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Energy Conservation Activities with Participation by All Employees through Realization of Energy Visualization

Toyota Motor Corporation
Plant Engineering Department
Energy Efficiency Visualization Working Group

◎ **Keywords** **Energy management system for each facility**
Rationalization of conversion of heat to motive power, etc.

◎ Outline of Theme

The choice of the most appropriate operation method for motive power equipment is infinite due to the diverse conditions, and it is difficult to judge which operation to use.
Accordingly, software was created that was able to display the equipment efficiency, CO_2, and costs in real time, and a system was introduced in the operation departments that allowed on-location visualization of the results of choosing the most appropriate operation combination and improving the operation methods in response to the demand. Further, using this system, the creation of a program relating to the Plan → Do → Check → Action (PDCA) cycle of "Establish Operation Plan → Implement Operation → Check Efficiency, CO_2 and Costs → Propose Improvements" could be developed in the motive power operation departments of each plant. This improvement allowed a large energy conservation result to be attained, and the measures and activities are introduced here.

◎ Implementation Period for the Said Example

- Project Planning Period January 2007 – March 2007 Total of 3 months
- Measures Implementation Period April 2007 – March 2008 Total of 12 months
- Measures Effect Confirmation Period April 2007 – March 2008 Total of 12 months

◎ Outline of the Business Establishment

- Scope of Business Manufacture of automobiles
- No. of Employees 69,478 persons

- Type 1 designated energy management factory

1. Reasons for Theme Selection

The mission of the operation departments is to minimize the CO_2 and costs for each intensity under the primary role to supply energy with care of quality. In January 2005, the motive power departments were integrated (Fig. 1) to implement concentrated operation and monitoring of 12 plants under the Toyota Energy Control System (TECS) (See below). Previously, efficiency management and improvements had been repeatedly implemented to achieve the CO_2 reduction targets, but there had been no end to the improvements, so this was again taken up as a key issue of the fiscal 2007 department policy, in which the departments decided to strive to realize further improvements.

◆ Fiscal year 2007 department policy “Establishment of High Efficiency Motive Power Operation Control responding to Production Amounts”

◆ Activities that were actually implemented

① Loading Prediction based on the Production Plan
② Operation Know-how Analysis and Visualization of Each Energy Type
③ Clarification and Systemization of the Operator Operation Processes
④ Determination of the Operation Methods using Operation Simulations
⑤ Creation of Daily Operation Progress and Effects

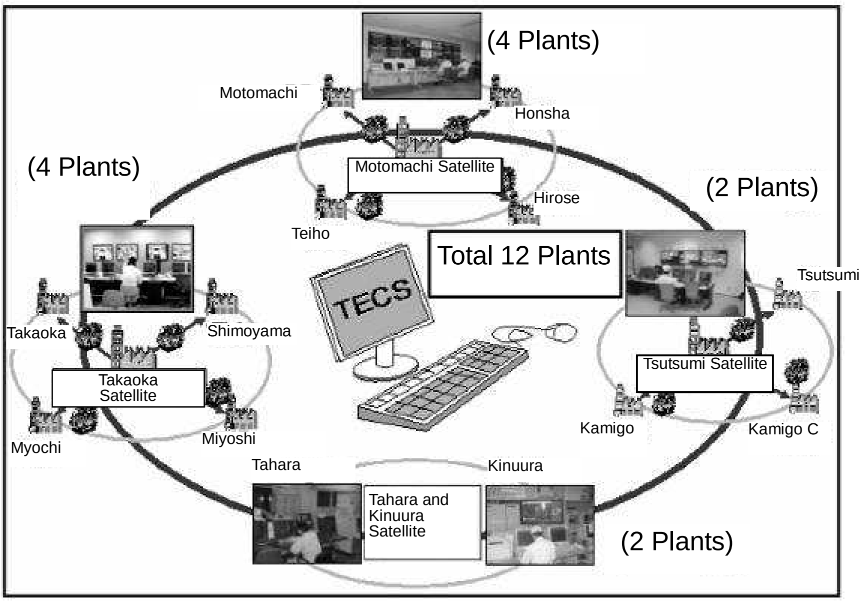


Fig. 1 Integration of Motive Power Departments

◆ Outline of TECS

The Toyota Energy Control System (TECS) is a system that monitors the automatic operation and remote operation of the (2 Plant) electric power and steam energy-supplying equipment and the air conditioning equipment. The system was first introduced in the latter half of the 1970s, and by currently implementing concentrated monitoring at satellite factories in 4 locations, it is planned to further reduce the number of persons required.

2. Progress of Activities

(1) Target Settings

Under the "Fourth Toyota Environmental Action Plan", the CO2 emissions target achieved by fiscal year 2010 was set at a 1,680,000 t-CO2, which is reduction of 20% compared with below the fiscal year 1990 level. In the fiscal year 2006, 1,600,000 t-CO2 had already been achieved, so currently, in response to worldwide global warming prevention measures, it is planned to review the targets, as additional emission reduction activities will be essential. In the Toyota's "motive power department", the reduction targets are being set higher each year.

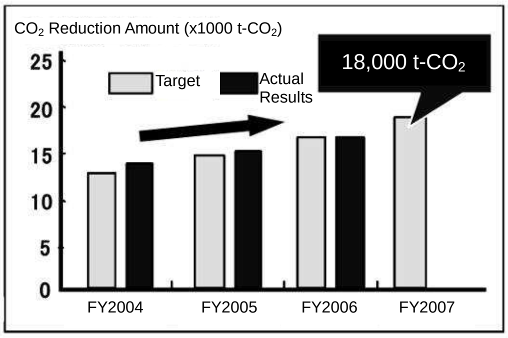


Fig. 2 Reduction Targets and Actual Results

The target for fiscal year 2007 was a reduction of 18,000 t-CO2, which is a 1,000 t greater reduction target than the fiscal year 2006 values. (Fig. 2)

(2) Background to Motive Power Work Place

Following the integration, although the energy indexes (Motive power monthly reports) of all 12 plants had been standardized to allow comparison, there was a difference in the degree of enthusiasm for the system in each plant, and it was a period when it was necessary to jointly share the operation know-how and improvement processes.

(3) Implementation Structure

As a specially assigned project for all the 12 plant operation departments, 20 members were selected and an "Energy Efficiency Visualization Working Group" (known below as the WG) was established.

(4) Understanding of Current Situation

Using the remote operation monitoring and the daily report and monthly report tabulation realized by the TECS, efficient control of the motive power equipment is being implemented. In each plant, a loading prediction-optimized operation system has been introduced to the automatic control system and other parts so that the operator can implement “various settings” and can “judge the operation/halting” to carry out “Best Mix” operation.

◆ About the “Best Mix” operation in this company

“Best Mix” operation means carrying out the combination and loading assignment among several pieces of cogeneration equipment and boiler equipment relating to the electric power and steam that is to be supplied, in order to minimize the CO_2 intensity and operation costs.

(5) Analysis of Current Situation

As the WG investigation case study, an investigation was carried out into the situation in October 2006 when the Honsha Plant No. 2 Cogenerator suddenly halted. During normal operation, the cost index for each ton of steam was 100, and the CO_2 emission amount was 0.18 t-CO_2. However, when the cogenerator suddenly halted, it was found that due to the backup operation methods the operator had to choose between prioritizing CO_2 and prioritizing the stable supply, and there was a variation of 28 in the cost index and 0.02 t-CO_2 in the CO_2 emission amounts. This was an example of a case where the work standards had not been determined in a situation that differed from the normal operation patterns. (Fig. 3)

Problem Area (1): The Best Mix Operation has not been visualized.

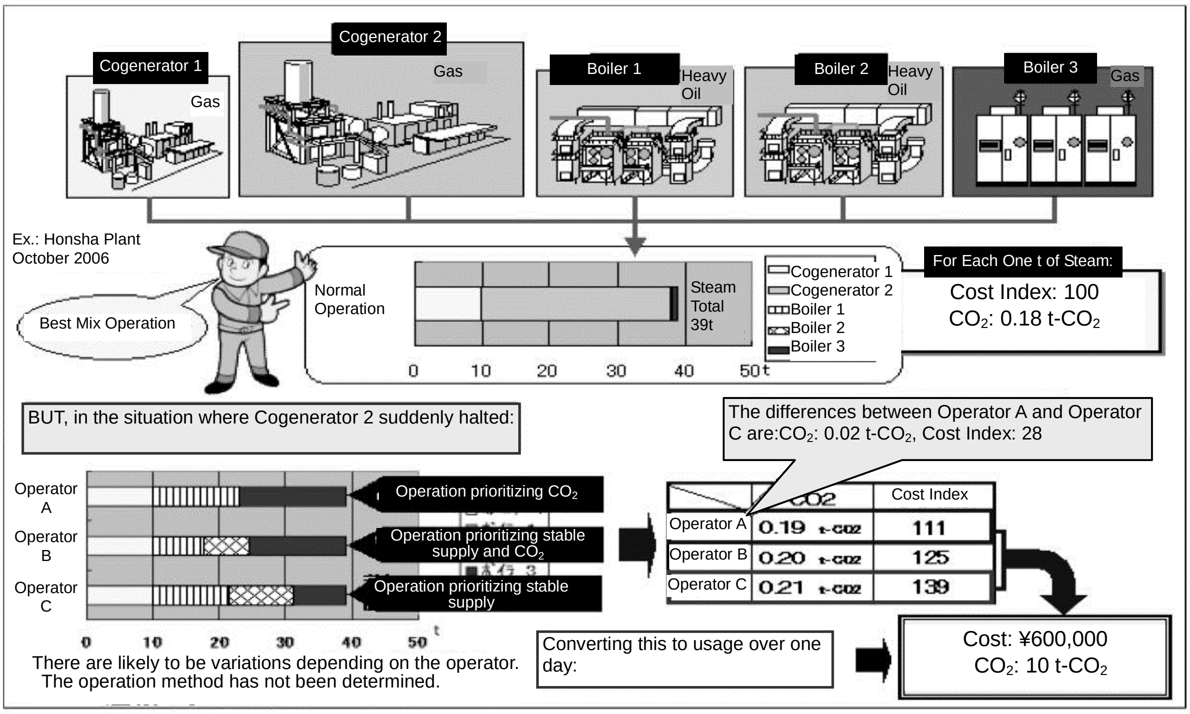


Fig. 3 Honsha Plant: Example of Situation where Cogenerator 2 Suddenly Halted

Additionally, as a result of investigating the operation control cycle in each plant, the following problem areas were found.

1) Because the P (Plan) is usually created through planning by experienced veteran employees, the ways of thinking are not being conveyed to the younger workers.

2) Because the D (Do) operation is carried out in a condition where the operator can not visualize the Best Mix, there is no feeling of achieving the Best Mix.

3) Because the C (Check) efficiency calculations are not carried out until the end of the day or the month, it is not possible to understand the situation in daily or hourly units.

4) Because the A (Action) improvement takes place one month after the discovery, the improvements can not be made in a timely manner.

Problem Area (2): The operation control PDCA cycle is not operating.

(6) Measures (1): Introduction of a "Visualization System"

For CO_2 and costs, too, if the operator could make judgments in real time, they would be able to respond swiftly, and they would have a greater feeling of achieving the Best Mix. Accordingly, we focused our attention on the Prius Fuel Consumption Monitor (Fig. 4).

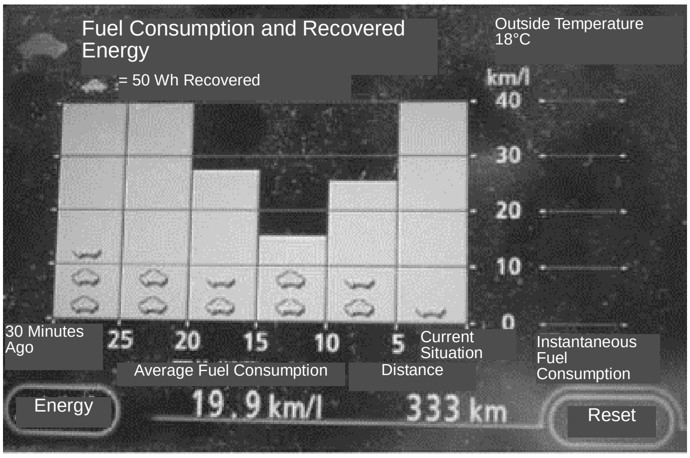


Fig. 4 Fuel Consumption Monitoring Screen

We believed that if the results of the motive power equipment could also be swiftly judged it would be possible to visualize improvement topics that had previously been overlooked.

1) Benchmarks

Efficiency control systems are being developed by many system manufacturing companies, and realize visualization in a variety of forms. However, if the manufacturing had been outsourced, the cost would have been so expensive that the outsourcing expenses would have greatly increased. It was therefore decided unanimously among all the group members to try to manufacture the entire system in-house. Concerning the decision to manufacture everything in-house, an opinion was expressed that "Unless we clarify the results that we want to see, the output will not be of practical use", and the required graphic displays and functions were contributed jointly.

2) System display and function items (Fig. 5)

① Data should be viewable in any location using the in-house LAN.
② By specifying the date, comparison with past data should be possible.
③ The loading allocation condition for all the loading should be understood.
④ The profit and loss of the costs should be understood.
⑤ The CO_2 and cost intensities for each equipment unit should be understood.

⑥ The CO_2 reduction amount should be understood.

⑦ The comprehensive intensity should be understood.

⑧ Daily changes regarding the monthly targets should be understood.

The data collection devices use the existing TECS system, and software was created to read in the energy data every hour

The equipment loading situation, efficiency, CO_2 and costs are shown as “Daily Reports” and “Monthly Reports” in real time

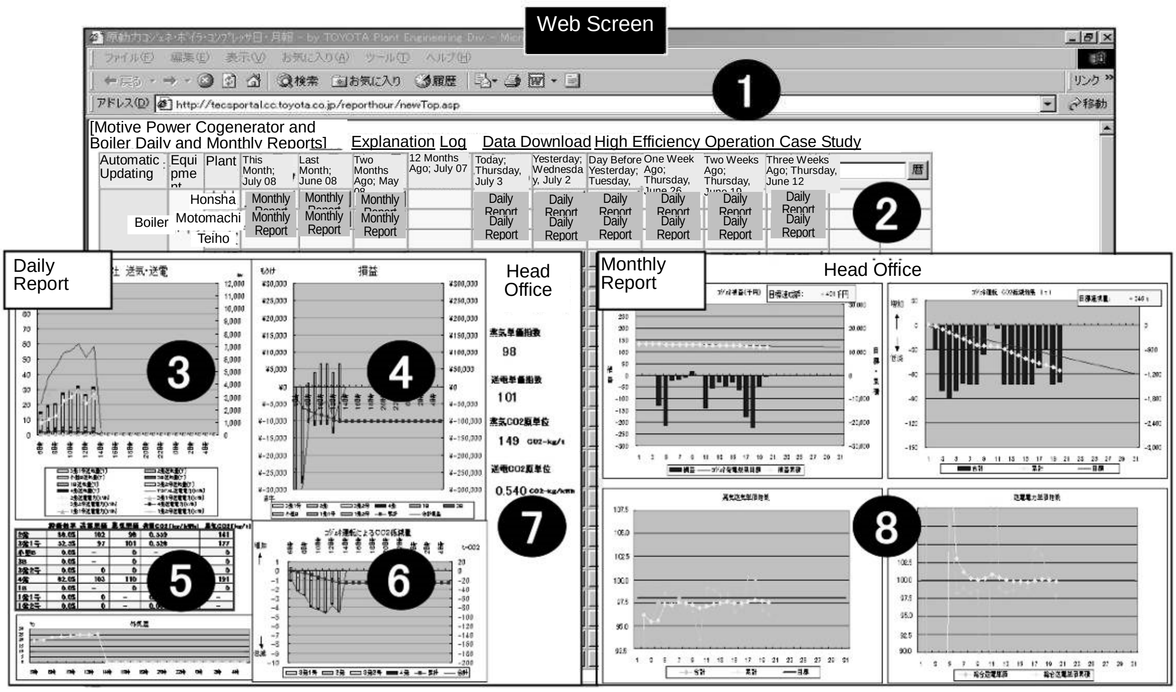


Fig 5 Screen Data of the Visualization System

(7) Measures (2): Activities to Adopt PDCA and Implement Human Resource Training in the Operation Departments

In each plant, a conventional way of working (work culture) had been ingrained, and initially none of work places made use of the “visualization system” by merely showing it on the exclusive monitor. Accordingly, an investigation meeting was implemented by the WG and activities were carried out to promote the system adoption.

1) Implementation of efficiency control explanatory meeting

Regarding the “Plan → Do → Check → Action” for the efficiency control, it was planned to carry out development as daily routine work.
First, regarding “Plan”, an operation plan is established for each month, and the operation pattern is determined referring to the “Production information, seasonal loading change prediction, and the primary energy unit cost, etc.” This is a good opportunity for younger operators to study the veteran operators’ way of thinking. Next, regarding “Do”, operation is implemented following the plan. Then, in “Check”, the operating efficiency, CO_2 and cost results are confirmed for each hour and each day. Finally, in “Action”, the next day’s and next month’s operation plans are influenced by the results. The WG members visited each of the plants and explained the above contents to all 170 target operators until they were completely satisfied.

2) Implementation of a skills festival

In August, a Best Mix Operation Simulation Meeting using the “Visualization System” was implemented in the motive power departments. The large-scale meeting of operators selected from each of the plants comprised 80 persons including related staff in a large-scale event. The related plant staff were even more enthusiastic than the operators themselves, and when the results of the judging were announced large cheers were heard from each plant. Comments were made by the participants that “We’ll win next year...” (Figs. 6 and 7)

Fig. 6 Selected Operators

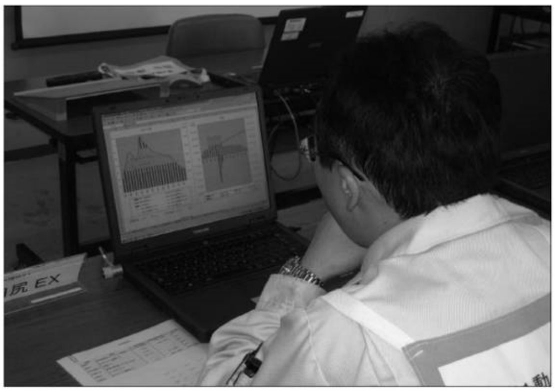


Fig. 7 View of Meeting Situation

3) Implementation of improvement presentations

Efficiency Improvement Case Study Presentations using the “Visualization System” were held in each plant in turn. At the presentations, it was planned to meet in a similar way with operators in the work place of each product and have interchanges to carry out investigations relating to improvement ideas and differences in equipment configurations in order that horizontal developments could be made in each plant.

Although initially there were few improvement proposals, a sudden increase in the number began to be observed after August 2007, and by the time activities reached their full potential 150 proposals were received by the end of the fiscal year in March 2008. Out of these, 17 were selected as outstanding proposals (Fig. 8) and were implemented as points for change in the motive power work places. Next, several of the outstanding proposals were selected as improvement case studies for the Honsha Plant and were explained following the Plan → Do → Check → Action cycle.

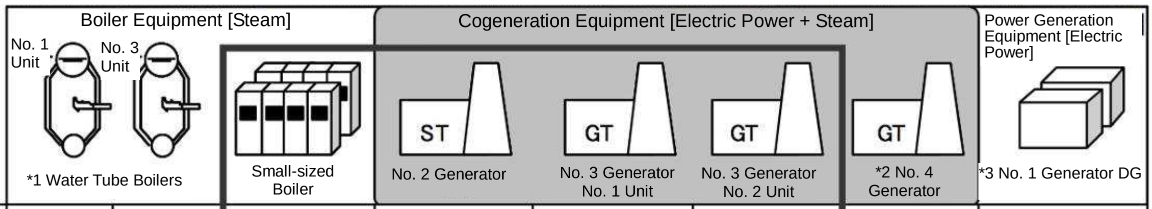
Plant	Year/ Month	Improvement Proposal Title	CO_2 (t-CO_2/year)	Amount (x¥10,000/year)	System Display/Function in which Proposal was Practically Used
Kamigo	07/8	Change to Timely Steam Supply to Machine Plant	240	596	⑤ ⑧
Takaoka	07/9	Review of Cogeneration Usage Method over the Medium Term	264	672	② ③ ⑤ ⑧
Myochi	07/9	Night Shift Startup Method Establishment Improvement	74	143	③ ④ ⑧
Honsha	07/10	CO_2 and Cost Reductions due to Medium Term Operation Pattern Changing	229	3816	② ③ ⑤ ⑧
Shimoyama	07/10	No. 2 Power Generating Station Power Generation Amount Adjusting Work Improvement	46	127	③ ⑤ ⑧
Miyoshi	07/11	Energy Conservation due to Changing Gas Turbine Startup Time	144	336	③ ⑧
Tahara	07/11	No. 3 Power Generating Station Aspirated Cooler Stable Operation	43	248	④ ⑤
Motomachi	07/12	Boiler Supply Pump Electric Power Consumption Reduction	132	155	⑤
Kinuura	07/12	Boiler Holiday Operation Method Improvement	72	204	③ ⑧
Tsutsumi	08/1	Gas Engine Operation Efficiency Improvement	900	896	③ ⑤ ⑧

Fig. 8 Details of Outstanding Proposals

(8) Improvement Case Studies due to Utilization of the “Visualization System”

An equipment outline under the theme name “CO_2 and Cost Reductions due to Medium Term Period Operation Pattern Changing” is as shown in Fig. 9. The medium term operation is supported by four equipment units. Operation is based on the Generator 3 No. 1 and 2 units, while the Generator No. 2 and small-sized boiler are used for loading adjustment.

* 1: Only operate in wintertime * 2: During regular inspection * 3: Operates when responding to electric power demand
* 4: Reduction amount with regard to standard CO_2 (Steam: Water tube boiler, Electric power: Purchased electric power)



	Boiler Equipment [Steam]			Cogeneration Equipment [Electric Power + Steam]				Power Generation Equipment [Electric Power]
	*1 Water Tube Boilers: No. 1 Unit	*1 Water Tube Boilers: No. 3 Unit	Small-sized Boiler	No. 2 Generator	No. 3 Generator No. 1 Unit	No. 3 Generator No. 2 Unit	*2 No. 4 Generator	*3 No. 1 Generator DG
Fuel	LSA	LSA	LNG	LNG	LNG	Kerosene	LNG	LSA
Steam	30 t	30 t	35 t	30 t	11 t	1 t	1 t	—
Electric Power	—		—	4800 kW	4100 kW	290 kW	290 kW	3000 kW
*4 CO_2 Reduction Amount	Standard		-0.07 t/t	-0.13 t/t	-0.18 t/t	-0.08 t/t	-0.10 t/t	+0.17 t/kWh

Fig. 9 Honsha Plant Equipment Overview

1) Plan: Operation plan

The plan between the latter half of September and the first half of October is shown in Fig. 10. The equipment operation priority is from the units that have the greatest CO_2 reduction amounts, so that the order is No. 3 Generator No. 1 Unit > No. 2 Generator > No. 3 Generator No. 2 Unit > Small-sized Boiler. However, for the nighttime bands (10 p.m. to 6 a.m.), while securing the minimum loading (13t) of the No.2 Generator, the overall efficiency of the No. 3 Generator No. 1 Unit has its output adjusted so that it does not fall into extremes.

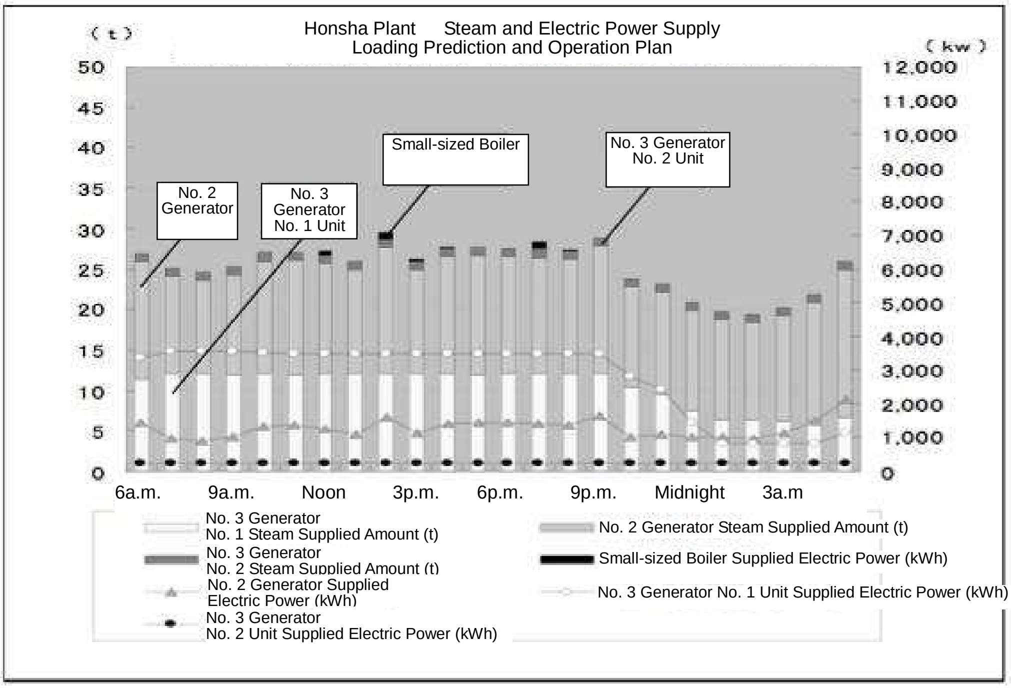
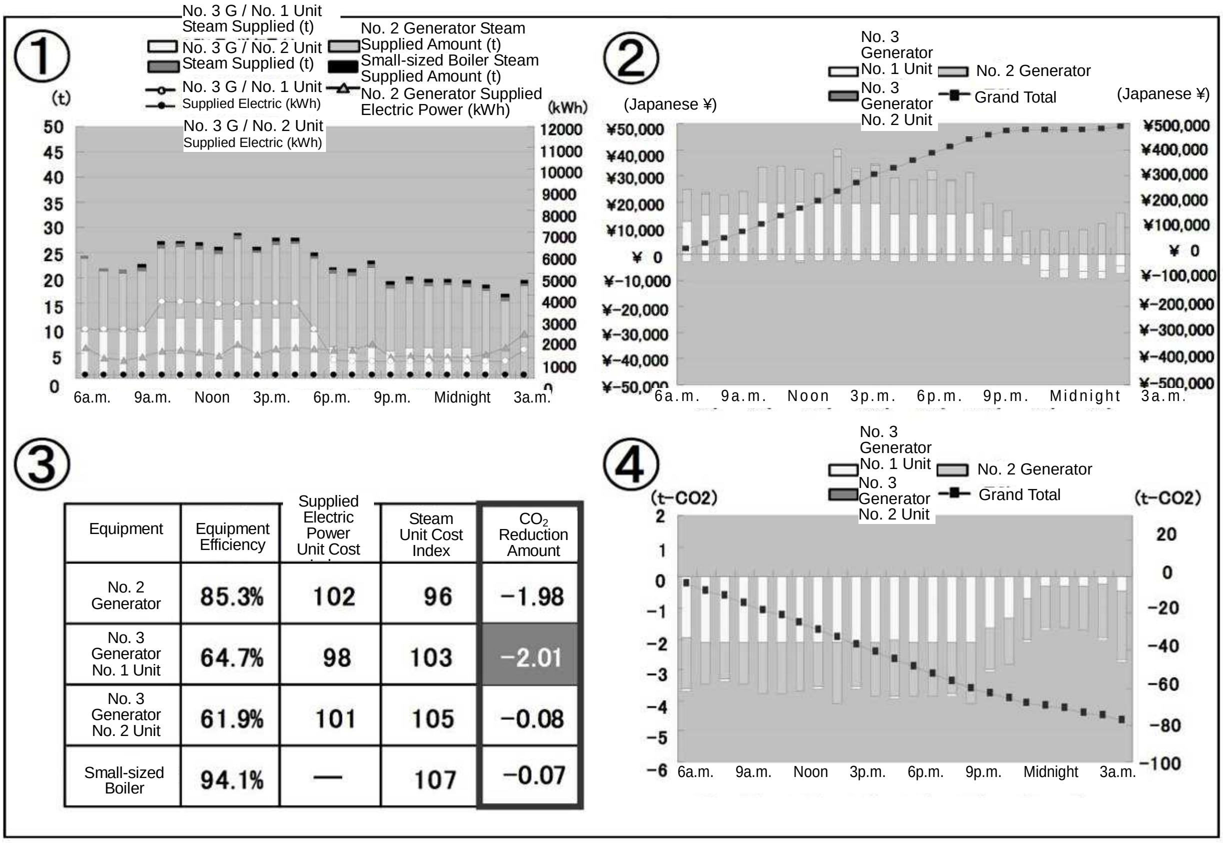


Fig. 10 Loading Prediction and Operation Plan

2) Do: Operation implementation

In the “Daily Report”, time unit monitoring is used to confirm each item including ① each equipment unit loading allocation situation, ② cost profit or loss, ③ efficiency, CO_2, and cost of each equipment unit, and ④ CO_2 reduction amounts. (Fig. 11)



Equipment	Equipment Efficiency	Supplied Electric Power Unit Cost	Steam Unit Cost Index	CO_2 Reduction Amount
No. 2 Generator	85.3%	102	96	−1.98
No. 3 Generator No. 1 Unit	64.7%	98	103	−2.01
No. 3 Generator No. 2 Unit	61.9%	101	105	−0.08
Small-sized Boiler	94.1%	—	107	−0.07

Fig. 11 Change Data for Each Hour in the “Daily Report”

In the “Monthly Report”, as the daily administration to achieve the monthly targets, judgment is carried out of whether the CO_2 reduction amount and steam unit cost targets are being realized. At the graph’s point in time at September 20 the monthly targets were in the process of being realized. (Fig. 12) The characteristics of the graph enable good or bad judgment to be made concerning the totals of the target lines, and the target lines are based on the previous year’s data.

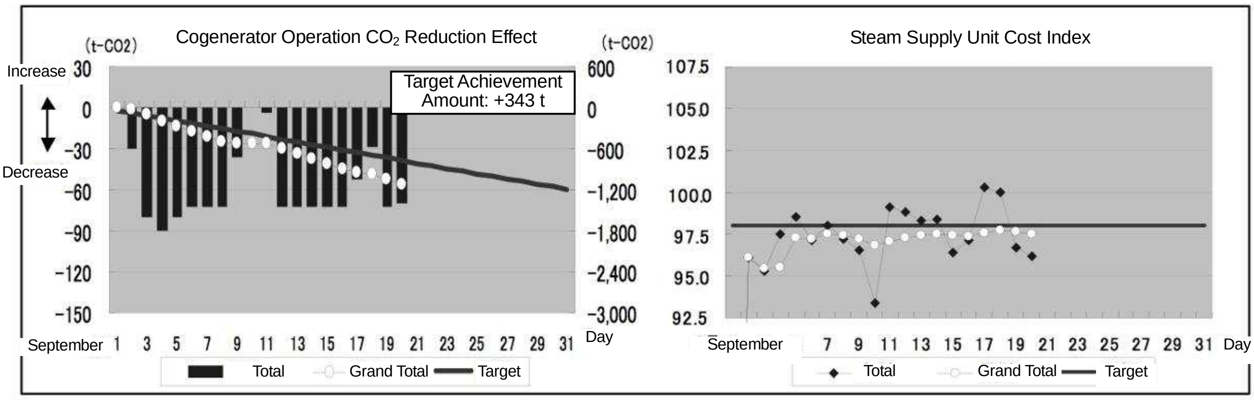


Fig. 12 Change Data for Each Day in the 'Monthly Report"

3) Check: Efficiency, CO_2 and cost checking

After entering October, there were two consecutive days in which the various targets of the "Daily Report" and "Monthly Report" control were not achieved. Looking at the "Daily Report" in detail, there was a situation where the efficiencies of the No. 2 Generator and the No. 3 Generator No. 1 Unit were mutually declining. (Fig. 13)

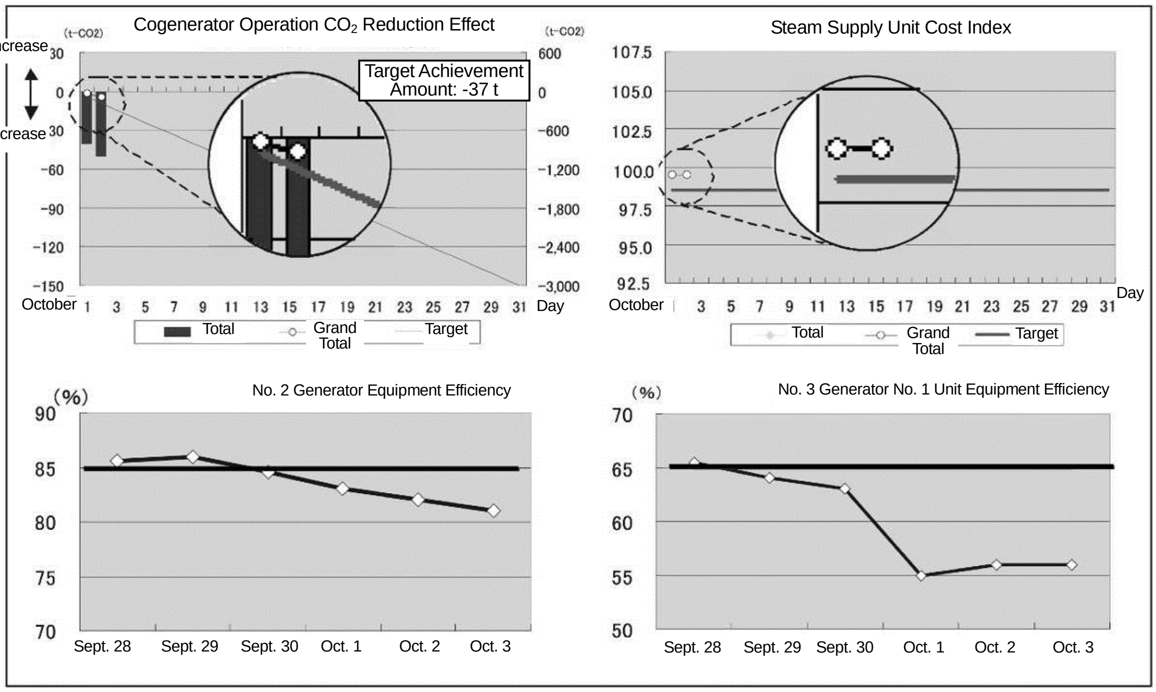


Fig. 13 Each Type of Unrealized Target

Compared with the anticipated loading, the steam loading became 70t less for each day from October 1. Concerning the change points, there was a reduction in the air cooling loading and a reduction in the production amount.

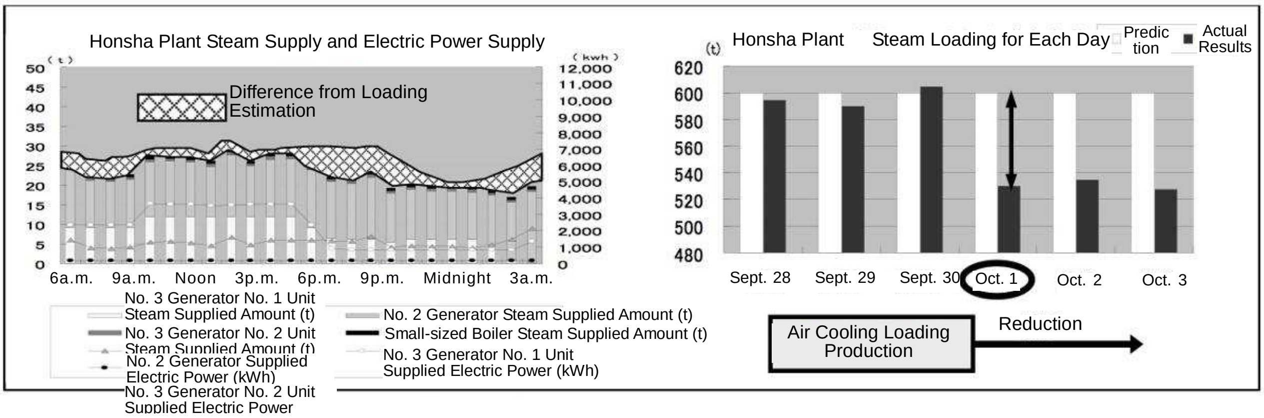


Fig. 14 Investigation of Causes of Not Achieving the Targets

4) Action: Improvement

As the resolution measure for the short in achieving the target, a proposal was made to carry out cogenerator streamlining due to the fact that there had been a reduction in demand for electric power since the beginning of October. Making practical use of past data, simulations were carried out of the operation patterns, and from among these patterns it was decided to choose Proposal B, consisting of “Based on No. 2 Generator, with Loading Adjustment using the Small-sized Boiler”, which was found to be best both for CO_2 and for costs. (Fig. 15)

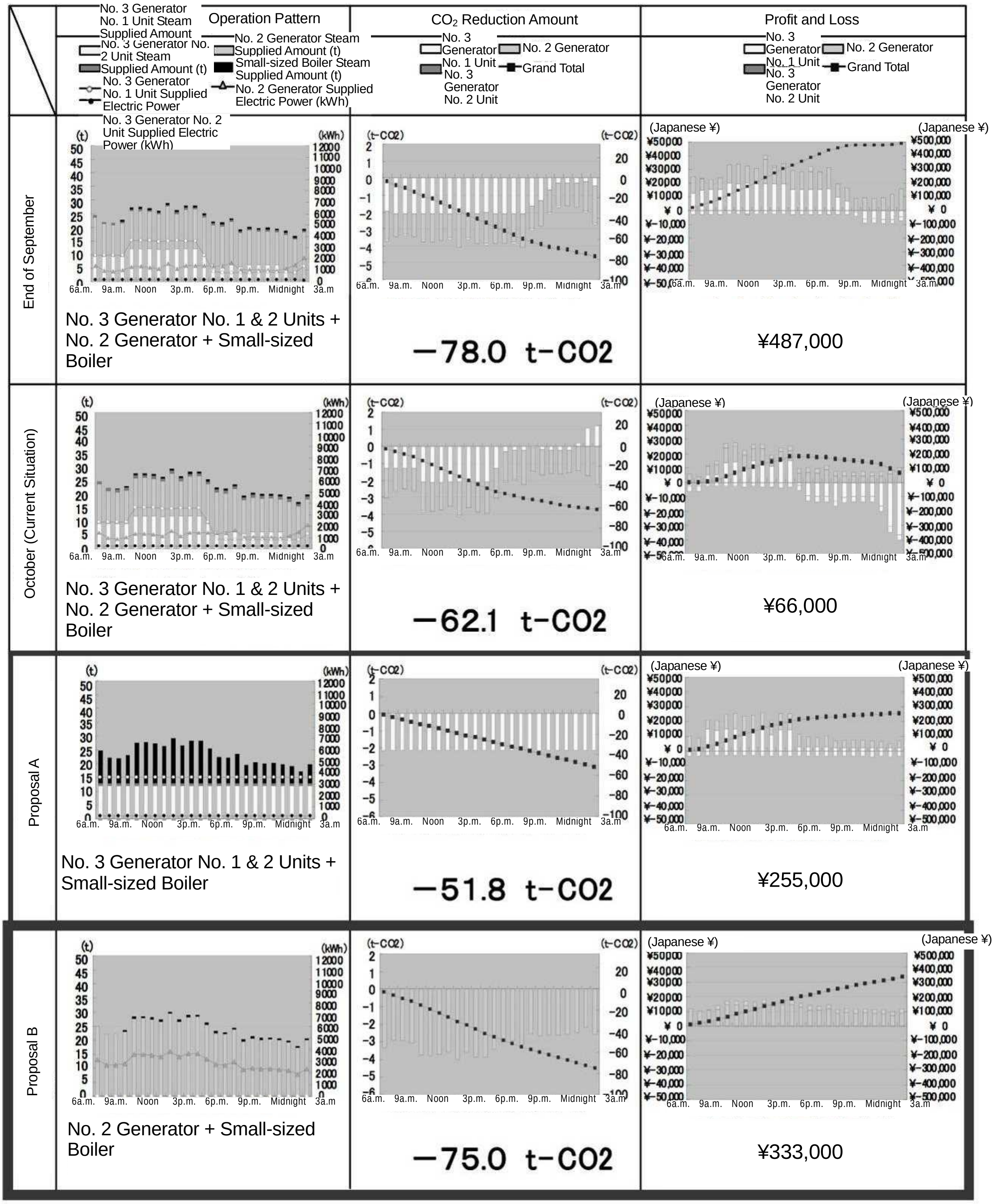


Fig. 15 Cogenerator Streamlining Proposal

Although it was previously believed that the cogenerators should be operated in series, under the current conditions of production reduction (Steam loading reduction) and the substantial rise in fuel prices, it was possible to verify the practicality of using the visualization system to allow units to be selected in this way. In addition, because the use of the system allowed prompt confirmation of the results from the CO_2 and cost points of view, the improvement speed has become faster.

As a result of the improvement effect of this case study, the CO_2 reduction amount was 229 t-CO_2/year and the cost savings were ¥38,190,000/year.

(9) Effects Achieved after Implementing Measures

The development of energy control using the “Visualization System” achieved a reform of operator awareness and reactivation of energy conservation proposals, so that in fiscal year 2007 the CO_2 reduction amount for all 12 plants was 23,000 t-CO_2/year, which was 5,000 t-CO_2/year greater than the target amount. (Fig. 16) The cost reductions were ¥509 million/year.

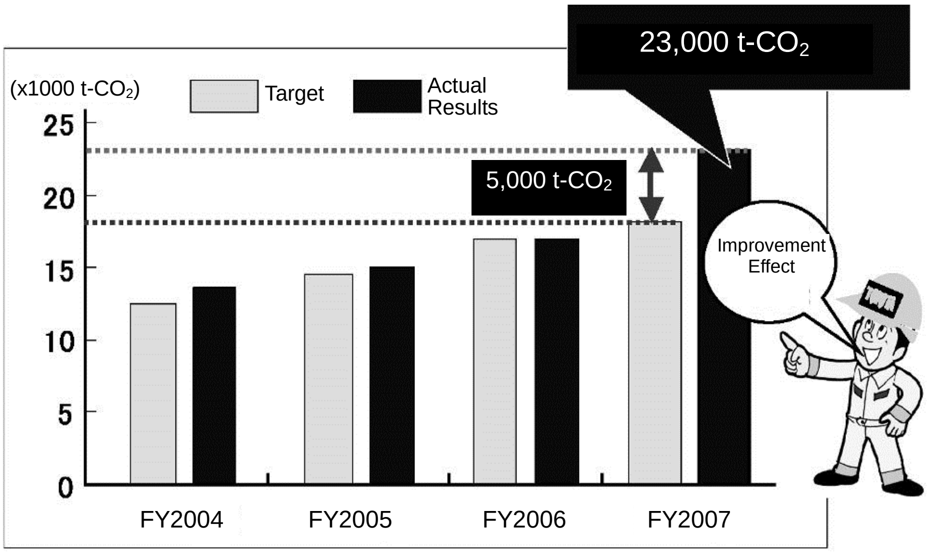


Fig. 16 Actual Results of Fiscal Year 2007 CO_2 Reduction Activities

3. Summary

Through the “Energy Efficiency Visualization Working Group” comprising 20 members gathered from the various plant operation departments together with the operators in each plant, activities were carried out to realize a large target with the participation of all employees, and it was possible to achieve a large result and a considerable feeling of accomplishment.

Energy control due to “visualization” is carried out in many companies using various systems, and the system developed by this company this time is certainly no better than any other company's system. However, because the system was tackled in-house, it is simple and slimmed-down, and revisions and modifications can be implemented immediately. Further, the most important point for the development was the implementation of various activities until the system had fully become adopted, building "motivation" and a "feeling of solidarity" among all the personnel in the motive power divisions which created "ideas" that were incorporated to make the system practically useful.

4. Future Plans

Currently, the visualization of the compressor equipment is being implemented under a new working group. Further, activities are also being carried out to develop planning staff, educate human resources using skill festivals, and realize activation through improvement proposals. In the future, we will continue to make maximum practical use of "visualization systems" by seeking to realize operations that have even higher efficiency.