The Factors on the Influences of Energy Consumption of IoT in Manufacturing Industries

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IoT in manufacturing industries has increased attention in recent years with various concepts including Industrie4.0 in Germany. This paper organizes the characteristics of IoT, verifies the current status from manufacturing industries in Japan and considers the factors that affects energy consumption. IoT can be classified in terms of technologies and application process. The core technologies consist of ①things, ②cloud serer and ③open channels of communication. The application process can be categorized into 5 stages;①Collection ②Visualization ③Management（monitoring） ④Forecasting(analysis) and ⑤ Control(Implementation). Based on the examples, while the introduction of things and cloud servers is advancing in terms of technology, we can see that introduction of open channels is lagging. As for the application process, most of examples still remain in ②visualizing phase. For the quantitative study, it will be important to examine policies taking into account comprehensive perspectives not just for the manufacturing industries, but of the supply chain, as well as the possibility of implementation in materials industries and small and medium companies and the potential for energy savings, as well as cross-sectional impact focusing on the structural changes that will be caused by IoT implementation.

Keywords:Industrie4.0, IoT, Sensing, Cloud server, Open Channels

１． Introduction

In recent years IoT related activities have attracted much attention in various fields and industries, and manufacturing industries have been no exception. Industrie4.0, announced by the German government in 2011, has offered one opportunity for manufacturing industry IoT to attract attention. The objective there is to use IoT technology to further increase the efficiency of manufacturing and make major cost reductions.

In response to the German initiative, the Industrial Internet Consortium (IIC) was founded by private interests in 2014 in the US, and China announced the “Made in China 2025” vision to strengthen the nation’s manufacturing in 2015. Similarly, the Japanese government established the Robot Revolution Initiative (May 21015), and has announced various visions such as Society 5.0 (January 2016), and Connected Industries (March 2017). In Japan, it is characterized by plans for a future society where IoT is not limited to manufacturing industries, but extends to agriculture, health care, transportation, finance, resilience and various service fields, and those are all linked.

With this background, it can be said that use of IoT has already begun in Japan’s manufacturing plants. In practical terms, services that use data from sensors attached to construction and agricultural equipment to detect problems or to perform remote equipment maintenance have already begun to arrive. Meanwhile, the public has just begun to pay a lot of attention to IoT, and there has not been a lot of research into evaluation of the impact on energy demand from broader implementation of IoT. Therefore, we think that it will be important to study and verify the factors that have impact and the methods for understanding actual status. This article organizes the characteristics of IoT and verifies the current status of the use of IoT from the perspective of manufacturing in Japan, and at the same time considers factors that affect energy consumption and qualitative impacts focusing on the structure of IoT.

２． Characteristics of IoT

2.1 IoT Core Technologies and Processes that Use it

IoT is generally translated as “Internet of Things” and in this article we will mainly describe IoT in terms of the technologies and processes that use it. The core technologies that compose IoT

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are ① things, ② cloud servers, and ③ open channels of communication (**Figure 1**).

Figure 1. IoT Core Technologies

The differences between IoT and past technology are shown here in **Table 1**. In the past the things connected to the Internet were limited, such as computers and cell phones, and there was not a lot of data to collect. With IoT, all kinds of things are connected to the Internet that were not connected in the past, such as household appliances, medical equipment, agricultural equipment, vehicles, and furthermore construction machinery, agricultural machinery, and die casting in manufacturing industries, and it is possible to collect various and quality information by using sensing technology.

The information that is collected is accumulated in servers. In the past management servers were independent units owned by each company, and the tendency was for each company to keep its information for its own use. In the age of IoT, they use open, external cloud servers. These servers accumulate information collected from "things" that belong to various companies and projects, in addition to information from their own company. The information collected in this manner can be used by each company in manufacturing and other processes, according to their own purposes.

Furthermore, IoT uses open channels, typified by the Internet, as the communication network to connect "things" and the "cloud." In the past, there was a tendency to use dedicated lines that could only be used within companies, and they couldn't connect to other fields or businesses, but a society that uses IoT uses large amounts of data, and connections that cross barriers between industries can be expected.

Table 1. Comparison of IoT and Past Technology

	Past	IoT
Terminal equipment	・Limited to computers, cell phones, etc. ・Few types.	・All kinds of things including household appliances, medical devices, vehicles, construction machinery, agricultural machinery and die casting (①). ・Abundant and numerous types.
Management servers	・Information closed off within company. ・Most servers owned by companies.	・Uses open cloud servers (②). ・Collects massive amounts of data from all kinds of things, and stores it. ・Can be used for analysis of big data.
Information network	・Company LA N, etc, dedicated lines. ・No connections to other fields or businesses.	・Uses open channels typical of Internet lines (③). ・Advantage of being connected to all kinds of things

(Source) Created from various sources

Processes that use IoT are structured to use sensing and other technologies to ① collect (accumulate) information in cloud servers, and depending on the purpose, perform ② visualization, ③ management (monitoring), ④ forecasting (analysis), and ⑤ control (execution). However, depending on circumstances, not all 5 processes are always independent, and there are examples of ② visualization, and ③ management (monitoring) being equated, and of existing manufacturing processes performing ② visualization without performing stage ①, collecting information. In this article, the analysis is based on considering the 5 stages above to be fundamental processes.

2.2 Factors that Impact Energy Consumption

Table 2 shows the factors that affect both increased and decreased energy use based on utilization of IoT.

Table 2. IoT Factors that Impact Energy Consumption

		Factors that increase energy consumption	Factors that decrease energy consumption
Technology	① Things	Increased sensors.	–
	② Cloud ③ Open channels	Increased data center storage.	Decreased number of servers due to outsourcing..
Processes that use it	① Collection	Increased sensors	–
	② Visualization	Increased monitors.	Autonomous energy saving activity.
	③ Management (monitoring)	Increased monitors	Autonomous energy saving activity.
	④ Forecasting (analysis)	Introducing programming.	Optimization of automatic manufacturing processes. Optimization of automatic energy consumption reductions.
	⑤ Control (implementation)	Introducing programming.	Optimization of automatic manufacturing processes. Optimization of automatic energy consumption reductions.

(Source) Same as **Table 1**.

On the technology side, the number of sensors increases as the number of ① "things" that connect to the Internet increases, and energy consumption (mainly electricity) increases. We can also imagine that electric power consumption by data centers will increase with the increase of information accumulated in ② cloud servers and ③ open channels. Meanwhile, it can be pointed out that when company server functions are outsourced to external cloud servers, overall network energy consumption can be reduced because external servers can reduce the amount of energy consumed per unit of information[2]. Therefore, it is necessary to evaluate overall network energy consumption for energy consumption of IoT using ① "things," ② cloud servers and ③ open channels.

Meanwhile on the process side, at the ① collection stage, there is an increase in energy consumption as the number of things with sensors attached increases. Continuing to the ② visualization and ③ management stages, monitoring for visualization of operational status of equipment and energy consumption is necessary, so it is possible that the increased number of operational monitors will be a factor for increased energy consumption. Meanwhile, we can expect that if energy consumption in factories is more visible, that will be incentive for autonomous energy reductions such as when costs can be reduced by operating equipment more efficiently. At stages ④ forecasting and ⑤ control, it is possible that there could be increased energy consumption for the computers used for control for optimizing automatic production processes in programmed production process management. On the other hand, we might expect even bigger reductions in energy consumption due to reducing energy consumption with the optimization of production processes, and program controls with higher priorities for energy savings. In this way, it will be important to consider how IoT is connected to control of energy consumption as processes that use IoT go through each stage.

３. Analysis of Current Status

3.1 Status of IoT Implementation

In this section we analyze the spread of IoT in Japanese manufacturing plants, based on the characteristics of IoT described in the last section, and consider the impact on energy consumption for the present and future. Regarding the current status of the spread of IoT, we analyzed a map of IoT use based on a sample of 210 cases in manufacturing industries from the Robot Revolution Initiative[2]. It is necessary to note that this is a sample of a portion of IoT usage in manufacturing industries.

The results for the spread of IoT classified by technology and by process are shown in **Figure 2** and **Figure 3**.

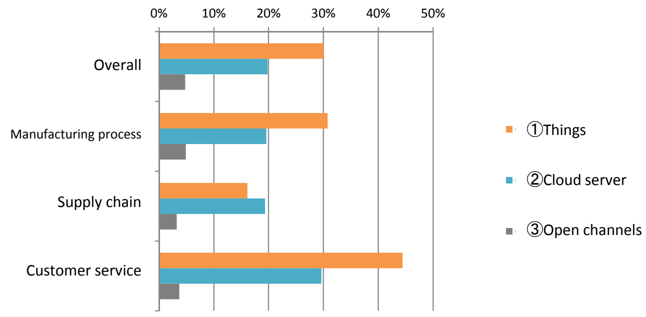

Figure 2. Status of IoT Implementation (Technology)

(Source) Created from reference documents 2)

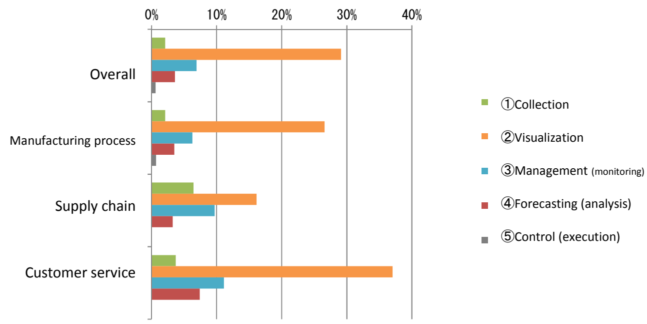

Figure 3. Status of IoT Implementation (Processes)

(Source) Same as **Figure 2**

The "manufacturing processes" referred to here include examples of visualization and analysis of manufacturing equipment operational status, remote maintenance services connecting service centers with manufacturing equipment when it breaks down for support of quick recovery, predictive maintenance when accumulation and analysis of equipment data indicates it is due, and virtual linking between factories when company A and company B have a contract for manufacturing systems. Also, "supply chain" refers to examples of demand prediction for products based on past sales results, for optimal management of orders, production, and shipping. "Customer service" aims for the diversification and further sophistication of user service, and includes examples of placing sensors on manhole covers over sewer lines to monitor changes in water levels in real time in the cloud, placing sensors in the area where gas is being supplied so that gas can be cut off when disasters occur there. "Other" primarily refers to establishment of the association and a summary explanation, and not to examples of IoT.

Based on the result, while the introduction of "things" and cloud servers is advancing in terms of technology, we can see that introduction of open channels is lagging. Also, looking at it by purpose of implementation, it is apparent that there are few implementations for supply chain. Further, among these examples there are cases of transitioning from paper input media to Excel input, and examples of companies using their own cloud for accumulating manufacturing plant data, many examples that are not correctly described as examples of IoT. In terms of processes there are many examples of using IoT for stage ② visualization, but relatively fewer examples for stage ③ management (monitoring) and especially for stages ④ forecasting (analysis) and ⑤ control (execution). Looking at the current situation from perspectives of both technology and process, we think that introduction of IoT in Japanese manufacturing industries is at the beginning stage.

3.2 Viewpoint on Impacts on Energy Consumption

So far we have looked at the basic structure of IoT implementation and factors that impact energy consumption, and done a qualitative analysis of the current status of implementation of IoT. In this section we will consider the requirements for a quantitative evaluation from the perspectives of within manufacturing plants and society overall (policy perspective).

From a perspective within manufacturing plants, businesses view implementation of IoT as being applicable for various purposes, including optimizing manufacturing processes and improving customer service (**Figure 4**). That is why it will be necessary to investigate what kinds of equipment and machinery and functions must be introduced for IoT in addition to IT equipment that is already in place, and to examine evaluation methods for the additional energy consumption that goes along with that introduction. In addition, the introduction of IoT makes it very likely that the structure of the company's supply chain might have to be changed. For that reason, in order for businesses to evaluate the impact of IoT on energy consumption, they must consider it not just from the perspective of direct changes in the manufacturing plant, but they must also look at changes to their distribution methods and service configuration.

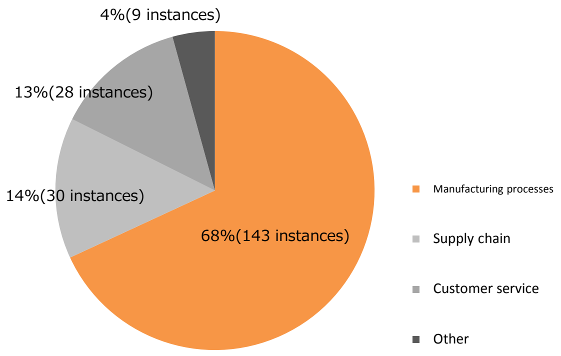

Figure 4. Purpose of Introduction of IoT

(Source) Same as **Figure 2.**

From the perspective of society overall, looking at implementation by industry, we can see that implementation in machinery-related industries is the highest (**Figure 5**). Meanwhile, the introduction of IoT in materials industries for energy savings, may have a relatively higher potential for reducing energy consumption than in machinery-related industries. For that reason, it will be necessary to evaluate the possibility of implementation separately by industry to look at the future impact of IoT.

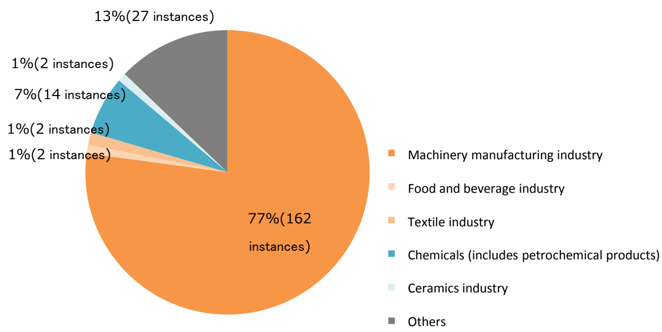

Figure 5. Share by Industry

(Source) Same as **Figure 2.**

In addition, current utilization of IoT by small and medium companies, which can be expected to further implement IoT under energy policies, is low compared to larger companies (**Figure 6**). We think it will be important to consider the impact of spreading implementation of IoT among small and medium companies on reducing social energy consumption overall.

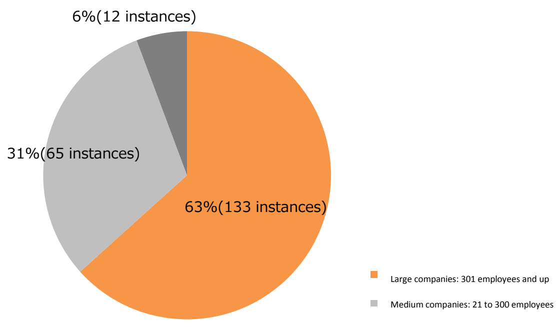

Figure 6. Share by Company Size

(Source) Same as **Figure 2**.

Further, there is a requirement to examine policies focusing on the structure of IoT. In practical terms, the advancement of IoT within manufacturing plants leads to construction of the networks relying on the services outside the factories such as the data centers and cloud servers, and it is possible that IoT implementation will bring about both increased and decreased energy consumption. When looking at it from the perspective of saving energy and countermeasures for global warming, in order to decide which efforts to emphasize, it will be important to develop cross-sectional and comprehensive methods to understand and evaluate the impact of IoT implementation on energy consumption for society overall.

４.Summary

Japan's implementation of IoT in manufacturing industries is at the beginning stage, and when considering quantitative examination of the impact on energy consumption in the future, it will be important to examine policies taking into account comprehensive perspectives not just for the manufacturing industries, but of the supply chain, as well as the possibility of implementation in materials industries and small and medium companies and the potential for energy savings, as well as cross-sectional impact focusing on the structural changes that will be caused by IoT implementation.

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