Improving Ovarall Performance of Factories – Launch of ENERGY CLOUD Factory™ –

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To maintain global competitiveness, it is necessary for companies to not only provide appealing products and services, but also differentiate them in consideration of quality, cost, and delivery (QCD) of energy usage such as the reduction of CO_2 emissions in the process, in addition to QCD of manufacturing.

The ENERGY CLOUD™ Service is a comprehensive energy solution service provided by Mitsubishi Heavy Industries, Ltd. (MHI), and ENERGY CLOUD Factory™ is its factory-focused package. We use AI&IoT technologies to integrate MHI's expertise in manufacturing and energy usage with ENERGY CLOUD Factory™ and have been promoting overall optimization including individual factory optimization and global corporate management for domestic and overseas bases with no limitations from regionalism.

This report introduces the ENERGY CLOUD™ Score, which is a unique KPI (key performance indicator) developed for this purpose, and its related display system.

1. Introduction

Our group manufactures products ranging from the production equipment that forms the backbone of production processes to the power generation equipment that is necessary for production. Through such activities as a manufacturing company, our group possesses various types of manufacturing and energy usage expertise.

In addition, as an effort toward the optimization of manufacturing, each manufacturing site is proceeding with IoT promotion activities. Specifically, the utilization of a scheduler and visualization at a factory level are realized and groups of data scientists that analyze acquired data are organized.

On the other hand, to improve corporate value, generally, it is necessary to objectively grasp the entity's own performance with a KPI. Within our group, we are monitoring manufacturing sites using various KPIs according to the product characteristics of the factory. There is a strong need to utilize KPIs that are objective and comparable between factories to improve factory performance. For this reason, it is generally assumed that many companies have similar needs.

Therefore, by combining various types of manufacturing expertise, which is a strength of our group, with proprietary AI&IoT technologies cultivated through energy solution services, we have independently defined the ENERGY CLOUD™ Score, which is a KPI that enables the comprehensive evaluation of a factory's performance from both aspects of manufacturing and energy. The ENERGY CLOUD™ Score has the following three features.

(1) A KPI that considers not only manufacturing, but also energy use performance.
(2) An objective and global KPI that leads to the extraction and improvement of problems at the manufacturing site and enables performance comparisons between factories.
(3) A KPI that can lead to far-sighted business operations through not only the visualization of

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the current situation, but also prediction.

2. Development of concept and display system of ENERGY CLOUD™ Score

In developing the concept and the display system of the ENERGY CLOUD™ Score, we proceeded with the following steps: (1) setting of the KPI concept and prediction of the future, and (2) systematization. The details are as follows.

2.1 KPI concept and future prediction

Traditionally, both the manufacturing site and utility management department individually worked on the analysis and optimization of manufacturing and energy usage.

In response to that task, we independently defined the ENERGY CLOUD™ Score, which is a comprehensive evaluation KPI that combines manufacturing and energy, and facilitated the evaluation of the comprehensive performance of the factory from both aspects of manufacturing and energy. **Figure 1** shows the concept of the ENERGY CLOUD™ Score.

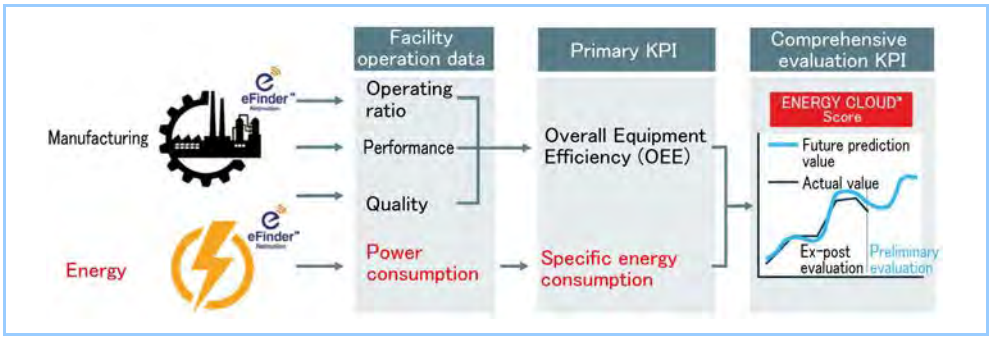

Figure 1 Concept of ENERGY CLOUD™ Score, comprehensive factory evaluation KPI

This ENERGY CLOUD™ Score can be broken down to the KPIs of manufacturing (OEE) and energy (specific energy consumption), which are the component elements, and can lead to the identification of problematic KPIs, ex-post evaluation, and the solving of problems.

The selection of the KPIs of manufacturing and energy is as follows.

2.1.1 KPI of manufacturing

Overall Equipment Efficiency (OEE) was selected for the following reasons.

- OEE is defined as "operating ratio" × "performance" × "quality," and QCD is included in the component elements, facilitating the extraction and improvement of problems at the manufacturing site.
- OEE is an objective KPI prescribed in ISO 22400[(1)], which is an international standard KPI in the manufacturing industry, and is widely applied globally.

2.1.2 KPI of energy

The specific energy consumption was selected for the following reasons.

- The specific energy consumption is the total amount of energy consumption required to produce a unit amount of product, represents the energy efficiency, and facilitates the extraction and improvement of problems in the utility management department.
- The specific energy consumption is an objective KPI prescribed by the Act on the Rational Use of Energy (Japan's energy conservation law).

2.1.3 Future prediction of KPI

Regarding tasks that were in the past handled when they occurred at the manufacturing site or thereafter, the application of prediction technology using AI can lead to the advancement of factory management using preliminary evaluation such as preventive maintenance and operation optimization. As shown in the graph on the right of Figure 1, the future prediction value of the aforementioned KPI was calculated using our unique AI technology which combines our company's manufacturing and energy usage expertise.

2.2 Outline of display system

For the acquisition of the data to calculate the ENERGY CLOUD™ Score, MHPS Control Systems' Netmation eFinder™, which is an easy-to-install IoT tool that can be incorporated

regardless of the equipment type and is ideal for the introduction of AI, was selected.

By utilizing the acquired facility operation data, a system was constructed that displays the actual values and future prediction values of the ENERGY CLOUD™ Score consisting of productivity and energy consumption, realizing ENERGY CLOUD Factory™ (**Figure 2**).

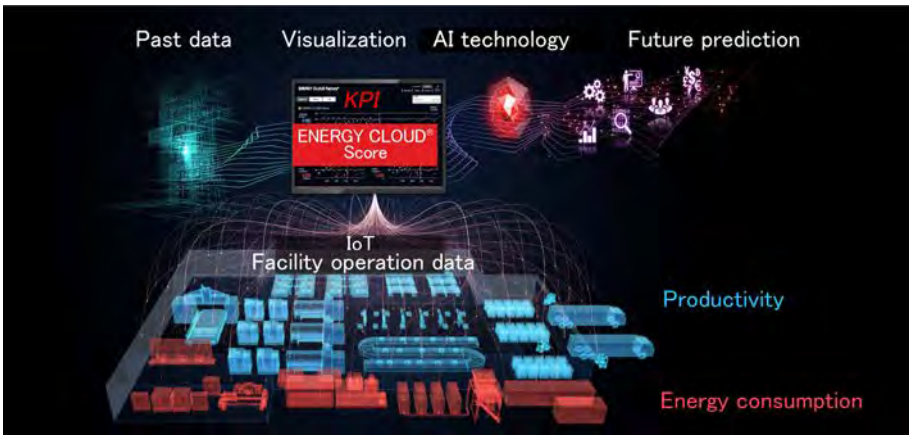

Figure 2 System realizing ENERGY CLOUD Factory™

Among the component elements of OEE, which is a KPI of manufacturing, “the operating ratio” is calculated by dividing the operating time by the load time, and “the performance” is calculated by dividing the net operating time by the operating time.

Figure 3 illustrates how to calculate the load time, the operating time, and the net operating time of the facility from the facility operation data of the Netmation eFinder™. The main power supply current value and the processing signal are measured from the facility as facility operation data by the Netmation eFinder™. For the two signal values, predetermined threshold values for determining the load time, the operating time, and the net operating time are set. The load time, the operation time, and the net operating time can be calculated as the time for which the signal exceeds the threshold value per unit time.

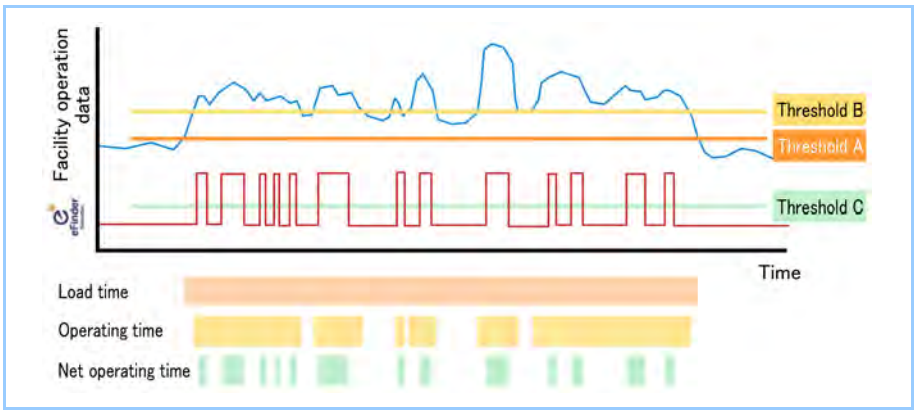

Figure 3 Automatic calculation of load time, operating time, and net operating time

Figure 4 shows the screen of the system displaying the performance of the entire target factory. The screen showing the entire factory displays trend graphs of the ENERGY CLOUD™ Score and its component elements, which are the specific energy consumption and the actual and prediction values of OEE. **Figure 5** shows the screen of the system displaying the status of each facility. The screen showing the status of each facility displays trend graphs of the specific energy consumption, the actual and prediction values of OEE of facilities composing the factory and the actual values of the component elements.

By referring to these screens at the manufacturing site, an in-depth confirmation of which component element affected a change in the value of the ENERGY CLOUD™ Score can be ascertained. Therefore, it is easy to analyze everything from the fluctuation of the entire factory to the confirmation of influencing factors.

In this way, we established the system of ENERGY CLOUD Factory™, which performs and

displays the calculation and future prediction of the factory's KPI to indicate the ENERGY CLOUD™ Score, a KPI that visualizes comprehensive performance objectively from both aspects of manufacturing and energy.

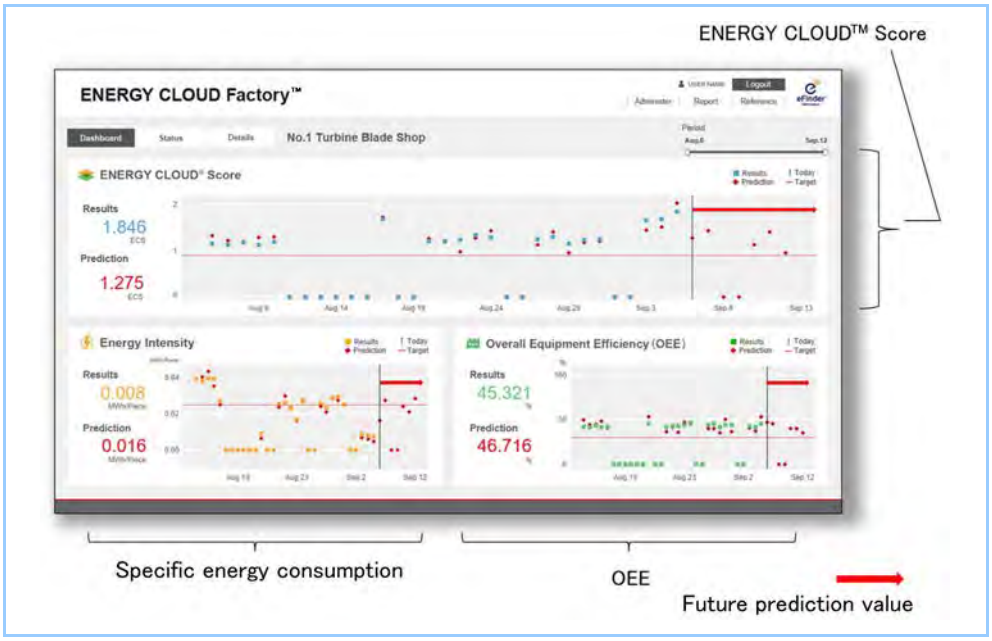

Figure 4 ENERGY CLOUD Factory™ display system (entire factory)

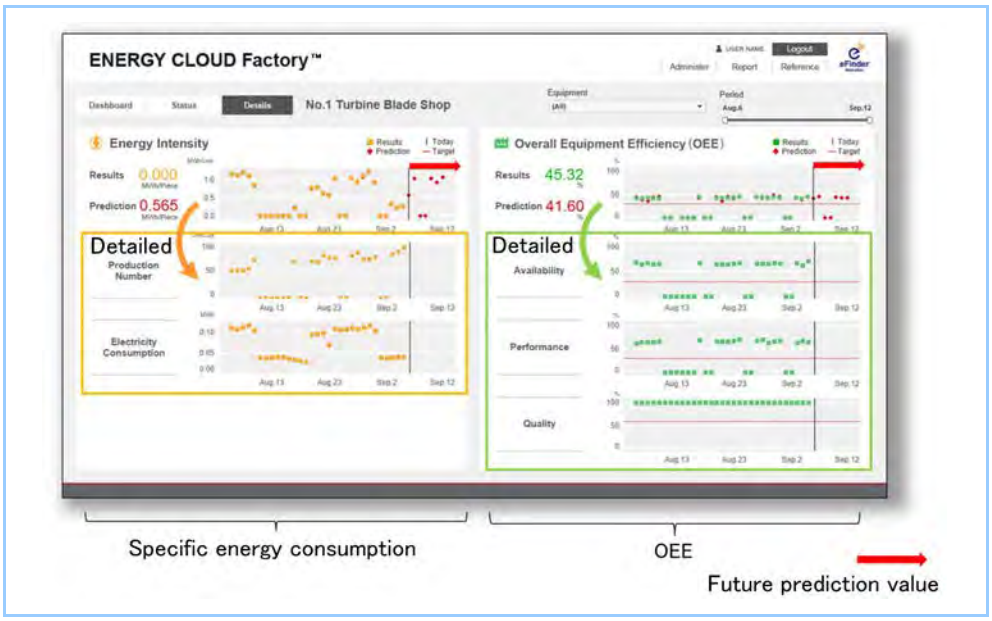

Figure 5 ENERGY CLOUD Factory™ display system (each facility)

3. Verification of ENERGY CLOUD™ Score

To evaluate the effectiveness of the ENERGY CLOUD™ Score, verification was performed at Mitsubishi Heavy Industries Aero Engines, Ltd. (MHIAEL), which manufactures and assembles aircraft engines.

MHIAEL has been working on acquiring manufacturing data utilizing IoT, and has abundant manufacturing data in its possession. Utilizing this data and opinions from actual manufacturing sites, we worked on the improvement of productivity and energy cost reduction using the ENERGY CLOUD™ Score.

The verification target was the machining process. This process consists of multiple machining facilities, and after the completion of the process, a machining quality judgment test is implemented.

We installed Netmation eFinder™ on the main power supply, spindle power supply, etc., of

these machining facilities, acquired facility operation data and verified how to utilize the actual and future prediction values of the ENERGY CLOUD™ Score.

(1) Utilization of actual values

By comparing the change of OEE constituting the ENERGY CLOUD™ Score with the operation data of the facility, the standby state of the facility in which the power supply of the equipment is turned on but no processing is performed could be visualized. By shortening these unnecessary standby times, it was found that the shortening of the lead time and the reduction of energy cost could be expected.

(2) Utilization of future prediction values

Among the KPIs of operating ratio, performance and quality, which are component elements of the ENERGY CLOUD™ Score, the prediction of the quality KPI was focused on because it was highly demanded by the manufacturing site.

The quality prediction model can be obtained by analyzing facility operation data and inspection result data. The quality prediction model can predict the degree to which the processing target is determined to be good or bad after processing. By incorporating this quality prediction model into the system, the degree of good or bad judgment can be derived as a quality KPI. The system can list the predicted value of the quality KPI and facilities with a strong correlation therewith. Engineers can prioritize efforts to solve problems such as the improvement of the quality of the listed facilities, which leads to the improvement of productivity.

As mentioned above, we were able to determine that the measured values and future prediction values of the ENERGY CLOUD™ Score can contribute to energy cost reduction and the improvement of productivity.

4. Conclusion

We defined the ENERGY CLOUD™ Score, which combines manufacturing and energy using unique AI&IoT technologies, developed the display system as "ENERGY CLOUD Factory™," and verified them at a factory of our group company.

We will continue to introduce "ENERGY CLOUD Factory™" to several factories within our group and evaluate its effectiveness by applying the ENERGY CLOUD™ Score to various manufacturing sites. In parallel, we will promote the incorporation of new KPIs that will be effective, as well as the development of global optimum evaluation across multiple plants as new solution services.

In addition, we are preparing to provide our customers' factories with the knowledge gained through the efforts at our group factories, aiming to contribute to the overall optimization of manufacturing and energy at as many factories as possible.

References

(1) ISO- 22400 :2014