# Utilizing ICT to Stabilize Energy Use

## *— Comprehensive optimization of the entire factory through visualization —*

**Harutaka Hokahara**
Power-Distribution&Energy-Saving Solution Sect., Marketing Dept.
Fukuyama Works, Mitsubishi Electric Corporation

## 1. Introduction

Concern about countermeasures against global warming is growing globally, and many countries are moving toward achieving carbon neutrality in 2050. In October 2020, Japan also declared that it aims to achieve carbon neutrality in 2050. As a medium-term goal before 2050, Japan also announced that it aims to reduce greenhouse-gas emissions in 2030 by 46% compared to 2013 levels and that it will further strive to reach an even higher reduction of 50%. Moreover, fossil fuels (mainly oil, coal, and natural gas) account for approximately 90% of Japan's primary energy supply (as of 2020), and most of Japan's supply of mineral resources (i.e., raw materials) relies on overseas sources (according to the Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, Energy White Paper 2022).

To achieve carbon neutrality and stabilize energy use, it is necessary to further promote energy conservation in the future. In recent years, it has become essential to promote not only the conventional rationalization of energy use but also further energy conservation through (i) energy management that considers the balance between electricity supply and demand and (ii) implementation of "factory energy-management systems" (FEMS) that utilize the Internet of Things (IoT).

At Fukuyama Works, we have deployed a system that incorporates part of a concept called "e-F@ctory" (our IoT technology) as a FEMS to implement energy management in the factory. The efforts that Fukuyama Works has been comprehensively undertaking to optimize energy saving in the entire factory using FEMS are introduced hereafter.

## 2. Mitsubishi FA integrated solution: e-F@ctory

As Mitsubishi's factory-automation (FA) integrated solution, e-F@ctory visualizes sensor-collected data by linking FA and information technology (IT) in a way that reduces TCO (total cost of ownership) by repeating the plan-do-check-act (PDCA) cycle at several stages. At the Fukuyama Works, e-F@ctory is being used to save energy and improve productivity (Figure 1). The architecture of e-F@ctory is divided into three main layers: "shop floor," "IT system," and a middle layer ("edge computing") that links them.

On the "shop floor" layer, FA-manufactured products such as sequencers, various devices, and sensors, which are the brains of production equipment, are connected by FA networks, and various data are collected in real time. The data are then seamlessly linked to the IT system for analysis, and the analysis results are fed back for utilization on the shop floor. However, data obtained on the shop-floor layer cannot be fully analyzed because it contains special know-how, circumstances, and other causal relationships that cannot be understood if sent directly to the IT system. Therefore, primary processing, namely, edge computing, is needed to associate causal relationships to the data and make the data informative. One of the key features of e-F@ctory is that the middle (edge-computing) layer between the FA and IT layers is responsible for not only seamless linkage but also optimization of the entire FEMS.

**■ Figure 1: Conceptual diagram of e-F@ctory**


## 3. Efforts concerning energy saving at Fukuyama Works

### 3.1 Background of energy-saving activities

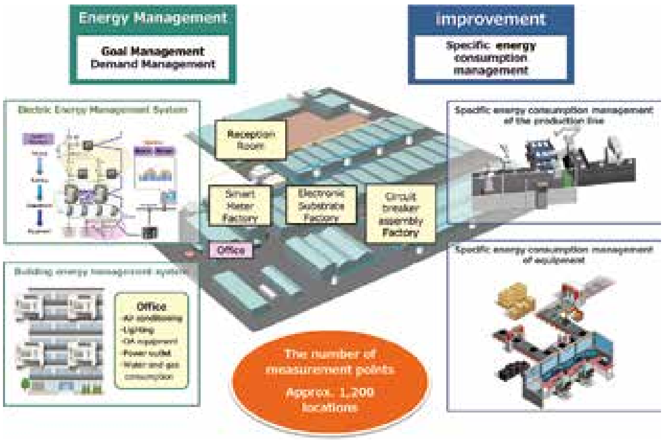
While energy-saving activities have been promoted to comply with the Japan's "Act on the Rational Use of Energy" (i.e., "Energy Conservation Act"), recently, companies are required to continue even more long-term efforts to solve global environmental issues. We have also positioned environmental contribution as an important management issue and formulated "Environmental Vision 2050" to take the initiative in solving environmental issues.

Under these circumstances, aiming to achieve virtually zero $CO_2$ emissions in 2050, we will respect international trends toward the creation of a decarbonized society and promote the reduction of greenhouse-gas emissions throughout the entire value chain—from design and development to raw material procurement, manufacturing, sales, distribution, use, and disposal. To achieve the goal, the Fukuyama Plant is promoting energy conservation by replacing aging facilities with high-efficiency equipment, using renewable energy sources such as solar-power generation, and implementing EM ("energy-loss minimum") activities to detect and reduce energy loss in production activities through the use of FEMS.

### 3.2 Overview of energy saving

The Fukuyama Works aims to both improve productivity and save energy by utilizing control technology from the production-equipment field and measurement technology developed in the field of power distribution and reception. The products that we manufacture are circuit breakers, meters and gauges, smart meters, uninterruptible power supplies (UPS), and energy-saving support equipment, which is installed at various locations around the factory and utilized in energy-saving activities through visualization of sensor data (Figure 2).

**■ Figure 2: Overall diagram of the energy-management system at Fukuyama Works**




Our energy-saving activities are twofold. The first activity is "target management" (i.e., "demand management") that uses measured energy usage to set and manage target values. As for the second activity, we set production lines as role models for energy-saving activities. We then collect their production volumes and measure their energy consumptions and determine their specific consumptions from that data. These activities are then constantly managed by using specific consumption. Moreover, the automatic assembly line for circuit breakers measures energy consumption of each individual facility, collects the production volumes, and correlates production-related data (such as product quality, errors, and results) as an indicator for managing energy consumption. Energy saving through specific consumption management involves four steps: "measuring," "visualizing," "reducing," and "managing." When measuring energy consumption, it is important not only to collect energy-use data on the shop floor but also to collect data in conjunction with production information such as production volume.

In the visualizing step, the measured energy and production information is visualized by using IT, the data is analyzed, points at which energy loss occurs are identified, and those points are handled in the reducing step. In the reducing step, for example, operations are improved by utilizing energy-saving drive products such as inverters and high-efficiency motors, stopping idling of equipment on standby, and optimizing the startup and shutdown of equipment.

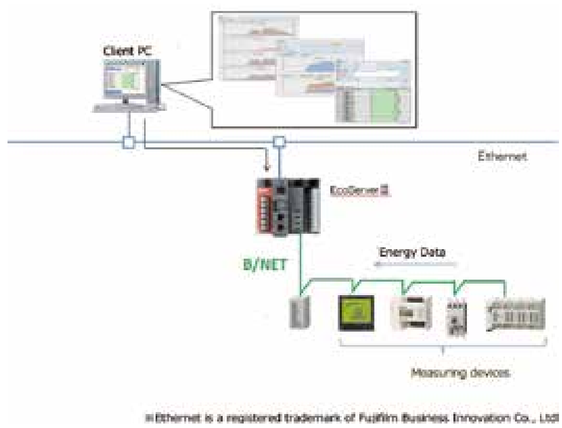
In the managing step, energy usage and specific consumption of lines and equipment are monitored in real time, and those actual values are managed so that they do not exceed the target values. To improve in terms of productivity and energy saving, four consecutive steps, "measuring", "visualizing", "reducing", and "managing," are repeated multiple times along with each PDCA cycle.

Recently, focusing on five key points for energy saving (equipment-start-up time loss, equipment-shutdown time loss, utility time loss, production intensity, and production-loss time ratio), we are utilizing one of our products, "EcoAdviser", an energy-saving analysis-and-diagnosis application equipped with our AI technology, "Maisart" to extract notices of energy loss automatically from data on power consumption and production volume measured and collected at the transformer production line. The insights that we gained from this process have led to energy-saving improvements.

### 3.3 Energy saving through target management (demand management)

Fukuyama Works received ISO14001 "Environmental Management System" certification in 1997, and we started energy-saving activities from that time. Utilizing the ISO 14001 organizational structure, each department manages electricity-consumption targets to ensure that actual results do not exceed the targets. The amount of electricity used at each location is measured by a measuring device at that location, and the measurement information is transmitted to an energy-saving data-collection server (one of our products, EcoServerIII) via B/NET transmission (a field network for power distribution and control of equipment) for data collection. The web-server function of EcoServer III connects to the Fukuyama Work's network system and discloses the collected data on the web server. In this way, we

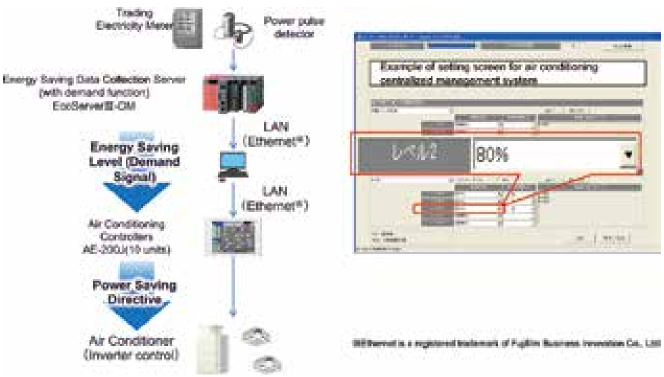
**■ Figure 3: Energy-management system**



have created an environment in which workers can monitor their energy use (Figure 3).

As for management of power demand, electric-power pulses supplied from transactional watt-hour meters of the electricity utility providing our electricity are used, and the number of pulses is imported into EcoServer III, which uses its demand-monitoring function to monitor demand. When the demand reaches the energy-saving level, the energy-saving level is sent as a "demand signal" to AE-200J centralized air-conditioning controllers, which send a "power-saving-operation signal" to inverter-type air-conditioners installed in the factory and offices to achieve automatic energy-saving operation (Figure 4).

■ **Figure 4: Energy-saving control of air-conditioners based on energy-saving level**

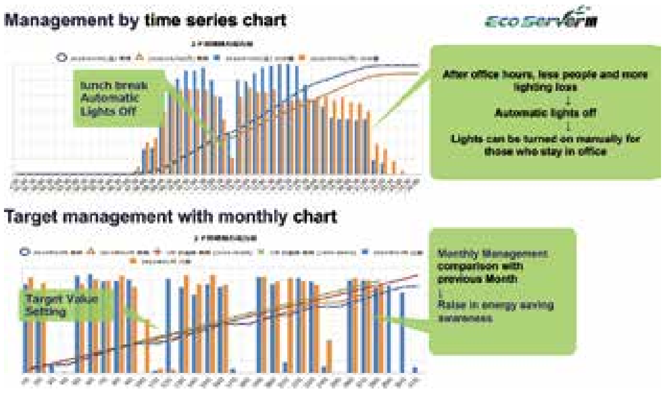



In our five-story office building (General Administration Building), where general affairs, sales, and design staff work, electricity consumption for air-conditioning, lighting, office automation (OA), and outlet circuits on each floor is measured. This measurement information is collected by EcoServerIII and can be checked on the web, so it is possible to manage targets based on the measurement data. Energy-conservation measures cover lighting and air-conditioning; as for the former, lights are turned off before the start of work and during lunch breaks. As for the latter, we are working to ensure "schedule management" (e.g., shutting down operations before and after work hours) and "temperature management" (28°C is the target for air conditioning and 20°C is the target for heating). To avoid going back to the previous energy-conservation (energy saving) measures, the compliance status of the countermeasure-applied operations is checked with the measurement data collected by EcoServer III (Figure 5).

### 3.4 Energy saving through production-intensity management

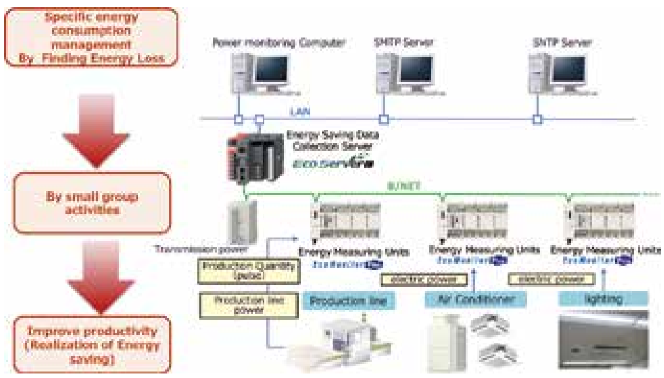
Energy use on production lines increases in proportion with production volume. Managing energy usage only is insufficient to determine whether energy is being used efficiently, so it is necessary to manage trends in energy usage while comparing it with production information. At the Fukuyama Works, we link production volume to energy consumption and practice production-intensity management. On performing production-

■ **Figure 5: Energy management of the office building**



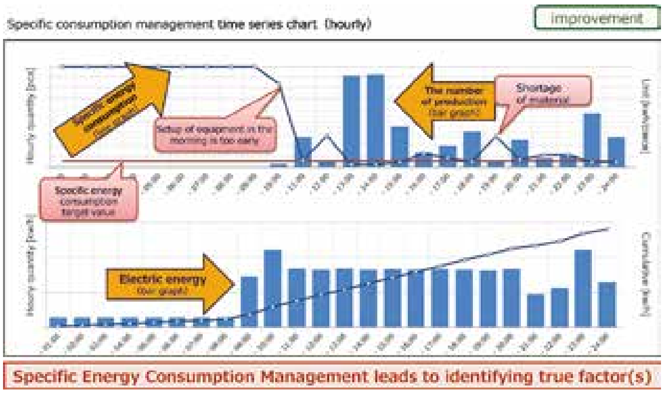

intensity management, we construct energy-saving model lines by targeting lines that are likely to be effective when improvements are made. The targeted lines include lines that consume a lot of energy, lines that can be expected to be expanded laterally after being improved, and lines with significantly fluctuating production volume due to changes in types of products manufactured. A case study of one of these energy-saving model lines, namely, a production line for printed circuit boards in our electronic-module factory, is introduced hereafter. An EcoServer III, the above-described energy-saving data-collection server, is connected to the line, measurement devices are installed at the switchboards of the production line and used to measure the electricity consumption of the entire line, and sensors are installed along the production line and used to collect production figures and visualize production intensity (Figure 6).

■ **Figure 6: Energy-management system for electronic-module factory**



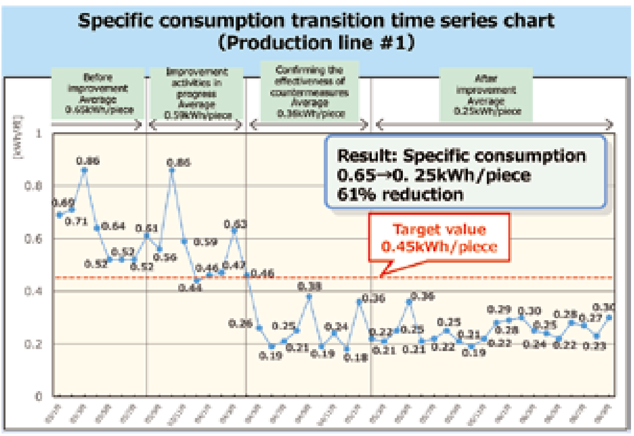

By linking the amount of electricity used on the line with the number of products produced, the energy-management system for our electric-module factory (as shown in Figure 6) manages specific consumption by using the amount of electricity consumed to produce one product (kWh/item) as an index. In small group activities, which are improvement activities undertaken at production sites, we check the temporal fluctuations in production intensity, analyze the factors that exaggerate the points along the line at which the production intensity exceeds the target value, and discover points at which production intensity can be reduced. As shown in Figure 7, items for improvement were hidden at points where specific consumption exceeded the target value, and specific consumption was improved through small group improvement activities.

**■ Figure 7: Example of analysis using production intensity graph**




To reduce specific consumption, it is effective to improve and increase productivity as well as to reduce energy consumption, and by promoting these activities in conjunction with improvement activities at production sites, the efficiency of production lines can be improved. By accumulating improvement activities to address the identified improvement points, we reduced production intensity by 61% compared to before we implemented the small group activities (Figure 8).

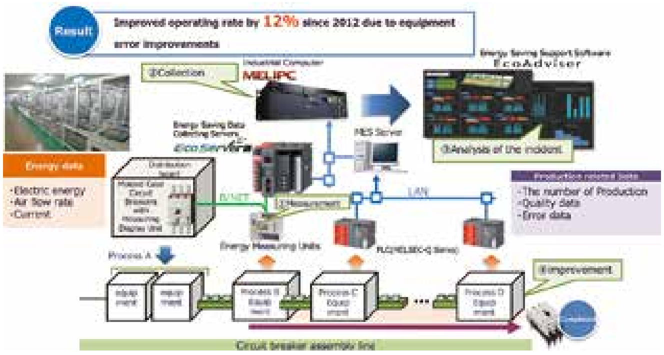
**■ Figure 8: Improvement effect through production-intensity management**




Moreover, by building a system that visualizes energy and production information for each manufacturing facility, we were able to make more detailed improvements in specific consumption, improve productivity, and achieve optimal use of energy. In the above-mentioned case study (as shown in Figures 6 and 7), we implemented production-intensity management on a production line basis, and factors that worsened the consumption rate and improvement measures were identified through small group activities. However, in the case of production intensity management for each line, only rough production information and energy information was available, so it took a huge amount of time and effort to analyze the factors that worsened the production intensity. And it was difficult to identify which piece of equipment in the line was making the production intensity worse (i.e., increasing it).

In 2010, when the automatic-circuit-breaker assembly line was upgraded, we introduced production-intensity management for each piece of equipment comprising the line (as shown in Figure 9). This upgrade allowed us to (i) identify the equipment that was causing the energy-consumption rate to increase immediately and (ii) collect information on production, quality, and equipment errors (short stoppages) from the sequencers used to control that equipment. Then, by comparing the collected data with the production-intensity data, it is possible to analyze the causes of the increase in the production-intensity. As for the features of the energy-management system, energy consumption and production information for each unit comprising the production line is measured. Data on energy consumption is collected and integrated by EcoServer III, and production information collected via the sequencers is collected and integrated by EcoAdviser, an energy-saving support application installed on MELIPC (our industrial computer).

**■ Figure 9: System for collecting energy and production-information from automatic-circuit-breaker assembly line**



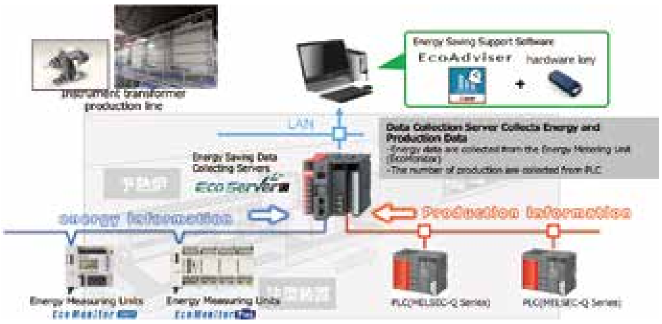

The collected data is displayed as energy and production information on a dashboard, one of EcoAdviser's functions, on a large monitor that is set up on the shop floor, as shown in Figure 10, and the monitor is used to share information with the shop-floor workers. To manage productivity, a ranking of first-pass yield by process and number of "pass" or "failed" products for each process is displayed in a manner that makes it possible to identify bottleneck processes easily. The number of equipment errors and cycle time are also managed, so it is easy to link awareness of processes that need to be improved to improvement actions. As a result of daily improvement activities, production intensity (kW/unit) was reduced by approximately 30% (compared to 2012 figure).

As for a recent initiative, on our transformer production line, as shown in Figure 11, EcoAdviser, the energy-saving analysis and diagnosis application equipped with our AI technology Maisart,

■ **Figure 10: Dashboard of EcoAdviser on the circuit-breaker automatic assembly line**

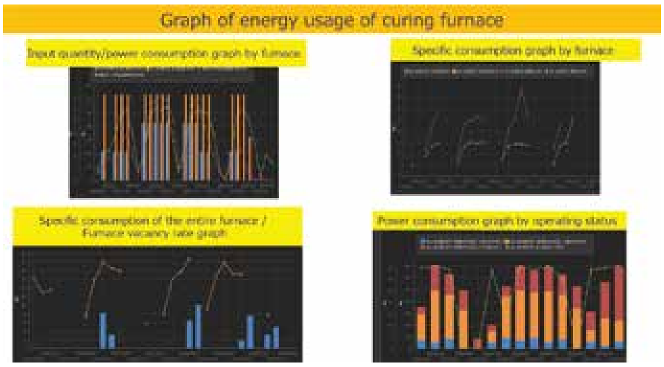
is being used to measure and collect electricity consumption and production volume for each piece of equipment on the production line, automatically diagnose energy loss, and make improvements based on the insights gained from these measurements.

■ **Figure 11: Energy-management system of production line for transformers**




First, from the preheating furnaces, pouring equipment, and curing furnaces on the transformer production line, the curing furnace with the highest electricity usage was selected as the target for improvement. As a step toward improvement, the graph function of EcoAdviser is used to determine the electricity usage of the furnaces from various graphs plotting (1) number of products and energy by furnace, (2) production intensity by furnace, (3) overall production intensity and vacancy rate of the furnace, and (4) energy consumption by operating status as shown in Figure 12.

■ **Figure 12: Graphs for energy-saving operation of curing furnaces**

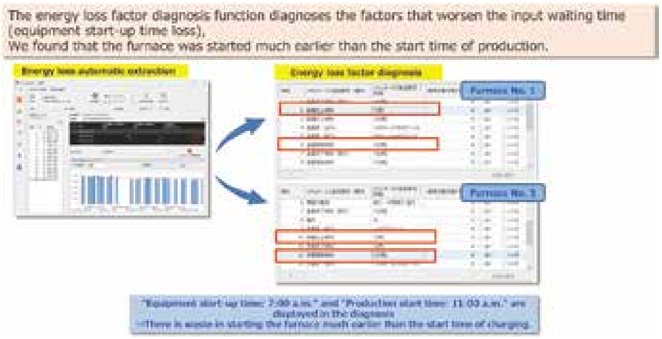



Analyzing the information obtained from the graphs revealed (i) a furnace with poor furnace efficiency (large vacancy rate) and (ii) power loss due to waiting for workpieces to be loaded. These findings have enabled us to improve the efficiency of the production line for transformers.

The "energy-loss automatic-diagnosis function" of EcoAdviser—which focuses on five key energy-saving perspectives (equipment-start-up-time loss, equipment-shutdown-time loss, utility time loss, production intensity, and production-loss time ratio)—is used to automatically extract "energy-loss notices" from the data on amount of energy consumption and production volume for each curing furnace. We focused on two of those perspectives, namely, equipment-start-up-time loss and production intensity, which are the most-common energy losses, and proceeded to understand their current status we determined and analyzed their status as explained hereafter.

As a countermeasure for equipment-start-up-time loss, as shown in Figure 13, we found that the start-up time of the curing furnace was earlier than the production start time. As for production intensity, we found that among several curing furnaces, a particular furnace routinely showed about three-times-higher consumption than that of the others. After checking the on-site curing furnace in question, we found that hot air was leaking from the product-loading door, so we fixed that leak; consequently, we reduced $CO_2$ emissions by approximately 50 tons per year.

■ **Figure 13: Energy-loss diagnosis screen**




## 4. Conclusion

A case study of a factory that uses FEMS to optimize energy use comprehensively throughout the entire factory and reduce energy consumption in the utility and production systems was described. We will continue our efforts as described in this case study to achieve the goal of carbon neutrality by 2050.

＊This article is only a case study of Fukuyama Works, which may not necessarily be applicable to our overseas works.