degree through traditional IT (pre-IoT), we believe that greater efficiencies can be achieved by gathering big data through IoT, and using AI and other technologies for analysis and learning to identify optimal implementations, and reflecting the optimal implementation in logistics and agriculture.

Table 1: Examples of environmental benefits achieved with the use of IoT in logistics and agriculture

(1) Energy used for transport can be reduced by using IoT to gather data on travel routes associated with transport, analyzing this data, carrying out learning and other processes, and using these results to identify optimum travel routes (to reduce travel distances, avoiding congestions, etc.).

(2) Energy used for transport can be reduced by using IoT to gather big data on the weather, analyzing this data, carrying out learning and other processes, and using these results to identify optimum travel means (modal shifts, etc.).

(3) Unneeded excesses and energy used for transport can be reduced by using IoT to gather big data on logistics and consumption, analyzing this data, carrying out learning and other processes, and using these results to improve the precision of demand forecasts.

(4) Unneeded excesses in product supply and disposal can be reduced by using IoT to gather big data on logistics and consumption, analyzing this data, carrying out learning and other processes, and using these results to improve the precision of demand forecasts. (reduction of food product spoilage)

(5) The quality of agricultural products can be made more consistent and the amounts of products that are disposed of can be reduced by using IoT to gather data on the growth of crops, analyzing this data, carrying out learning and other processes, and using these results to implement advanced management (reduction of food product spoilage).

(6) The ability to maintain the quality of transported items can be improved, and amounts of items that are disposed of can be reduced by using IoT to gather temperature data inside frozen transport vehicles, analyzing this data, carrying out learning and other processes, and using these results to implement advanced management (reduction of food product spoilage).

2. What are the Green Benefits enabled by IoT solutions?

Benefits to society enabled through the use of IoT are expected to increase in a diverse range of areas. Conceivable benefits include benefits to environmental conservation as shown in Fig. 3, improvements in comfort and satisfaction, and the mitigation of societal issues such as labor shortages.
The environment is intrinsically a far-reaching concept and appears to be gradually shifting alongside the changes in societal needs and the awareness of people. Article 1 of the Basic Environmental Law reads as follows.

> **Article 1:** The purpose of this law is to comprehensively and systematically promote policies for environmental conservation that ensure a healthy and cultured life for both the present and future generations of the nation, as well as that contribute to the welfare of mankind, through articulating the basic principles, clarifying the responsibilities of the State, local governments, corporations and citizens, and prescribing the basic policy considerations for environmental conservation.

As we reflect on IoT's possibilities based on the perspectives noted above, and given how IoT introduction is rapidly expanding, we can expect to see a variety of benefits in many areas of society. JEITA's Green IT Committee has evaluated and expressed the benefits of IT in terms of reductions in CO2 emissions. If, however, there is a possibility of ensuring a "healthy and cultured life for both the present and future generations of the nation, as well as contributing to the welfare of mankind" through the use of IoT, what are the appropriate methods for evaluating and expressing these benefits?

■ Perspectives centered around the environment

In this report, we attempt to quantify the degree of benefit to straightforward areas that can be considered within the environmental perspective, and lead to CO2 emissions reductions. In other words, the scope of this review in as far as calculating CO2 emissions reductions based on a number of examples was defined to be the area enclosed in the red box in Fig. 3 . Calculations were done using the method developed by the Green IT Promotion Council[3]. (See Table 2 below.)
Of the items enclosed in the red box, while the Green IT Promotion Council did not include the "reduction of food product spoilage" in its calculations of potential CO2 emissions reductions from IT solutions (pre-IoT), this has been included in the current calculation as significant benefits can be expected in this area through the use of IoT. (See “4. Results from Trial Evaluations of Green Benefits”.)

■ Perspectives that derive from the environmental perspective

The range of images elicited by the word "environment" appears to have expanded in recent years. Even the word "adaptation," which refers to actions in response to a variety of phenomenon that can be attributed to climate change, is occasionally discussed within the framework of the environment. Energy conservation is no longer the only proposition for the smartification of buildings and roof areas, which are increasingly being presented as a means of "smart wellness" that includes comfort and health benefits.

[3] The Green IT Promotion Council (fiscal 2008-2012) was founded under the Ministry of Economy, Trade and Industry's Green IT Initiative with a membership of seven IT related organizations. The Council carried out a variety of projects in Japan and overseas for a period of five years to promote IT and energy conservation in societies through IT.
http://home.jeita.or.jp/greenit-pc/about/index.html

We expect that these benefits can be developed even further through the use of IoT.
With regards to the benefits of IoT solutions, in this report, we explore "CO2 emission reductions" from the “environmental perspective” as our first item of review. Moving forward, we intend to gradually extend the ideas associated with the “environment” to “adaptation” and “smart wellness,” and evaluate and express these areas as "**Green Benefits**." Depending on the specifics of each area of benefit, there may be cases where these benefits may require additional methods of evaluation and expression that may not necessarily correspond with or can be converted to the equivalent of CO2 emissions. Indeed, discussions in this vein have already been raised in the process of compiling this report.
(See "4.3 What we have discovered in these trial evaluations".)

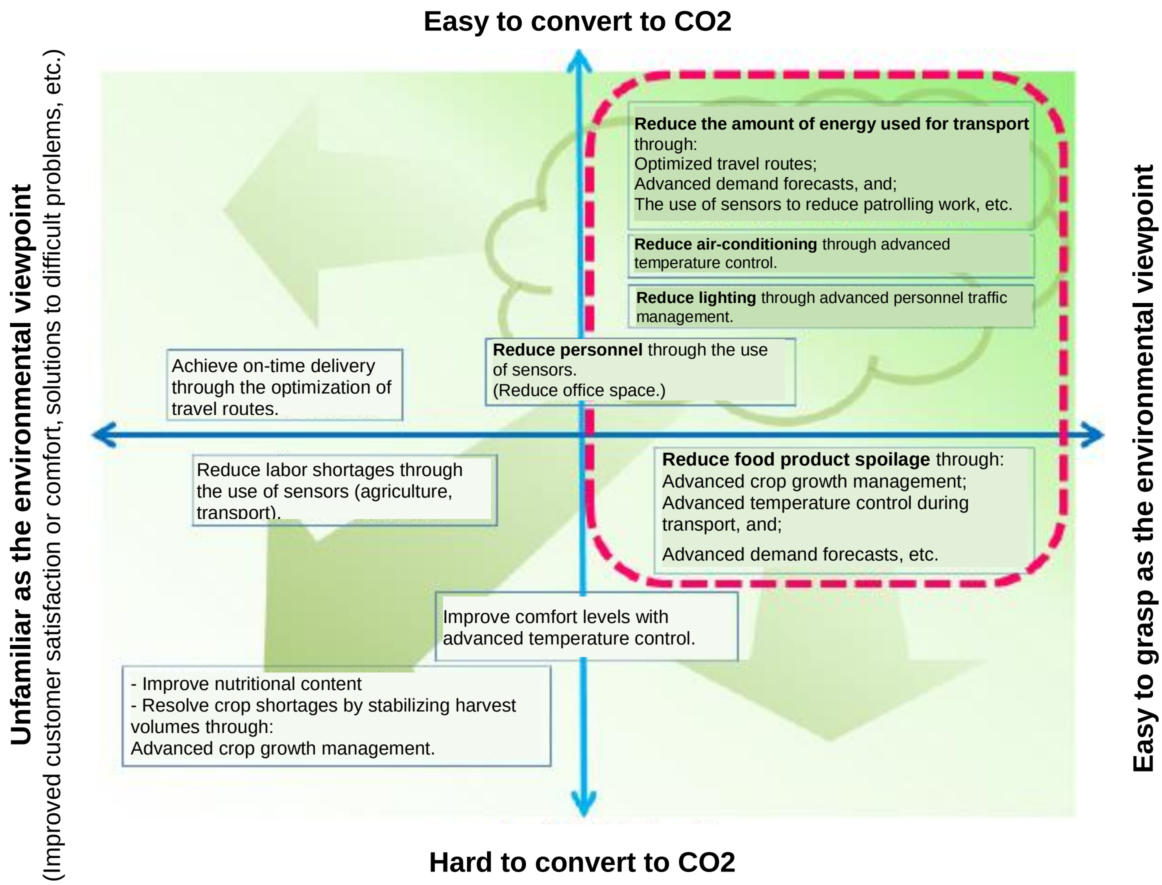

Fig. 3: Benefits enabled by IoT utilization, and areas that were reviewed for this report (in the red box)

3. Evaluation of Green Benefits enabled by IoT solutions: -- As envisioned in this report

3.1 Evaluation methods

In this report, we have calculated CO_2 emissions reductions for a number of examples of IoT solutions. Calculations were done using method developed by the Green IT Promotion Council (Table 2). Moving forward, we hope to expand our scope of evaluations of "Green Benefits" achieved through IoT solutions as shown in Fig. 3. In doing so, not all cases may be readily convertible to CO_2 emissions, but there are a number of cases where this can be done with some ingenuity, such as the "reduction of food product spoilage."

In this report, we seek to evaluate and express those that can be considered straightforward from an environmental perspective and converted into CO_2 emissions. (See 4. “Results from Trial Evaluations of Green Benefits”.)

Table 2: Components of the effects of IT solutions, and formulae for their calculation developed by the Green IT Promotion Council (fiscal 2008-2012)

Components	Component subjects	Component calculation formulae
(1) Consumption of material	Paper, CDs, books, etc.	Reduction in consumption of material x Primary unit of consumption of material
(2) Amount traveled by persons	Aircraft, automobiles, trains, etc.	Reduction in personal travel distance x Primary unit of travel
(3) Amount traveled by items	Trucks, railroad, cargo, etc.	Reduction in item travel distance x Primary unit of travel
(4) Office space	Space occupied by persons (including work efficiency), space occupied by IT equipment, etc.	Space reduction x Primary unit of energy consumption per space ** Space reduction equals the number of persons reduced multiplied by the space occupied per person, or the number of pieces of equipment reduced multiplied by the space occupied per piece of equipment.*
(5) Warehouse space	Warehouses, refrigerated warehouses, etc.	Space reduction x Primary unit of energy consumption per space
(6) Electricity and energy consumption (IT and network equipment)	Power consumed by servers, PCs, etc.	Amount of change in power consumption x Primary unit of grid power ** This applies when converting electrical power into CO_2 emissions.* ** This represents the amount of energy consumed from the use of IT equipment, and does not include energy consumed for the manufacture or disposal of such equipment.*
(7) Network data communication volume	Network data communication volume	Amount of change in data communication volume x Primary unit associated with data communication ** The amount of energy consumed for network communications includes energy consumed for Internet communications, but not intranet communications.*
(8) Other	Activities other than the above	Amount of change in activity x Primary unit of the amount of change

Source: Green IT Promotion Council, Feb. 2013, "Energy-Saving Benefits from IT Solutions for Society as a Whole -- Perspective on Evaluations of Benefits from 'Green by IT' -- Explanatory booklet"
http://home.jeita.or.jp/greenit-pc/activity/reporting/110628/pdf/survey02.pdf

3.2 Items to be included in the evaluation

Listed below are the subjects that are calculated in this report as "Green Benefits" enabled by IoT solutions.

(1) Items that represented benefits enabled by IoT solutions and were the subject of calculation for their contribution to CO_2 emissions reduction by Green IT Promotion Council were included as before.

[Ex 1] Reductions in the consumption of material

[Ex 2] Reductions in the amount traveled by persons, and other items that can be evaluated in the framework of Table 2 above.

(2) Items that represented benefits enabled by IoT solutions but <u>were not the subject of calculation for their contribution to CO_2 emissions reduction</u> by Green IT Promotion Council were included in the evaluation if one of the following applied.

[a] Is a benefit that was achieved with IT solutions (pre-IoT) and was not converted into CO_2 emissions by the former Council, but whose degree of benefit will significantly grow through the use of IoT.

[b] Is a benefit that was not conceivable with IT solutions (pre-IoT) but will be newly created through the use of IoT.

For example, items included in Table 1 "Examples of environmental benefits achieved with the use of IoT in logistics and agriculture" fall into this category.

3.3 Areas evaluated (logistics and agriculture)

3.3.1 Reasons for choosing logistics for evaluation

In order to improve the efficiency of logistics—the foundation of the country's economy and lives of its citizens—the General Outline of Logistics Initiatives of 2013-2017 pushed forward with initiatives aimed at (1) achieving efficient logistics that support industrial activities and the lives of the country's citizens, (2) further reducing environmental footprints, and (3) ensuring safety and peace of mind in logistics. Activities relating to Green Benefits ((2) further reducing environmental footprints) were also seen as important and playing a major role. Specific subjects included implementing enhancements to transport capabilities in railroad and coastal shipping, promoting modal shifts, reducing the energy consumption of trucks, ships, trains, etc., and promoting joint transportation and delivery through collaboration between cargo owners and logistics operators.

In the subsequent Outline (2018-2022), discussions included background factors that affect the area of logistics, including the declining population resulted from dwindling birthrates and an aging population; technological developments such as IoT, automated driving, and drones; further growth of the e-commerce market; growth in the Asian region; risks of earthquakes, typhoons or other disasters; and implementation of the Paris Agreement. Due to these factors, it is expected that far-reaching policy actions will be required in logistics, including productivity improvements and overseas expansion, improved robustness of logistics networks, and the formulation of environmental policies. Of these, "technological developments such as IoT, automated driving, and drones" and the "implementation of the Paris Agreement" in particular are in direct accordance with the aims of the reviews carried out by the Green CPS/IoT Review Working Group.

The logistics area was spotlighted as an example in this report as further consideration of these factors have led us to believe that Green Benefits that utilize IoT in logistics will become important moving forward for both society and policy.

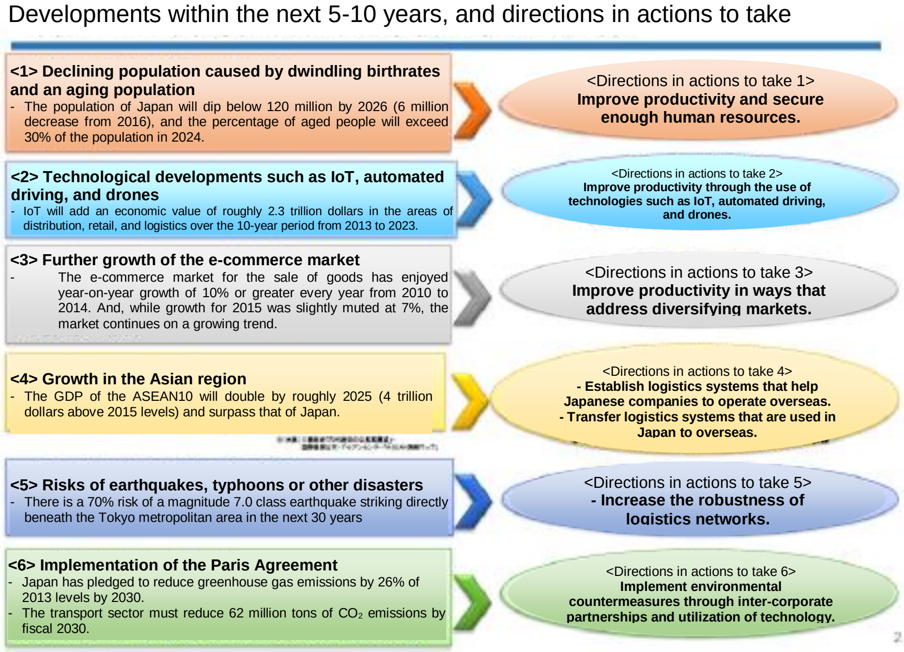

Fig. 4: Shifts in the state of affairs and key initiatives following the formulation of the current Outline of Logistics Initiatives

Source: Ministry of Land, Infrastructure, Transport and Tourism (Dec. 2016)

3.3.2 Reasons for choosing agriculture for evaluation

The utilization of IT has been ongoing in the agricultural sector for some time. Meanwhile, the "Japan Revitalization Strategy 2016 -- In Approaching the Fourth Industrial Revolution [4]" announced by the government in June 2016 cites a number of key initiatives including the "Fourth Industrial Revolution," "Overcoming environmental and energy constraints, and increasing investments," and "Proactive development of agriculture, forestry and fisheries, and strengthening their export capabilities." The strategy states the need for “making fundamental productivity improvements through the utilization of innovative technologies” and other new initiatives to enable the "Proactive development of agriculture, forestry and fisheries, and strengthening their export capabilities", and cites the promotion of IoT and big data utilization, as well as the utilization of AI (artificial intelligence) as specific initiatives.

Furthermore, the Ministry of Agriculture, Forestry and Fisheries' "Study Group on Achieving Smart Agriculture" is advancing ideas that can be enabled by the fourth industrial revolution such as ultra-labor-saving agriculture, and strategic production through extensive use of data as shown in Fig. 8. The agricultural sector was spotlighted as an example based on these factors.

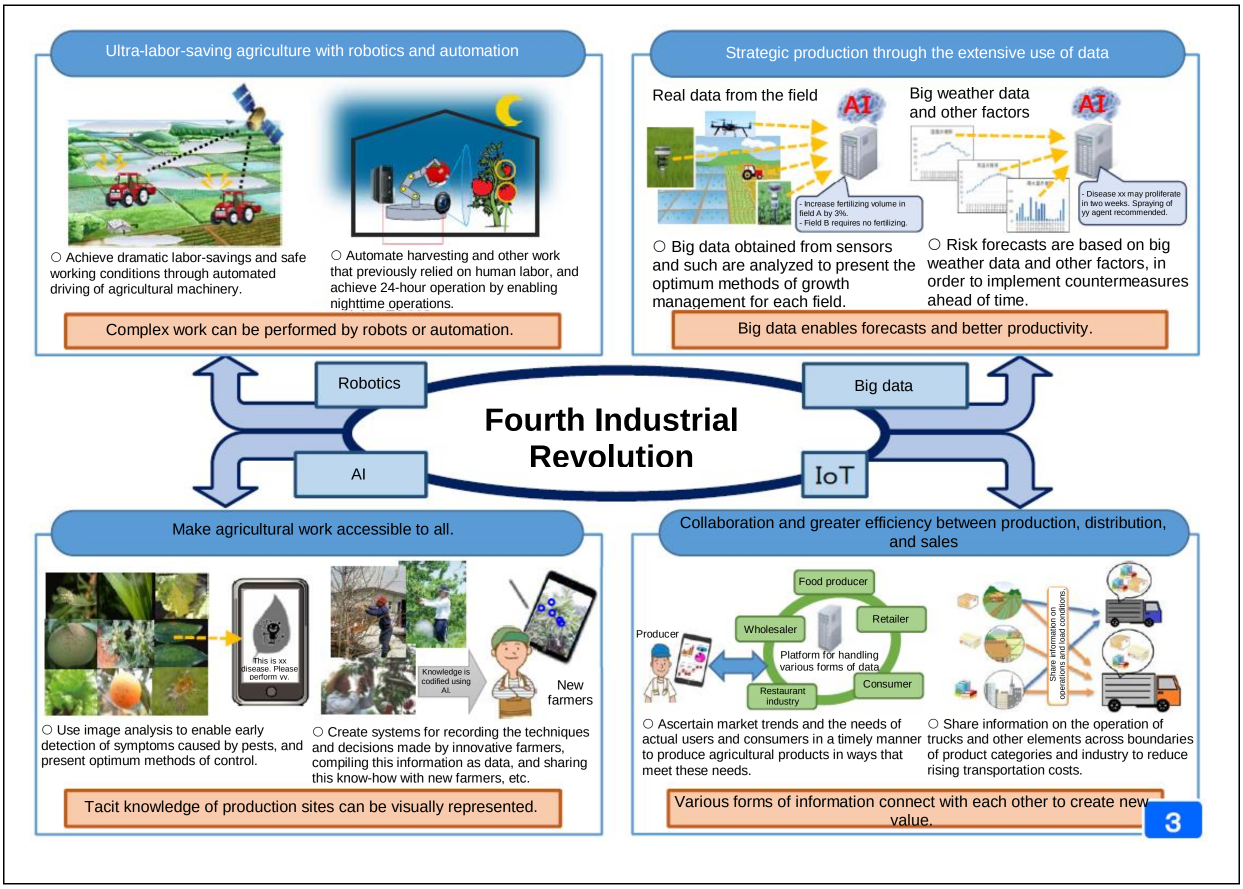

Fig. 5: Possibilities of AI and IoT utilization in agriculture (schematic)

Source: Ministry of Agriculture, Forestry and Fisheries, Fifth Study Group on Achieving Smart Agriculture (Nov. 2016)

[4] Japan Revitalization Strategy 2016 -- In Approaching the Fourth Industrial Revolution – http://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/2016_zentaihombun.pdf

4. Results from Trial Evaluations of Green Benefits -- Examples in Logistics and Agriculture --

4.1 IoT utilization in logistics

4.1.1 Status of IoT utilization

Logistics is an area where IoT utilization is expected to move forward. With the popularization of e-commerce, delivery lots have shrunk while shipment frequencies have grown. And, with the working age population shrinking, shortages of delivery truck drivers and workers at logistics depots are becoming an issue. Also considered an issue is the increase in the frequency of re-deliveries due to households having fewer members and shifting lifestyles. Moreover, owing to the growing convenience of e-commerce and other factors, requirements in the area of delivery quality, such as delivery timeframes and temperature control during delivery, are intensifying.

Given these conditions, IoT is being utilized in a broad range of areas of logistics including delivery, storage, and cargo handling (Figs. 6, 7, and 8). One area that can be cited as an example is logistics planning. Systems are now in place for monitoring truck location, operating status, and driver conditions for the purpose of truck dispatch planning, driver management, and delivery planning. Cargo is also being tracked with the use of electronic tags attached to pallets, cargo, or vehicles, and methods for visually representing cargo and workers are being employed at warehouses and depots to improve working efficiency. Warehouses and depots are also introducing automatic sorters, automatic transporters, and picking robots to save on labor and improve efficiency. Verifications are also underway on enhancing the convenience of the "last mile" by using receiving boxes that are linked up with smartphones, as well as for the practical implementation of real-time delivery services using self-driving vehicles or drones.

These various forms of IoT utilization also contribute in a number of ways to the reduction of CO2 emissions in logistics. While efforts have been underway to use IT to reduce CO2 emissions, we believe that these efforts are progressing into new approaches that utilize IoT.

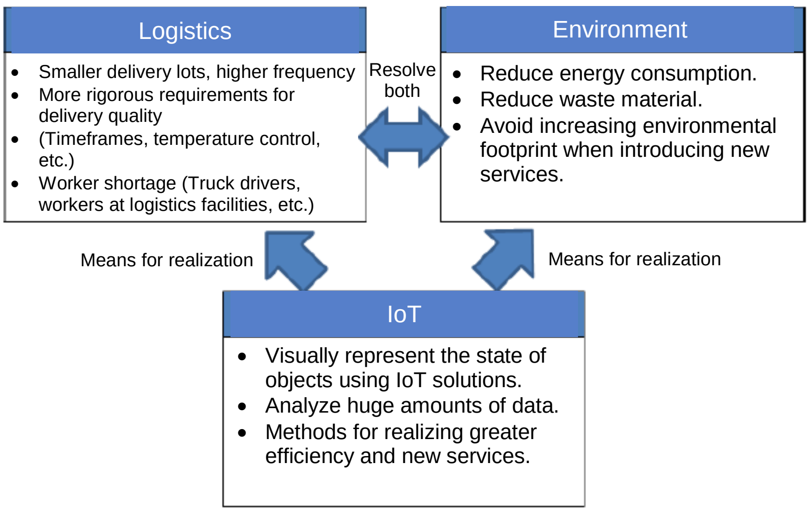

Fig. 6: Relationship between logistics, IoT, and the environment

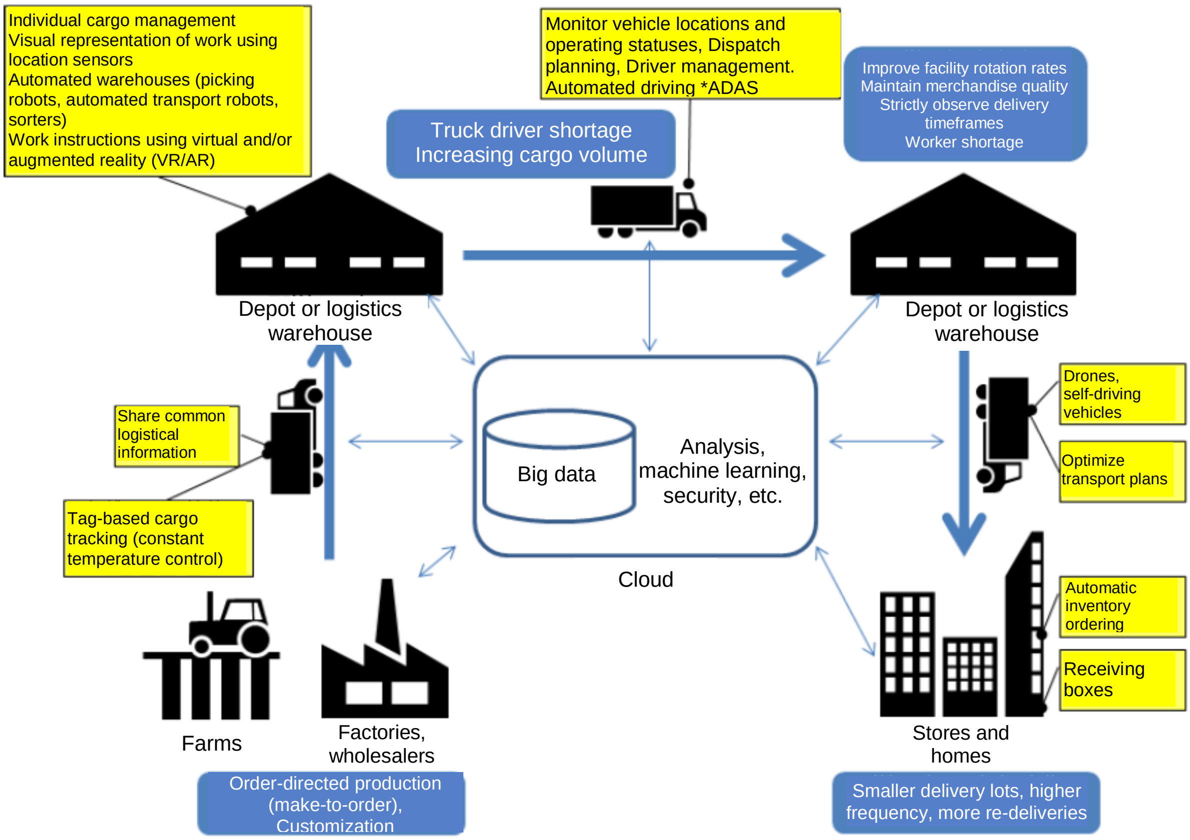

Fig. 7: Areas in logistics where IoT is being utilized

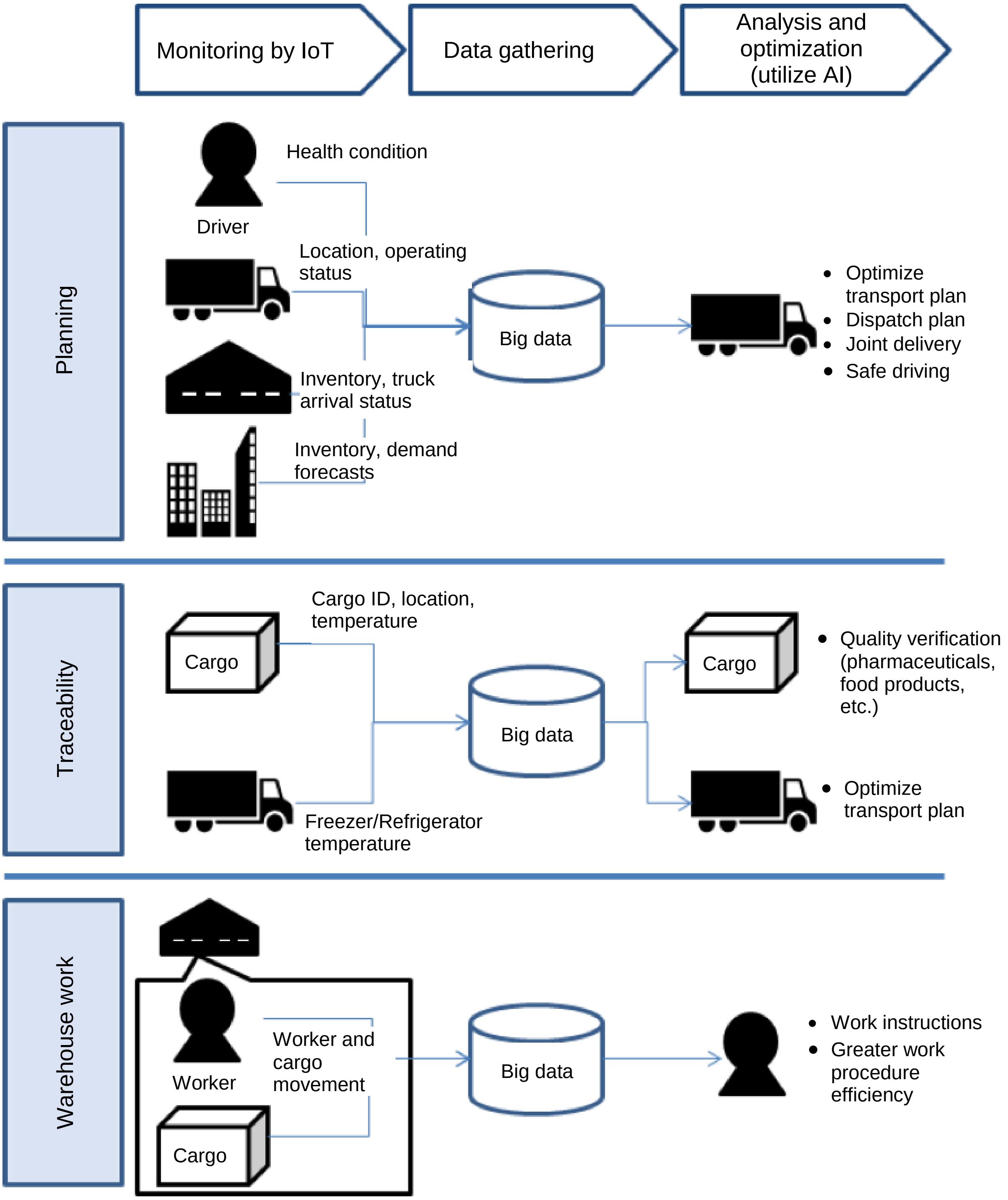

Fig. 8: Examples of utilization of big data gathered through IoT

4.1.2 Results from evaluations (trials) of specific examples

Trial evaluations were carried out for a number of examples to determine how CO2 emissions were being reduced in logistics with the utilization of IoT. Calculations for quantification were carried out using calculations developed by the Green IT Promotion Council (Table 2). The document below was also referenced for CO2 conversion indices and other values.

- Document
  "Energy-Saving Contributions to Society from IT Solutions -- Perspective on Evaluations of Contributions from 'Greening by IT' -- Explanatory Booklet"
  Green IT Promotion Council, Feb. 2013,
  http://home.jeita.or.jp/greenit-pc/activity/reporting/110628/pdf/survey02.pdf

- Calculation methods

Table 2 (re-listed from above): Components of the effects of IT solutions, and formulae for their calculation developed by the Green IT Promotion Council (fiscal 2008-2012)

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(7) Network data communication volume	Network data communication volume	Amount of change in data communication volume x Primary unit associated with data communication * *The amount of energy consumed for network communications includes energy consumed for Internet communications, but not intranet communications.*
(8) Other	Activities other than the above	Amount of change in activity x Primary unit of the amount of change

[Case 1] Forklift traffic line analysis service

■ **Overview and key points from an IoT perspective**

- Forklift location information acquired by autonomous locating devices (sensors), IMES, and cameras are analyzed in the cloud to achieve work optimization and improve operations.
  - Optimize warehouse entry and exit routes, and determine better inventory locations.
  - Utilize basic data for reviewing logistics center layout and optimum number of forklifts.
- Key points from an IoT perspective
  - Gather and capture detailed traffic line data through locational corrections made by autonomous locating devices (sensors) and cameras.
  - Categorize work patterns by linking them with work information, thereby detecting unneeded excesses.
  - Improve efficiency of inventory locations by linking them with cargo data.

■ **Calculation of effects, and trial results:**

[Scope of calculations]

- Enumerations were hypothesized for each calculation component for the effects of implementation at one refrigerator/freezer warehouse.

[Calculation conditions]

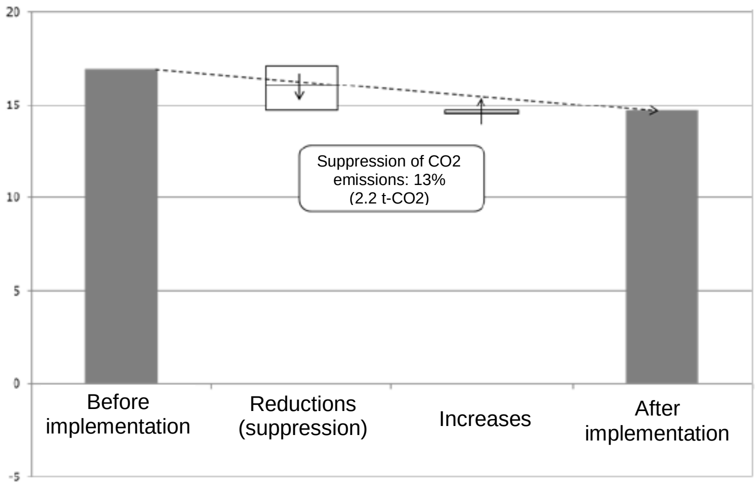
- Distances were inferred from forklift operating times and average speed. As these were electrically operated, the primary unit was deemed to be that of electric vehicles.
- It was supposed that an autonomous locating device (sensor) was attached to each forklift. The primary unit was deemed to be that of mobile communication devices.

[Points of the evaluation]

- Upon categorizing the large amounts of data into "required," "accessory," and "no-value" forklift traffic line patterns, appropriate entry and exit routes were identified based on more appropriate inventory locations. Effectiveness measurements of operational improvements were done from the perspective of CO2 emissions reductions.

[Calculation results] Suppression of CO2 emissions: 13% (approx. 2.2 t-CO2/year)

Components		Before implementation	After implementation	Remarks
(3) Amount traveled by items	Number of forklifts: 10 → 9 Distance traveled daily: 7 km x 5 hrs Days operated yearly: 200	4.973	3.580	Distance was inferred from forklift operating hours. Daily average speed was presumed to be 7 km/h. The primary unit was deemed to be that of an electric vehicle.
(4) Office space	Driver's office: 12 → 11 persons	11.947	10.952	
(6) Electricity and energy consumption	Number of autonomous locating devices: 0 → 9 Laptop PCs: 0 → 1 Cloud	0.000 0.000 0.000	0.013 0.028 0.143	The primary unit was deemed to be that of a mobile communication device. Used for management purposes Derived from CFP verification locations
(7) Network data communication volume		0.000	0.001	

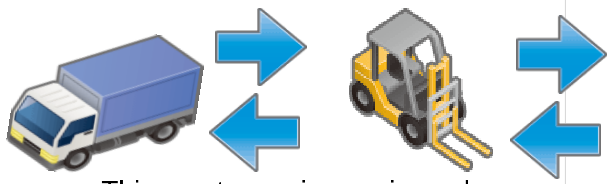


[Discussion]

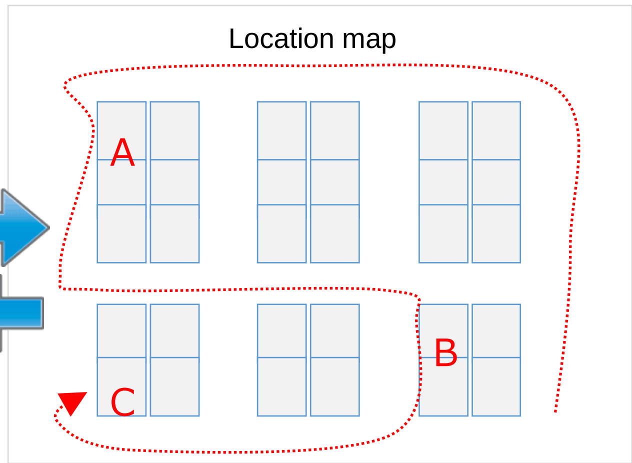
In addition to reducing CO_2 emissions, we believe that significant contributions can be made with regard to addressing labor shortages in the logistics industry. In other words, logistical quality can be ensured from the fact that the same amount of work can be efficiently undertaken by fewer numbers of people, as well as from the analysis of large amounts of data gathered with this solution to visually represent the knowledge assets held by experienced drivers so that they can be shared with new drivers for navigation.

■ Before implementation

- Cargo is retrieved and placed based on experience and on-the-fly decisions made by forklift drivers.

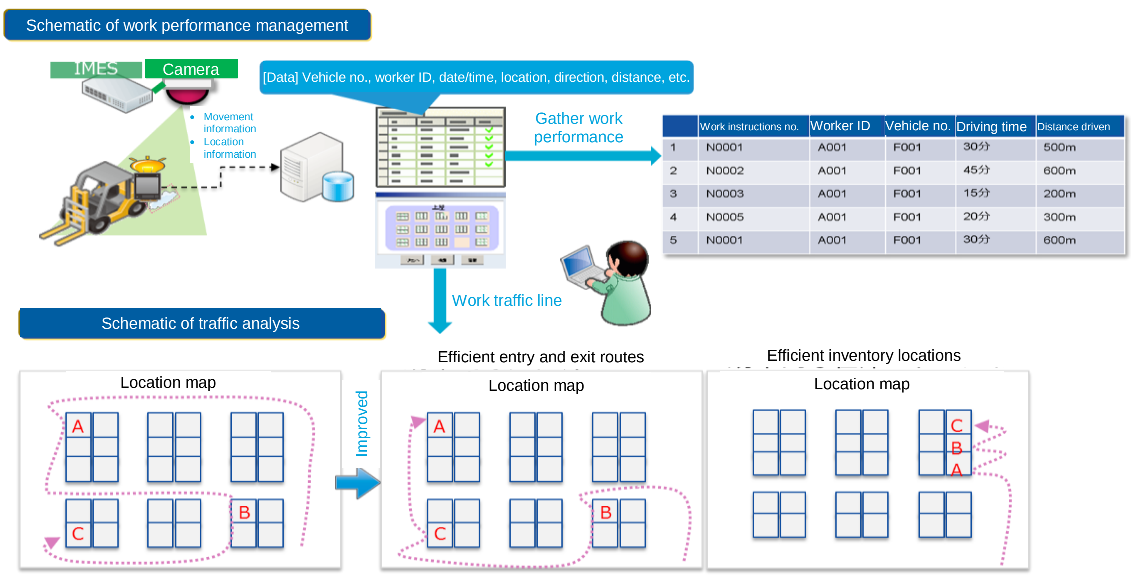


- This creates variances in work procedures and forklift traffic lines (efficiency) between experienced and new drivers.



■ After implementation

- By analyzing the causes of variances in work procedures and forklift traffic lines (efficiency) between experienced and new drivers, improvements were made to entry and exit routes and inventory locations to reduce unneeded forklift movement.



	Work instructions no.	Worker ID	Vehicle no.	Driving time	Distance driven
1	N0001	A001	F001	30分	500m
2	N0002	A001	F001	45分	600m
3	N0003	A001	F001	15分	200m
4	N0005	A001	F001	20分	300m
5	N0001	A001	F001	30分	600m

[Case 2] Visual representation of transport quality and analysis services using sensor logger

■ Overview and key points from an IoT perspective

- Sensor loggers mounted with several types of sensors (for temperature, etc.) were placed in the packaging of items being transported as well as in the transport media to gather and visually represent the acquired transport quality data.
- Data acquired on the sensor logger was analyzed by collating it with driving data and other data to visually represent and analyze transport quality.
- Transport plans can be improved and operations can be made more efficient by utilizing results from the analysis.

■ Calculation of effects, and trial results:

[Scope of calculations]

- Cargo consisting of processed food products were transported to two destinations on refrigerator trucks.
- Cargo to be shipped to these destinations was managed by control clerks at the depot.
- Soiling or damage to products occurred during transport.
- Power consumed at the data center for data analysis was not included in calculations.

[Calculation conditions]

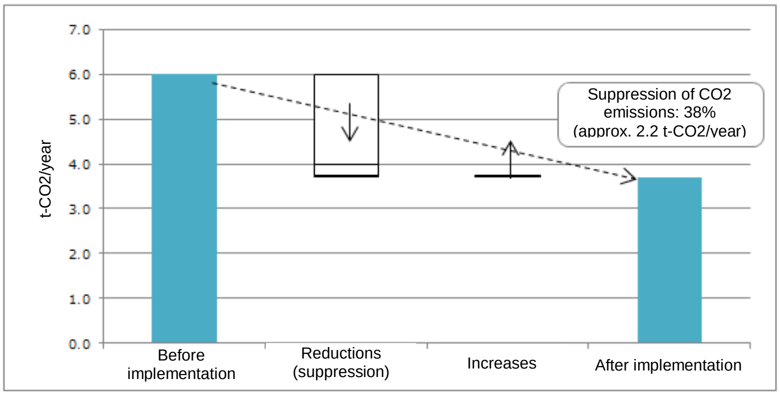
Delivery frequency: Once daily / Amount of cargo per destination: 1 ton / Warehouse operating hours: 8 hours daily / Cargo control clerk work hours for this work: 2 hours daily / Annual operating days: 365 days / Data gathering: Once daily / Sensor logger's data communication volume: 4 Mbytes per delivery / The rate of occurrence of soiled or damaged products was defined to be 0.004%* of the transported volume, all of which were to be disposed of (*Calculated by JEITA based on documentation published by logistics industry organizations and other organizations).

[Points of the evaluation]

- Optimization of transport processes, including route distance reductions, while enabling improvements to transport quality.
- Efficiency improvements and other effects stemming from IT solution implementation, as well as effects relating to IoT utilization targets (transport quality) were considered: Soiled or damaged products = Reduce product disposals

[Calculation results] Suppression of CO_2 emissions: 38% (approx. 2.2 t-CO_2/year)

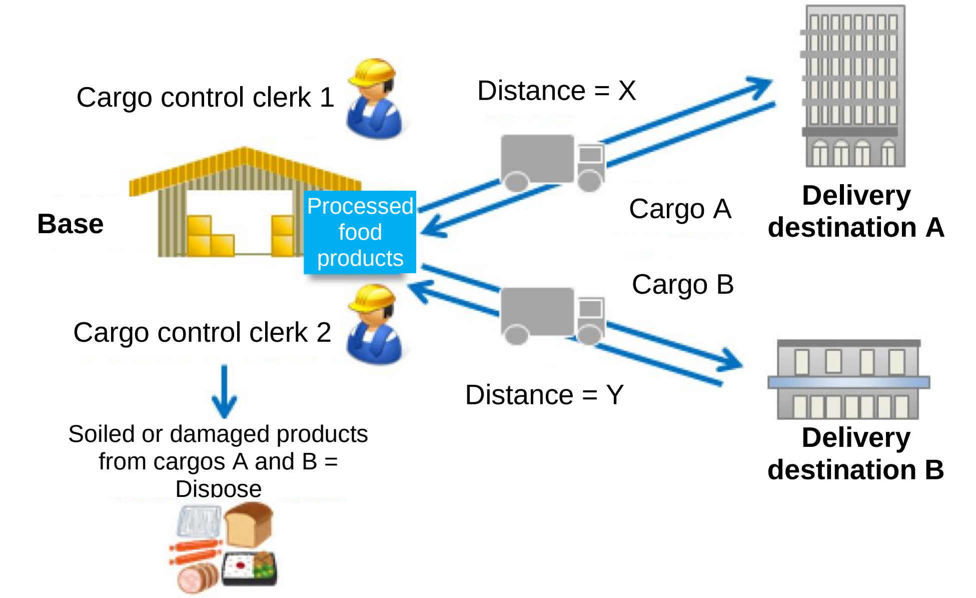
Components (*Enter amounts for before and after implementation)		Before implementation t-CO2/year	After implementation t-CO2/year	Remarks
(3) Amount traveled by items	- Number of refrigerator trucks: 2 → 1 - Distance traveled daily: 30 km → 23 km - Annual operating days: 365 → 365 - Delivery (cargo) amounts: 1 ton per delivery per truck → 1 ton per delivery per truck	5.4	3.4	- Two delivery destinations - Cargo content is different for each delivery destination. - Delivery routes will be optimized after implementation.
(4) Office space	- Number of cargo control clerks: 2 → 1	0.50	0.25	- After implementation, one control clerk will be able to manage cargo for both locations.
(6) Electricity and energy consumption	- Laptop PCs used: 2 → 1	0.014	0.007	- One PC used by each cargo control clerk.
(7) Network data communication volume	- Sensor logger data volume: 0 Mbyte per delivery (not used) → 4 Mbyte per delivery	0	0.0037	- One logger is placed in each refrigerator truck. - Data is gathered once upon the completion of one delivery.
(8) Other	- Amount of soiled or damaged products = Amount of products disposed of: 8g per delivery → 4g per delivery.	0.081	0.040	- One ton of cargo is delivered per delivery destination. - The rate of occurrence of soiled or damaged products is 0.004%* of the transported volume. - All soiled or damaged products were to be disposed of, and it is presumed that the rate of occurrence of soiled or damaged products will be reduced by 50% after implementation.



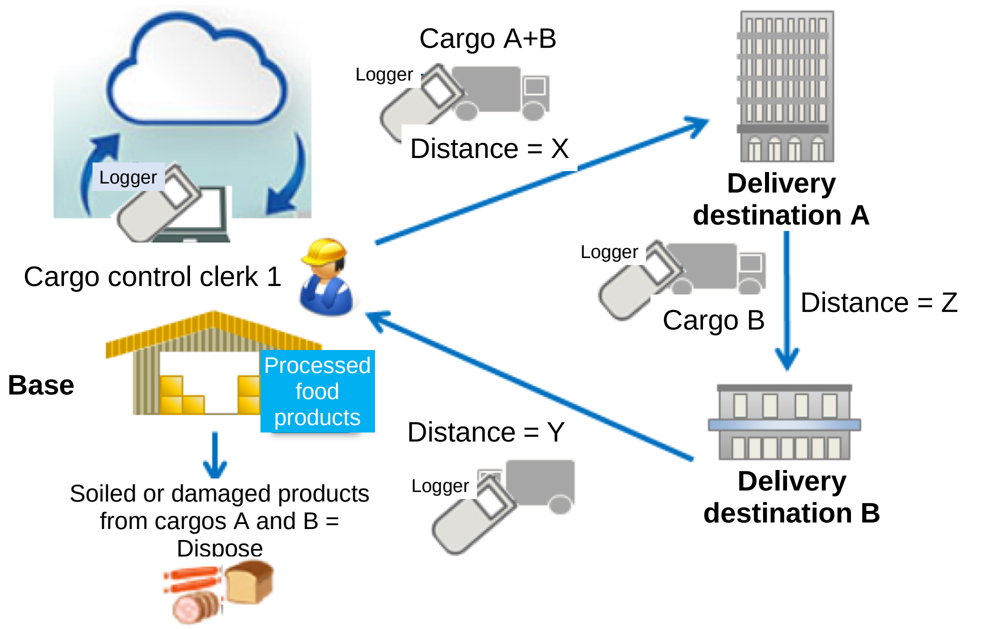
[Discussion]

- Calculations show that the optimization of transport routes for "Volume of items transported = Refrigerator trucks" has the largest CO2 emissions suppression effect (approx. 2t-CO2/year) . As such, the implementation of solutions to logistics processes can be expected to contribute to the suppression of CO2 emissions in this industry.
- The extent of electrical power consumed by servers to process data gathered by the sensor loggers could not be identified or estimated (To be addressed moving forward).
- In evaluations of the effects of IoT implementation, the above can be categorized under the "(8) Other" component as described in calculations of the amounts of emissions being suppressed from the use of IT solutions.

■ **Before implementation**



■ **After implementation**



[Case 3] Remote temperature control solution for freezer/refrigerator transport vehicles

■ Overview and key points from an IoT perspective

- Sensors for temperature control and an Internet communication device are installed on freezer/refrigerator trucks. During transport, temperature and location information are periodically sent to the control center to gather, store, and manage information on the temperature inside the trucks.
- The control center periodically monitors information on the temperature inside the trucks, and sends temperature control information to achieve the appropriate temperature to enable the transport of food products at the temperatures specified for different food products and ensure the quality of food products being transported.
- The gathered information is also used to prepare reports on temperatures during transport en-route to customers and to identify the causes of any problems that may occur during transport.

■ Calculation of effects, and trial results:

[Scope of calculations]

Before implementation: The scope of operations is to transport refrigerated food products (meat) at a constant temperature inside the truck during transport.

After implementation: The scope of operations is to transport refrigerated food products (meat) by monitoring and controlling temperatures inside the truck via communications between the truck and control center.

[Calculation conditions]

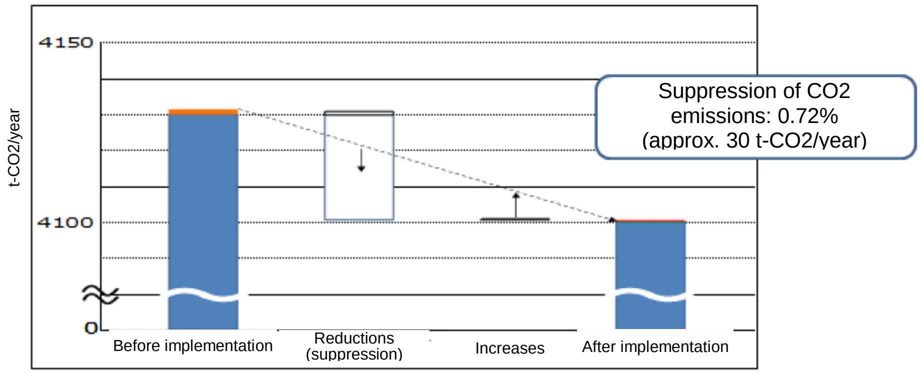
Refrigerated food products (meat) are transported from Tokyo to Yokohama (31.6 km) in a refrigerated 2-ton truck once a day, 250 days a year. The mass of refrigerated food products (meat) to be delivered to customers is one ton per day.

[Points of the evaluation]

The implementation of this solution reduces food product (meat) waste, and the evaluations (effects) of this aspect was evaluated as the lifecycle CO2 emission of meat (primary environmental footprint).

[Calculation results] Suppression of CO2 emissions: 0.72% (approx. 30 t-CO2/year) (t-CO2/year)

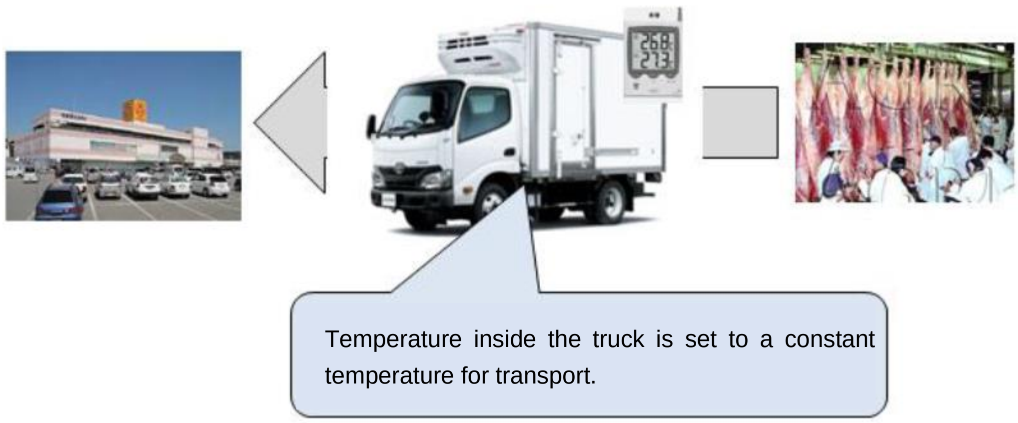
Components		Before implementation	After implementation	Remarks
(3) Amount traveled by items	Volume transported (*1): 1t per delivery Transport frequency: Once daily 250 days per year Transport distance: 31.6km	1.63	1.62	*1: The mass delivered to customers constitutes the volume transported. 1.006 tons were transported, taking into account the pre-implementation amounts that were being disposed of (insufficient temperature control).
(6) Electricity and energy consumption	Power consumed by data center equipment Power consumed by facilities	0	0.13	
(7) Network data communication volume	Temperature data: 1KB/delivery (send) Temperature control data: 1KB/delivery (receive) Number of transmissions: Once a minute Duration of usage: 38 minutes	0	0.00003	
(8) Other	Environmental footprint of food product being transported	4,130	4,100	Amounts disposed of during transport (percentage): Proportion relative to initial production volumes of meat in advanced industrial regions of Asia: Approx. 6% Amounts (percentage) disposed of due to insufficient temperature control during transport was hypothesized to be 10%.



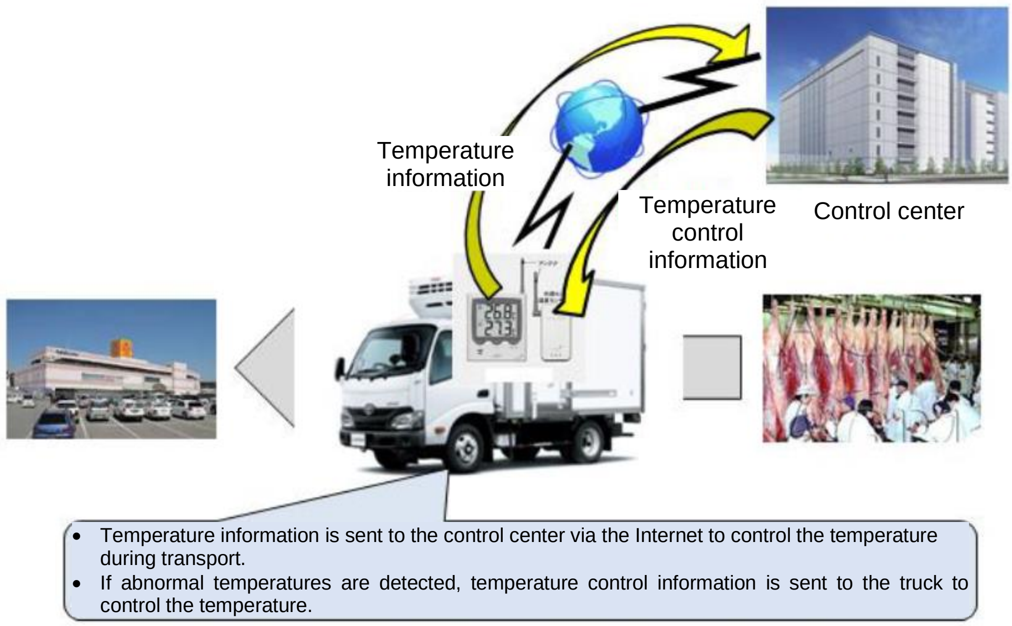
[Discussion]

- While "food product waste during transport" was expressed in terms of CO_2 emissions reductions in this evaluation, we intend to review other ways of expression that are more readily communicable.
- In this example of solution implementation, the reduction of "environmental footprints by IT" (reduction of food product [meat] waste) exceeded the increase in "environmental footprints of IT." As such, we can expect to see effects in reducing the environmental footprint.
- With regard to power and energy consumption at the control center, detailed calculations were made for individual servers and storage devices that make up the data center for evaluation. As future evaluations for IT/IoT solutions will include solutions that are founded on data centers similar to this control center, we believe that one of the issues moving forward will be to develop methods for evaluating data centers as single entities.

■ **Before implementation**



■ **After implementation**



Special Contribution

The following examples of utilizing big weather data as a tool to reduce CO_2 emissions in logistics were contributed by the Japan Weather Association.

[Case 4] Demand forecasts and energy-saving logistics operations through the use of big weather data

■ **Overview and effects of the solution**

- 6.32 million tons of food products are being wasted in Japan, and this exceeds the 3.2 million tons of global food aid by a large margin. In this project, we worked towards reducing food waste by making food product demand forecasts based on the latest weather forecast data for not only Japan, but also for Europe, and to carry out production operations in a precise manner based on these demand forecasts. We also achieved modal shifts that utilize these demand forecasts.
- In addition to demand forecasts, there are many areas where CO_2 emissions reductions and energy conservation can be achieved through the use of big weather data. We expect to see the use of big weather data in a variety of forms of business.

(1) Quantification of relationships between weather and food product demand

By analyzing the relationships between the weather and demand for specific food products, we have established methods for forecasting food product demand based on weather. For analysis, various weather parameters were converted to sensory temperatures and other metrics that demand is sensitively affected by. We also employed the latest AI technology for analysis.

(2) Reduction of waste of products delivered daily

The demand for "yose dofu" rises rapidly during the summer seasons, and due to the fact that its production requires two days and retailers place their orders only one day in advance, producers have had to guesstimate the actual demand, which in turn has led to the disposal of large amounts of products. In this project, we were able to reduce the amount of products disposed of by approximately 30% through operations that were based on demand forecasts provided in this project.

(3) Reduction of waste of seasonal products

Sales of "soup for hiyashi chuka (cold Chinese noodles)" drops precipitously after the peak of the summer heat. In the past, operations to clear these products before the autumn season had been a major issue, forcing operators to dispose of large amounts of product in September. In this project, by improving the precision of demand forecasts for the post-summer season, we were able to reduce the amount of products disposed of by nearly 20%.

(4) Achieving modal shifts that make use of demand forecasts

To date, the delivery of "coffee in PET bottles" involved the use of one-week weather forecasts to identify demand in different areas, based on which the products were transported by trucks. In this project, we used a high-precision two-week demand forecast and moved towards shifting the transportation mode to ships given the longer lead-time to delivery. And, for the ships, we implemented a system that would recommend optimal shipping routes based on weather and hydrographic conditions to reduce fuel consumption while ensuring on-time operations. As a result of these efforts, we were able to reduce CO_2 emissions by roughly 48% over a period of sixth months (*).

■ **This project was awarded the three awards below in fiscal 2016.**

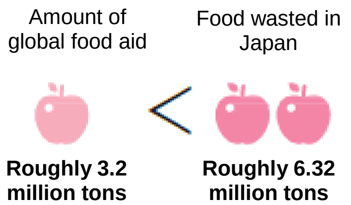
- 17th Grand Award for Logistics Environment, Grand Award for Logistics Environment
- Energy Conservation Grand Prize for Fiscal 2016, Minister of Economy, Trade and Industry Award (Business Sector)
- - 4th Food Industry Mottainai Awards, Ministry of Agriculture, Forestry and Fisheries Food Industry Affairs Bureau Chief Award

(*) Values as calculated by the Japan Weather Association.

Transforming logistics with weather forecasts

Special Contribution

Food waste in Japan amounts to roughly twice the amount of global food aid.
Not only is this situation wasteful, the disposal and return of these products have generated unneeded excesses of CO_2 emissions.
We intend to create a world with no unneeded excesses and transform the commonly held notions about logistics through state-of-the-art technologies that leverage weather forecasts and AI.



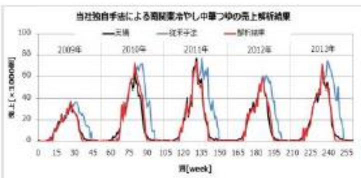
Source: "Approaches for Reducing Food Waste" (Ministry of Agriculture, Forestry and Fisheries)

Food waste was reduced with the use of refined demand forecasts that utilize weather information.

Amount of wasted tofu (Sagamiya Shokuryo)

Reduction of roughly 30%

The tofu index, which incorporates weather information, was independently calculated to refine the demand forecast. Operations were modified based on this forecast to successfully reduce food waste.

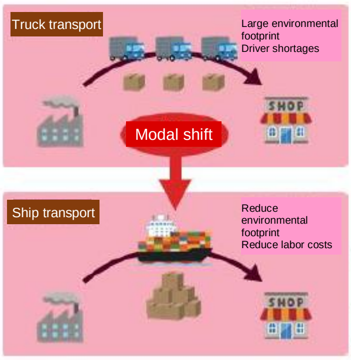


Amount of wasted soup for hiyashi chuka (cold Chinese noodles) (Mizkan)

Reduction of roughly 20%

Managing the "final production volume" is critical for seasonal products with relatively long "best by" dates. Given this, sensory temperatures were calculated from different factors, such as temperature trends leading up to the previous day, to refine demand forecasts and successfully reduce food waste.

Improve CO_2 reduction effects through collaboration in the supply chain



Modal shift*
(Nestle Japan, Kawasaki Kinkai Kisen Kaisha, Ltd.)

CO_2 reduced by roughly 48%

A two-week weather forecast was prepared using weather data from an overseas weather organization (ECMWF*). Quicker decision-making enabled a modal shift, leading to a successful reduction in CO2 emissions.

* Modal shift: To shift modes of transportation from trucks to freight trains or ships from the standpoint of CO2 emissions reduction and better logistics efficiency.

Reduce environmental footprint and improve transport efficiency

Moving forward with this modal shift helps to alleviating driver shortages and long-distance driving. Also, fuel consumption can be reduced by recommending optimal routes for ships based on weather and marine current information.

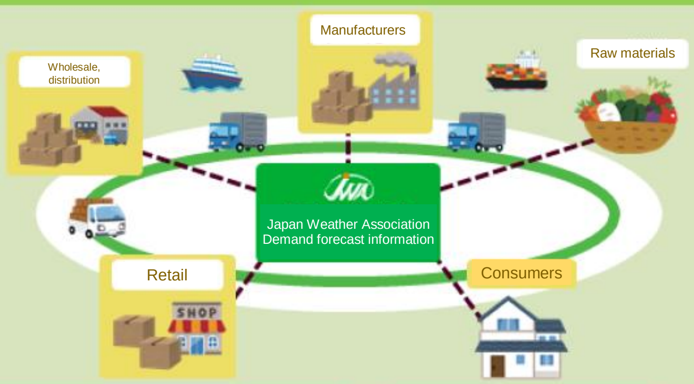
Supply chain vision to realize

Previous challenge 1: Limits to empirical demand forecasts

Global warming is causing weather phenomena that we have never experienced.

Previous challenge 2: Demand forecast mismatches

Demand forecasts were being made independently by manufacturers, distributors, and sellers with no sharing of information.



Utilization of weather information
Make demand forecasts based on weather information, whose precision has improved, and weather forecasts that now extend to two weeks.

Utilization of AI and SNS
Improve forecast precision through machine learning and clustering, and predict consumer behavior from SNS.

Information sharing
Manufacturers, distributors, and sellers share demand forecast information that factors in the weather are taken into consideration.

Setup for transforming logistics through the use of weather forecasts

Big data analysis

- Weather information: Temperature, weather, rain, wind, temperature forecasts, sensory temperature, etc. → Weather at a particular time, in a particular location
- SNS data: Tweets that include location information → People's moods at that time, in that location (Weather-induced mood changes)
- POS data: Product sales, product master, shop information, etc. → Product demand at that time, in that location

Future forecasts

- Weather slightly later in time, at that location
- People's moods slightly later in time, at that location
- Product demand slightly later in time, at that location

Weather forecasting technologies
Meteorological know-how
Ensemble forecasting technologies
Big data analysis, etc.

AI technologies
Machine learning
Natural language processing
Pattern recognition
Clustering, etc.

Results

Improve demand forecasts
Refine demand forecasts for products that have a close relationship with the weather.

Create value
Relationship between weather and product sales
Differences in sales peculiarities for different seasons
Products requiring special attention moving forward, etc.

4.2 IoT utilization in agriculture

4.2.1 Status of IoT utilization

Within the "production - distribution - consumption" supply chain in agriculture, we focused on the production stage. While a broad range of discussions have been carried out to date by relevant government agencies and other organizations on the topic of promoting IT utilization in agriculture, we expect the use of IoT will bring about further advancements. Based on reviews of several examples in which IoT will be (or can be expected to be) actively employed—reviews that were carried out in the context of its utilization in information gathering, analysis, and feedback to the field—the overall picture can be summarized, for example, as shown in the table below. This table was created by referencing the "Interim Summary Report[5]" by the Information Economy Subcommittee of the Ministry of Economy, Trade and Industry.

Table 3: Active utilization of IoT in agriculture

Case 1 (includes suppositions)

Information gathering - analysis	1. Automatic data acquisition with IoT	Acquire big weather data for temperature, precipitation, sunshine and other parameters, as well as growth status data.
	2. Data integration and analysis	Harvest forecasts by way of analysis using cloud technologies, and learning using AI, etc.
Utilization of analysis results	3. Feeding back analysis results into the real world.	Minimize harvesting losses and sales opportunity losses using forecasts from item 2 above.
	4. Value creation and achievement of full autonomy with AI	Improve harvest forecasts through repeated data gathering and AI learning.
■ Benefits of IoT utilization:	• Realize stability of supply. • Minimize harvesting loss, crop disposals, and loss of business opportunities, etc.	

Case 2 (includes suppositions)

Information gathering - analysis	1. Automatic data acquisition with IoT	Install sensors and cameras in the field to monitor soil and growth status to acquire data automatically.
	2. Data integration and analysis	Discover optimum modes of action (temperature control, watering, etc.) based on cloud analysis, AI learning, etc.
Utilization of analysis results	3. Feeding back analysis results into the real world.	Implement temperature control, watering, etc. using results from item 2 above.
	4. Value creation and achievement of full autonomy with AI	Use results from analysis to automatically control and implement the above tasks.
■=Benefits of IoT utilization:	• Reduce workloads. (Reduce consumption of energy used for personnel transport. Resolve labor shortages.) • Improve quality and stability of yield through precise temperature control, watering, etc. • Pass on of skills by integrating knowledge assets.	

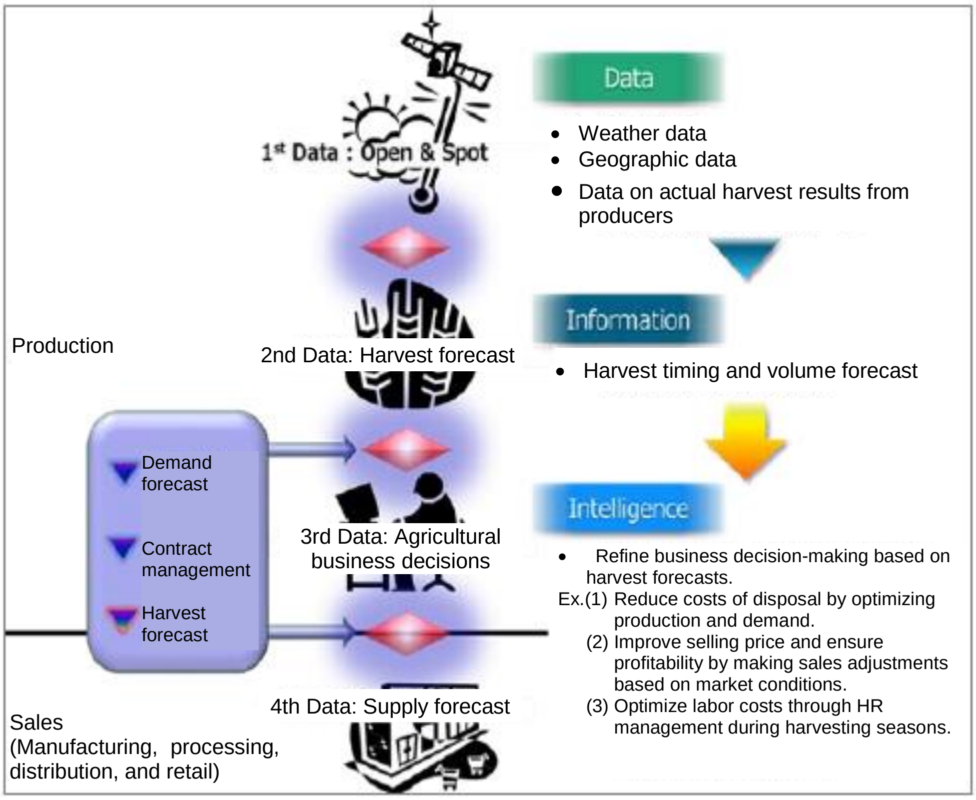
[5] "Interim Summary Report" (Apr. 2015) by the Information Economy Subcommittee, Industrial Structure Council, Ministry of Economy, Trade and Industry.
http://www.meti.go.jp/committee/sankoushin/shojo/johokeizai/pdf/report01_02_00.pdf

4.2.2 Specific examples

As shown in Table 3, the benefits of IoT utilization in agriculture cannot be fully represented as equivalents to CO2 emissions reductions. Therefore, while trial evaluations using CO2 conversions were not carried out for agriculture in this report, we would like to present a number of actual cases below.

[Case 1] Contributing to the environment through the reduction of harvesting loss and crop disposals based on harvest forecasts. (JSOL Corporation)

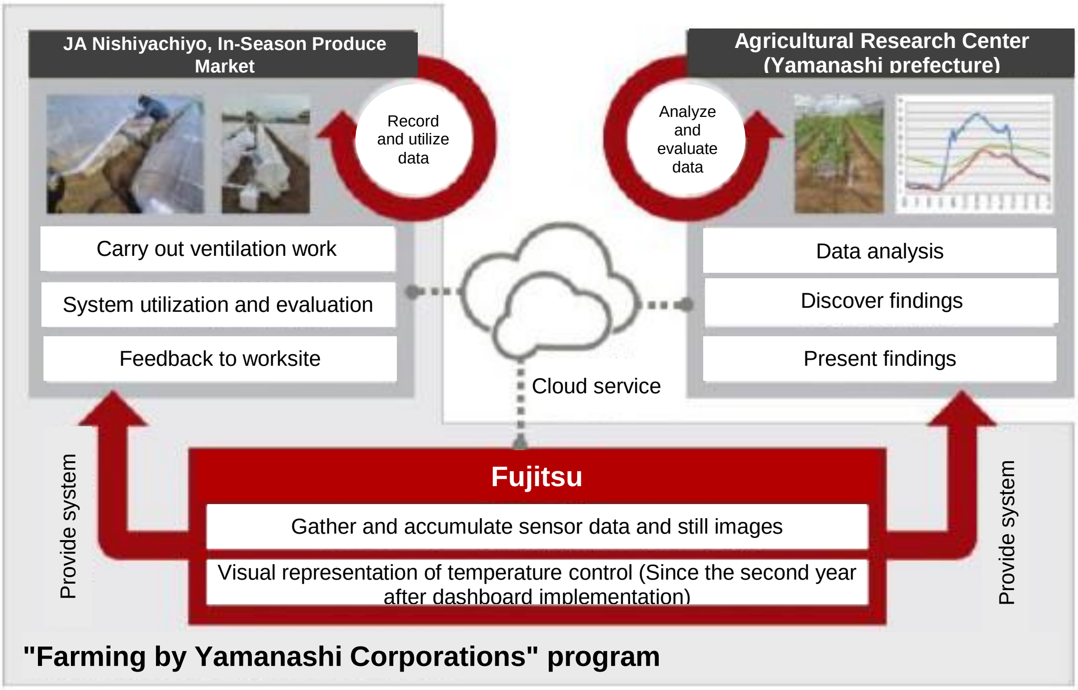
- Crops: Lettuces, cabbages, etc.
- Implemented regions: Nagano Prefecture, etc.
- Key points from an IoT perspective, and Green Benefits:
  - Enable advanced overall management of agricultural businesses, including areas such as production and shipment adjustments, based on harvest forecasts that are based on work data acquired from production sites and open data (weather, etc.).
  - Help reduce harvesting loss by introducing resources during harvesting season in a calculated way based on harvest forecasts, improve capabilities to respond to supply and demand fluctuations through partnerships between production regions (complementation), and minimize the amount of crops to be disposed of.
  - Because harvesting loss and crop disposals result in the wasteful consumption of land, water, fertilizer, labor and other resources that are used for production, and also cause unnecessary CO2 emissions, we will be able to contribute to the environmental cause by improving the precision of harvest forecasts.



[Case 2] Improvements to work efficiency and quality through the visual representation of temperature control know-how. (Fujitsu Limited)

- Crop: Corn (sweet corn)
- Implemented region: Yamanashi Prefecture
- Key points from an IoT perspective, and Green Benefits:
  - A multi-sensing network equipped with cameras was installed in sweet corn fields. Temperature control know-how of experienced famers was visually represented to improve the production skills of new farmers. Farmers were able to remotely monitor the temperature of their fields in real-time on their smartphones, and this reduced the labor associated with checking temperatures in fields that were scattered over several locations, and reduced the amount of fuel consumed for traveling as well as man-hours required for such work.
  - Additionally, the number of temperature control failures were reduced to less than half the levels prior to implementing the solution, and the yield of marketable produce increased by 10-20% over the previous year (quality improved).

Using ICT to visually represent temperature controls and support new farmers



Website
http://www.fujitsu.com/jp/about/environment/society/solutions/sustainability/case-studies/03/result/index.html

4.3 What we have found in trial evaluations

As we have mentioned in Section "3.2 Items to be included in the evaluation," subjects chosen for these trial evaluations as contributions by IoT solutions include subjects that were not included in previous calculations of CO2 emissions reductions, as well as those that may involve non-CO2 equivalent metrics of evaluation and expressions. Calculations of the contributions of these subjects were a topic of debate. Such subjects include, for example, "reducing food product waste," "resolving labor shortages," and "increases in the power and energy consumption from data processing." The topics of debate were the ideas of "categorization," "evaluation," and "expression." Another aspect of these evaluations was that there has been an increase in man-hours spent for quantification due to the expansion of the scope of calculations that resulted from IoT utilization.

For referential purposes, we present the discussions carried out by the Green CPS/IoT Review Working Group during fiscal years 2015 and 2016 below.

4.3.1 New subjects for evaluation

(1) Reducing food product waste

(1) Category

The disposal of food products, or "food product waste," has become a societal issue, and we have found that the utilization of IoT solutions in logistics and agriculture can be expected to have an effect on waste reduction. In the area of logistics, evaluations were carried out with respect to CO2 emissions reductions. That being said, because this subject did not belong to any of the calculation categories from (1) to (7) in Table 2, it was included in "(8) Other" for the time being to convert its effects to CO2 emissions reductions.
Meanwhile, some suggested that a new "Benefits" framework should be created to evaluate and express non-CO2 subjects in addition to evaluations made for CO2 emissions reductions.

(2) Evaluations

With respect to methods of evaluation for food waste reduction, conversions to CO2 in examples for logistics were made using publicly available data, such as food products CFP (carbon footprint) and LCA. In the <Reference> section below, we have listed URLs where utilizable data is available. If data for a specific product is not available, provisional calculations can be made through inference using similar data. That being said, inference may be difficult in some cases.

<Reference>

- Ministry of Economy, Trade and Industry CFP (carbon footprint) program trial project
  Examples of provisional calculations for fiscal 2009 thru 2011
  http://www.cms-cfp-japan.jp/info/index.php

- CFP Program Product, Japan Environmental Management Association for Industry
  https://www.cfp-japan.jp/info/index.php

- Ecoleaf, Japan Environmental Management Association for Industry
  http://www.ecoleaf-jemai.jp/

(3) Expressions

While evaluations in this report express results as equivalents to CO2 emissions reductions, there may be other means of expression that enable us to communicate, in ways that are easier to understand, the fact that IoT is beneficial in the resolution of many societal issues. Moving forward, we would like to continue our reviews.

(4) Summary

In this review, our primary aim was to cover the contributions that IoT solutions can make in our societies and can be easily considered within the environmental perspective. These included "food product waste" and other subjects that were relatively more difficult to convert to CO2 emissions, as well as those for which no method of conversion could be devised. How can we evaluate and express these environmental contributions in ways that can be readily understood by the general public? The following three proposals were raised in discussions in our working group:

[Proposal 1] Convert to CO2 emissions and add into the total with other elements. (Devise methods of conversion)

[Proposal 2] Do not convert to CO2 emissions. Express in different units in a different framework than the summed CO2.

[Proposal 3] If an element can be converted to CO2, convert it to CO2 emissions and add into the total with other elements. Other elements may be expressed in different units in a different framework.

Apparently, discussions are currently underway at logistics-associated organizations on the topic of reducing food product waste. Moving forward, we would like to pay close attention to discussions being carried out by associated organizations, and continue our reviews.

(2) Resolving labor shortages

We have found that the utilization of IoT can be expected to resolve labor shortage issues in both agriculture and logistics. While it would be possible to make conversions to CO2 emissions using traditional evaluation methods based on reductions in per-person energy consumption in the workplace, we intend to review other methods of evaluation and expression as the resolution of this issue is of great societal concern.

4.3.2 Factors that cause energy consumption to increase

(1) Power and energy consumption at cloud data centers

The calculation method "(6) Electricity and energy consumption (IT and network equipment)" shown in Table 2 must take into account the rise in energy consumption that results from operations such as communication of data gathered through IoT and analysis processes carried out at cloud data centers. In the case reviews in this report, the power consumed by servers, storage devices, network devices, and other devices that make up the data center was calculated and summed using traditional methods. This process was extremely man-hour intensive.

As a new proposal for future reviews, some voiced that it would be more appropriate to consider cloud data centers to be a single package, including all of its constituent devices, and define them as a primary unit. We plan to review these questions on an ongoing basis, including whether a defined scope (boundaries) for the evaluation, or evaluation parameters has been put into place.

5. In approaching future reviews

- **Perspectives centered around the environment: Provisional calculations of total CO2 emissions reductions**

The utilization of IoT has just begun, and a variety of solutions based on new ideas are being created. The primary subject of our reviews in this report are the contributions made by IoT solutions to society, based on which we have carried out trial calculations for CO_2 emissions reductions for a number of cases in logistics. While these are still limited to the numerical quantification of results from each case, we intend to use these as our starting point, and conduct provisional calculations of the total amount of CO_2 emissions reduced in specific areas, taking into account the popularization of IoT solutions.

- **Perspectives that derive from the environmental perspective: Reviews on the evaluation and expression of "Green Benefits"**

We have reviewed several examples of IoT solution utilization in the areas of logistics and agriculture, and have found that not all environmental contributions were necessarily readily convertible to CO_2 emissions.
Additionally, as mentioned at the beginning of this report, the number of topics that are being discussed in the context of the environment has been growing in recent years, and we can expect to see active utilization of IoT solutions for a variety of purposes, including enabling consistent crop yields, resolving labor shortages, and improving comfort levels in homes and offices to name a few. Moving forward, we intend to gradually expand our environment-related visions to "adaptation," "smart wellness" and other areas to evaluate and express these areas in terms of their **<u>Green Benefits</u>**. To this end, calculation methods will have to be improved or created anew as we move forward. In reviewing these approaches, we will be required to sort out various points in question, such as "calculation category," "evaluation methods," and "methods for evaluating results."

- **In closing**

In terms of the environment, IoT solutions are expected to make major contributions to CO_2 emissions reductions. But not only that, they should be able to make societal contributions that lead to happiness over a much wider spectrum. We intend to carry out further reviews moving forward so that we will be able to "visually represent" these possibilities through appropriate methods of evaluation and expression, and disseminate these results throughout society.

Reference Documents

Calculations for CO2 emissions reductions for the cases included in this report are based on methods developed by the Green IT Promotion Council (2008-2012). Details of these methods are described in document (1) below.

The line of thinking behind CO2 emissions reductions calculations in this report is consistent with that in the publications listed below. Please feel free to reference these documents as they are available as free downloads in their entirety.

------------ CO2 Emissions Reductions Enabled by IT Reference documents
(based on the same ideas as this report) ------------

- Green IT Promotion Council (fiscal 2008-2012)

  (1) "Energy-Saving Contributions for Society at Large from IT Solutions
  -- Perspective on Evaluations of Contributions from 'Green by IT' -- “Explanatory Booklet” (Published Feb. 2013)
  http://home.jeita.or.jp/greenit-pc/activity/reporting/110628/pdf/survey02.pdf

  (2) Comprehensive Report from the Survey and Analysis Committee of the Green IT Promotion Council
  -- Contributions of Green IT for a Low-Carbon World -- (Published Feb. 2013)
  http://home.jeita.or.jp/greenit-pc/activity/reporting/110628/pdf/survey01.pdf

- Green IT Committee, JEITA

  (3) Study and Research Report on the Energy-Saving Effects of Utilizing IT
  -- Energy-Saving Effects of Implementing BEMS in Buildings and Shops -- (Published Mar. 2015)
  http://home.jeita.or.jp/greenit-pc/bems/pdf/bems2.pdf

  (4) Report on the Framework for Quantifying IT Solutions' Contributions in CO2 Emissions Suppression
  -- Umbrella Method for Calculation and Aggregation -- (Published Mar. 2017)
  http://home.jeita.or.jp/greenit-pc/contribution/pdf/it-framework.pdf