Energy use optimisation technology by Green IT

RENKEI Control Guidebook

－From Introduction through Saving Verification－

August 2012

Japan Electronics and Information Technology Industries Association (JEITA)

Control & Energy Management Committee-WG1 (Energy Management)

Green IT Promotion Council
（GIPC）

This guidebook in English was produced under the Ministry of Economy, Trade and Industry (METI) Commissioned Project "Support for IT utilization aimed at fostering a knowledge economy in Asia (promoting Green IT)"

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1 Introduction

In recent years, demands for energy savings measures have been intensely heightened in Asia with rapid increase of energy consumption coming from growing economy. Various types of energy efficiency measures have been addressed and discussed, and many related programmes were implemented in line with policies of a national level. However, the essence of the energy saving activities is not only to identify saving opportunity and to implement the saving measure as one time project, but also to provide quantitative measurements to monitor and maintain the improved performance to further improve. This is the practice of the PDCA (Plan-Do-Check-Action) cycle ensuring continuous energy performance improvement.

This guidebook is to provide useful information and examples of various applications related to the energy performance improvement technique called "RENKEI control". The Japanese word "RENKEI" literally translated as "cooperation or coordination" which suggests that "RENKEI control" is to pursue energy efficiency optimisation with two or more elements interacting within one another to provide the most efficient and effective result from the control. The RENKEI control concept is a consolidation of a long time energy efficiency experience and accumulated knowledge in Japan with a smart utilisation of “Green IT” concept. The “Green IT” concept provides energy users with opportunities to achieve energy performance improvement without having to go through a major renewal or significant changes in existing facilities. The RENKEI control which is an integral part of energy management operation in this guidebook closely follows the recently focused guidelines such as ISO 50001 International Standard for energy management system and the guideline of IEC for automation controls for energy efficiency.

The purpose of this guidebook is to be used not only by experts in energy related technology but also by persons responsible in the overall energy management operation, and therefore it was written and edited with the clearest and the simplest possible terms. Our hope is that this guidebook serves as a useful tool for promoting energy performance improvement drive in Asian countries.

In Chapter 2 we explain what “RENKEI Control” is, what the background is in developing it, and what would be the benefits. We also categorise RENKEI by control functionality such as demand and supply RENKEI, supply side RENKEI, etc. with description of each mechanism and sample case studies. Additionally, we have demonstrated the energy performance improvement overviews with RENKEI control introduction and verifying benefits.

In chapter 3 the RENKEI control implementation guideline demonstrates specific implementation procedure in each defined step with some important remarks. For the crucial step of "Feasibility Study (hereinafter refer to as "FS")", we are providing necessary information regarding how to estimate economic benefits in introducing RENKEI control supported by actual FS case presentation.

In chapter 4 ways to verify energy performance improvement by implementing RENKEI control is provided. Since the verification has to be quantitatively demonstrated, special attention was made to explain key elements such as how to define a verification boundary, setting verification time period, data collection tips and handling deviation, ways to reveal verification result, handling of operator expertise, etc. in demonstrating verification methods in various categories.

In chapter 5 in explaining energy optimisation approaches, we firstly introduce our view regarding energy use and basic approach to energy management operation in key sectors such as commercial buildings, industrial factories, and plants. Secondly we demonstrate various approaches in identifying specific optimisation requirements, energy performance indicators, how they are to be measured, and which are the key factors in determining the most appropriate RENKEI control system to be employed for the site.

In chapter 6, the future prospects for RENKEI control are discussed.

In the final chapter 7, as the ending remark, it summarises the superiority of the RENKEI control that does not require a significant investment of having to build or replace a complete new facilities thus provides positive economic effect.

In Appendix 1 to 6, more specific and technical side of RENKEI control are explained taking into account of the updated technology trends in verification methods and energy management with measurement and verification (M&V) tools.

2 RENKEI Control

The energy saving approach until the recent years was focussed on the control of individual facility or equipment for energy efficiency. Coming into the era of seeking measures against global warming, energy saving approaches have shifted to controlling of an entire business unit (factories, commercial buildings, etc.), requiring to pursue optimum use of energy for the entire system. In response to the requirements, the concept of RENKEI control was developed.

In this chapter, the concept of RENKEI control is introduced in detail, together with demonstrating several pathways for the actual implementation of RENKEI control.

2-1 What is RENKEI Control

Buildings and factories are supplied with primary energy such as electricity, gas and fuel and secondary energy such as steam, chilled/hot water and compressed air. In recent years, many independent units performing highly efficient use of energy (commonly called "energy efficient units") are available in the markets with proven technology. This is termed "independent controlled unit" in energy management. Such energy efficient equipments are welcomed by energy users for their energy saving measures. Furthermore energy users recognise the effectiveness for promotion of their energy saving activities by energy “Miyeru-ka”, a Japanese terminology for “visualizing through energy monitoring methods, the actual energy consumption”. Having all the positive aspects in the energy saving measures, energy still bears difficulty of its own: storing and transferring. This issue inevitably generates a mismatch between supply and demand such as in the case of changed production volume. Commonly a building or factory at the time of birth, the energy supply was designed on the basis of the maximum load for energy demand. This requires a special attention when the demand is low in actual application; a simple throttling of energy supply will not do the job and can cause significant deterioration of energy efficiency of the facilities.

For the energy saving measures in the private manufacturing and transportation sectors, state of the art high energy efficient facilities and equipments are actively used as independent controlled units. In spite, some energy users do not get the saving result to their expectation. This is due to the combined use of the independent controlled units where the optimum control is only performed within the operated facility or equipment but not performing to the overall energy demand of the operation so that the highest energy efficiency was yet to be reached. When compromising to a facility or equipment with independent controlled solution based on rated load condition would only provide partial optimisation thus allowing energy to be wasted if it is not properly managed. In order to increase energy efficiency of a business unit such as factory or building, the supply side of the energy sources (such as power and heat source facilities, etc.) must be managed and operated optimally in respond to the demand situation changing constantly with irrational behaviour. In other words, it is necessary to find the best mix of energy sources to optimize the demand and supply balance, the total optimisation control approach, the RENKEI control.

"RENKEI" control is a generic concept of optimisation control technology that maximizes the total energy efficiency by controlling independent equipments to work in concert with each other for harmonizing the demand and supply of energy. There are several types of RENKEI Control such as "Demand and Supply RENKEI" that controls the load balance of energy supply equipments to get the optimized energy efficiency as a whole in eliminating the waste, and “Supply side RENKEI” that controls equipments of a supply facility for an optimum load balance with the demand. Additionally, energy supply facility can be controlled and operated based on the demand forecast reflecting the factors such as production schedule and weather forecast. Furthermore, the supply and the demand facilities can work gradually in concert with each other to enable step-by-step advancement of energy saving drive. RENKEI Control is an advanced control technology that provides energy savings solutions utilising existing facilities and equipments in both supply and demand sides.

By implementing RENKEI control, an overall integrated optimum control system can be established by having the demand and supply side facilities operate in concert with each other. As the result it will reduce the energy waste otherwise generated with the unbalanced situation of demand and supply or with inefficiency situation between multiple energy supply facilities.

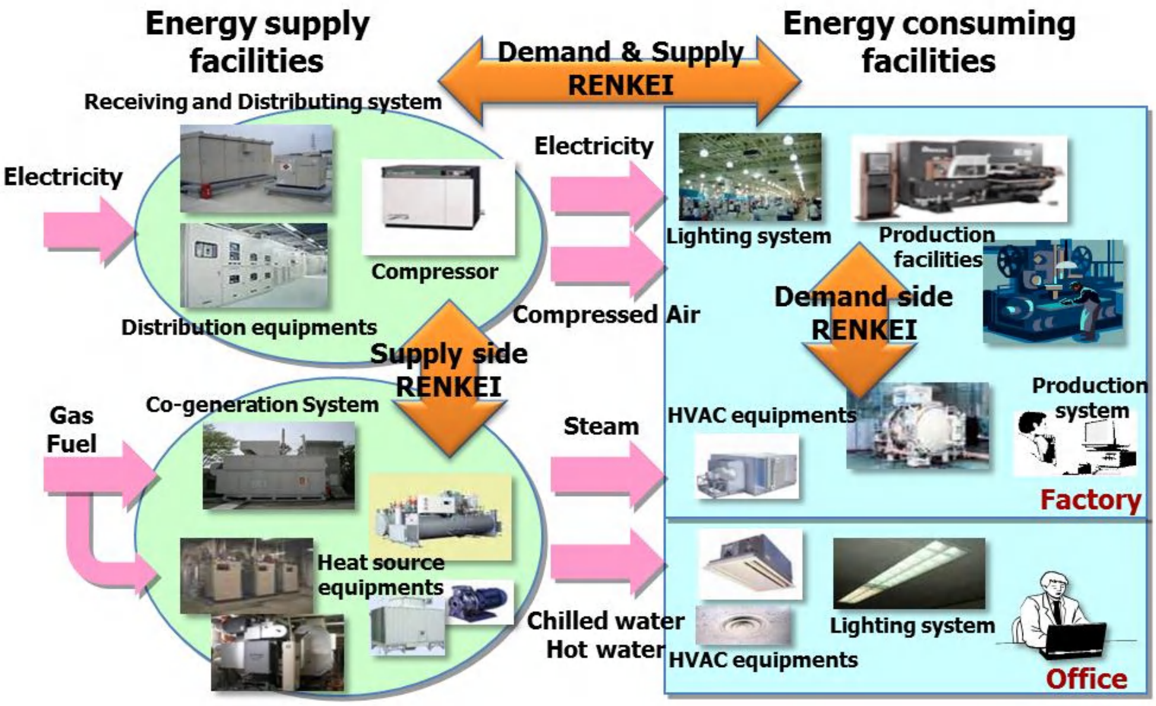

Figure 2-1: RENKEI Control Conceptual Structure

In Figure 2-1, the RENKEI Control Conceptual Structure is depicted. As you can see, for the RENKEI control concept, there are basic categories such as supply facilities in concert with each other (Supply side RENKEI), demand side and supply side in concert with each other (Demand & Supply RENKEI) and multiple demand side groups in concert with each other (Demand side RENKEI). In the following section, these categories are described in detail. One thing is to be noted that RENKEI control does not necessarily mean automatic control. It includes the manual control such as guidance systems. Guidance systems are useful approach when the automatic system is too costly or the automated reasoning appears to be more risky.

2-2 RENKEI Control Categories

When considering the RENKEI control, one must recognise that there are several types in RENKEI concept. For example, one type of the RENKEI control is by inputting the real production values or the forecasted demand values based on production plan, or by inputting the weather forecast factors in identifying the load distribution for energy supply equipments, enabling to operate each energy supply facility efficiently. As the small size application examples, one common type is to control the flow rate of cooling water in response to the operational intensity of the production facilities. As the large size application examples, one common type is the optimum operational control of the heat source and thermal storage tank typically used at the energy center of large size plant or the district heating and cooling plant.

In this section, the types of RENKEI control are categorised. Five categories are introduced hereafter, the information based on the actual implementation.

(1) RENKEI among Equipments within Energy Supply Facility

This category is to demonstrate the method of controlling the operation of energy supply equipments by recognising the characteristics within the facility for achieving optimum control. The RENKEI control in this category is to minimise the cost or CO2 emission by combining equipments for the best mix or settings optimum allocation of operation units. For example, one case is to provide the optimum load allocation of heat sources using electricity, fuel and gas, and another case is to perform the optimum operational control of multiple equipments such as boilers, pumps and compressors, etc. They are to implement the optimum load allocation by recognising the equipment characteristics (e.g., the combination of large and small sizes, old and new models, etc.) in achieving the optimum operational control.

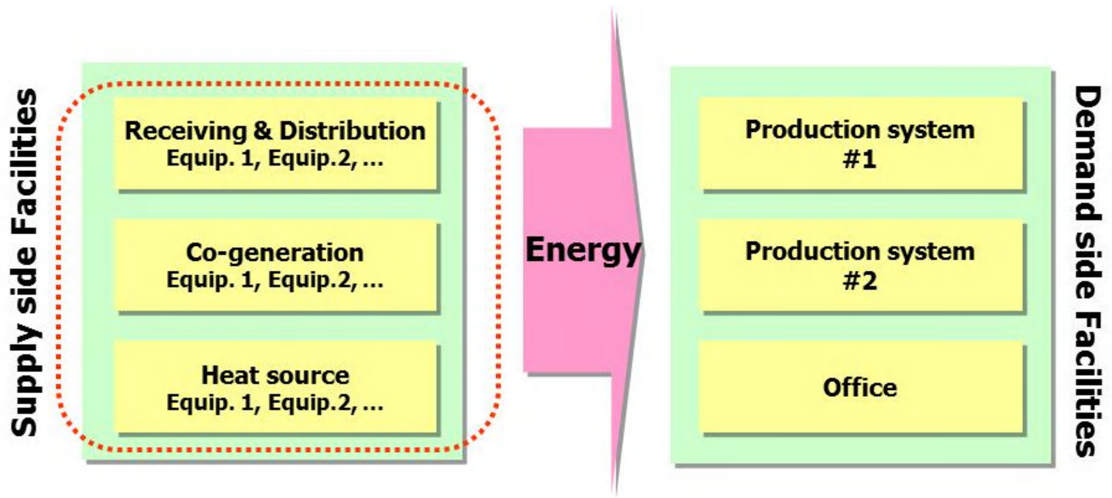

Figure 2-2: REMKEI among Energy Supply Facilities

(2) RENKEI among Energy Supply Facilities

This category is to demonstrate the method to control the operation of the neighbouring energy supply facilities in concert with each other. For example, one method is to provide the optimum load allocation by integrating the energy supply facility of the neighbouring factory as one energy supply facility, and another method is to provide the optimum load allocation by integrating the multiple energy supply facilities as one energy facility. They are to implement the optimum load allocation from the available supply facilities in concert with each other.

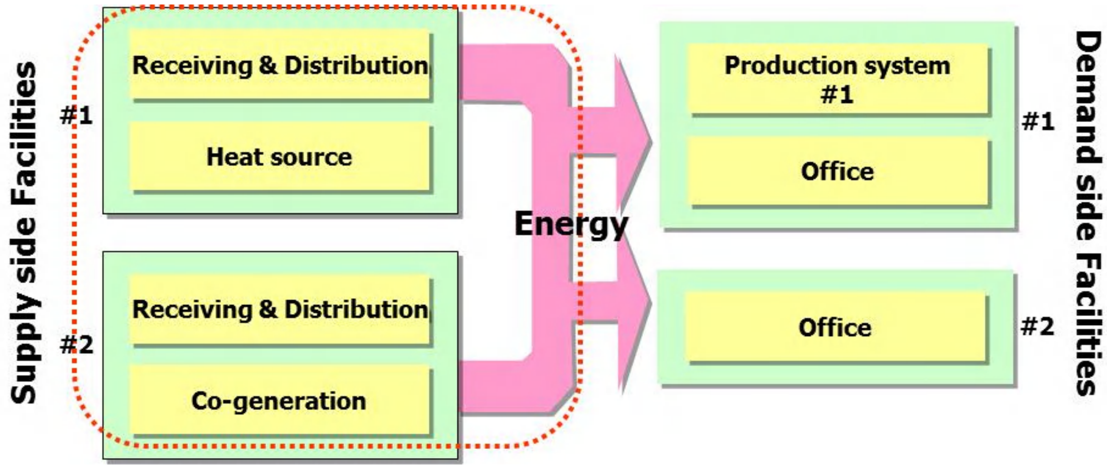

Figure 2-3: REMKEI among Energy Supply Facilities

(3) Demand and Supply RENKEI

This category is to demonstrate the method to control the operation of the energy supply facility in response to the energy demand amount of the demand facility. In order to identify the supply equipment optimum load allocation, the energy demand amount can be based on the actual value or using the forecasted value, etc. For example, to control the cooling water flow rate in response to the status of the production facility operation is a typical method in a small scale application. The other method in large scale application is to achieve the optimum operational control for the heat source and thermal storage tank in the energy center of large size plant, or the district heating and cooling plant, by using control elements such as weather information, etc.

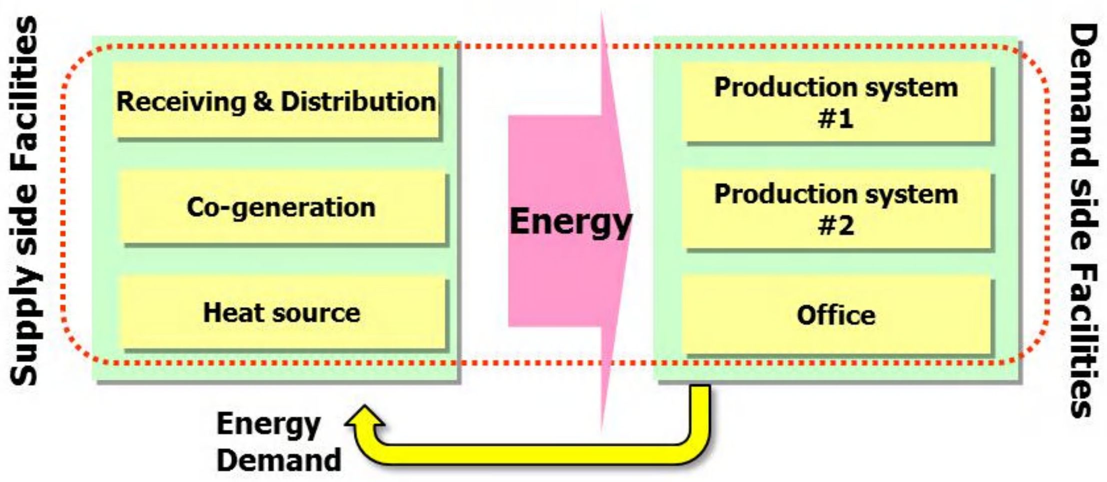

Figure 2-4: Energy Demand and Supply RENKEI

(4) Demand and Supply Bidirectional RENKEI

This category is to demonstrate the method to control the operation of the energy supply facility in response to the energy demand amount of the demand facility, and when the demand has exceeded the capacity of supply facility, it is to provide adjustment at the demand side. For the adjustment method in the demand side, one method is to change the production plan in adjusting the demand work load. For a large plant consuming a large amount of electricity, the typical method was to adjust the demand work load when the electricity demand suppression is required. As the interactive approach between energy demand and supply sides is making progress, the scope of control will become wider to include a factor such as rescheduling of the production, etc.

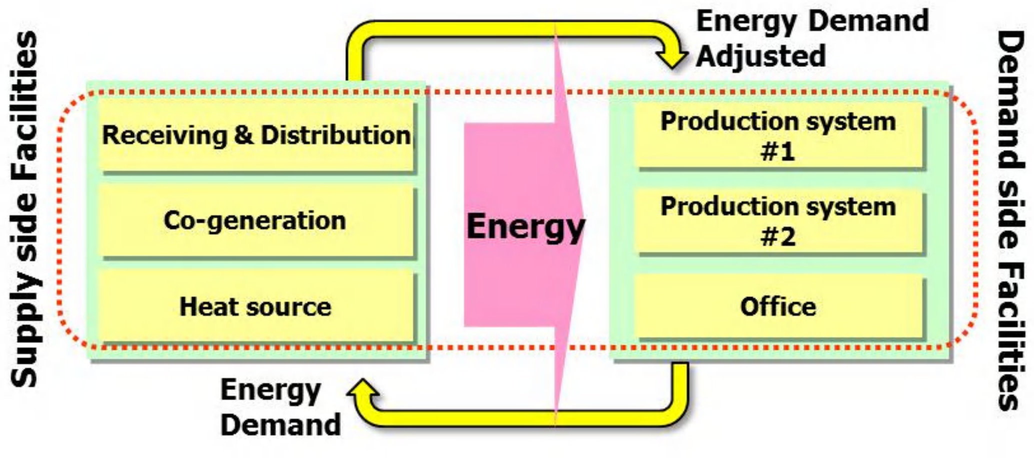

Figure 2-5: Demand and Supply Bidirectional RENKEI

(5) RENKEI among Demand side Facilities

This category is to demonstrate the method of executing control of the production systems (energy demand-side facilities) in concert with each other to optimise the demand for energy. In order to do this, the key approach is either to control the operation intensity or to change the scheduling of production. The reduction of the operation rate in response to the electricity demand suppression has been widely executed by the large electricity consuming plants. The most common way to reduce the operation rate is simply to put some production lines to stop. With the control technology enhancement, the use of RENKEI control concept provides operational improvements such as to automatically putting production lines to stop with the suitable sequences based on the production plan priority, etc.

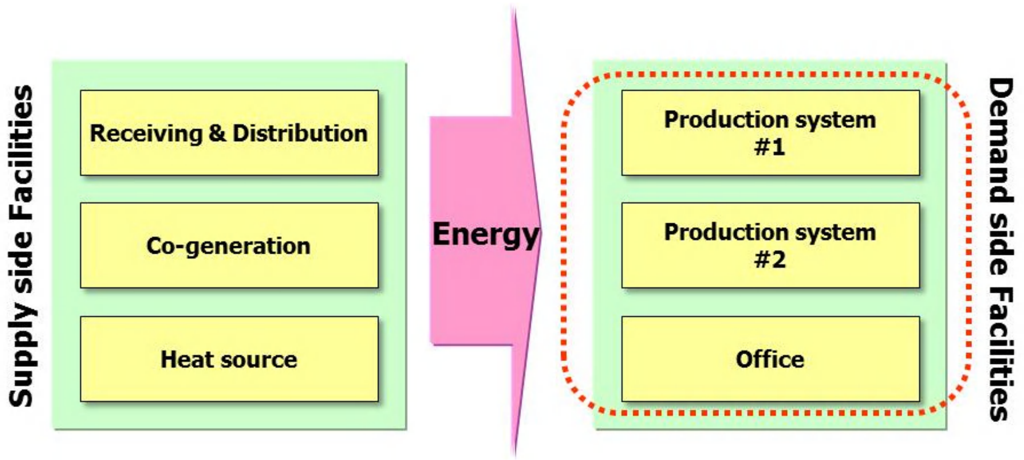

Figure 2-6: RENKEI among Demand-side Facilities

2-3 RENKEI Control Examples

Typical RENKEI control categories and sample cases are shown in Table 2-1 below.

Table 2-1: RENKEI Control Categories and Sample Cases

	Categories	Sample Cases
1	RENKEI among Equipments within Energy Supply Facility	・Heat source equipments load distribution optimisation ・Utility equipments load distribution optimisation ・Optimised unit control* for heat source/compressed air/transfer equipments (pumps) * Equipments in concert with each other have to be distinctive in capacity to be in this category.
2	RENKEI among Energy Supply Facilities	・In between heat source facilities load distribution optimisation ・In between utility facilities load distribution optimisation ・Auxiliary equipments RENKEI control (such as compressors in concert with cooling water pumps, etc.) ・Multi-compressor rooms total control, etc.
3	Demand and Supply RENKEI	・District heating and cooling, Compressed air system, Cooling system, etc.
4	Demand and Supply Bidirectional RENKEI	・Night operation of the large power consuming plant ・Make use of the off gas generated by blast furnaces in iron works ・Utility facilities as the supply side
5	RENKEI among Demand side Facilities	・Production line adjustment ・Demand side management / Demand response

The district heating & cooling application represents as one of the typical RENKEI control ideal applications. Figure 2-7 depicts the heat supply facility in the demand and supply RENKEI category. Demand forecast is implemented using the information such as weather information, etc.

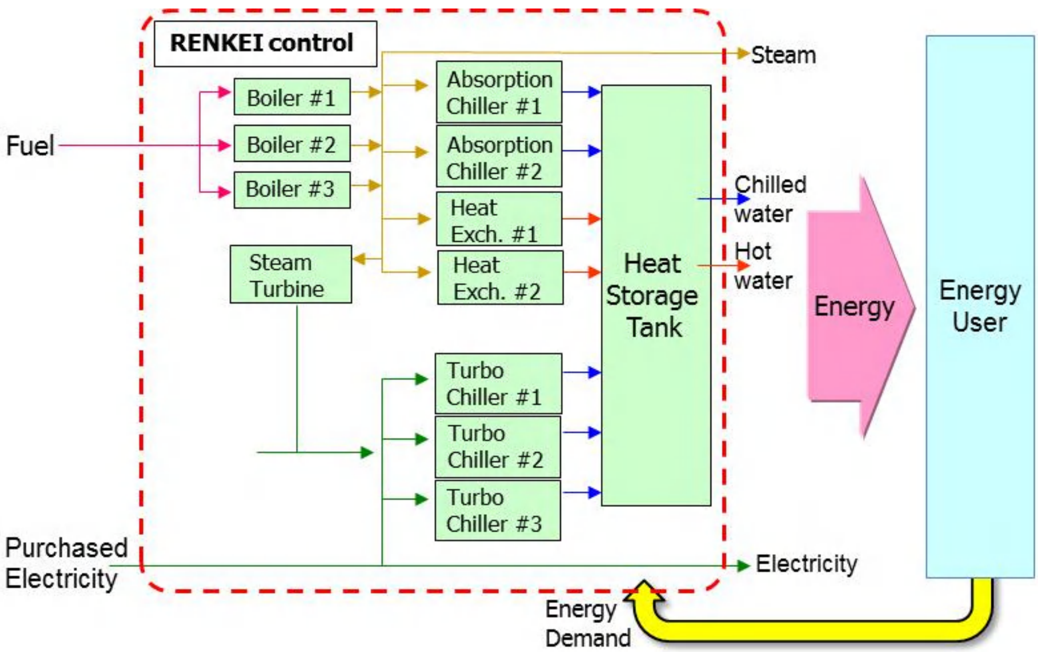

Figure 2-7: Demand and Supply RENKEI: District Heating & Cooling

In recent years, in the district heating and cooling applications, due to quality improvements in energy demand forecast and practical use of the information communication technology by energy users have made possible of executing more efficient heat source operation from the supply side.

The demand side management (demand response), which is one of the demand side facility RENKEI control applications, is a highly evaluated technology in relationship to the social awareness towards smart grid technology in recent years. Demand side management draws participation of energy users in electricity supply planning operation cycling enabling the realisation of the most economical power supply structure as a whole whereas in the past was solely managed by the power utility companies. In the scope of demand side facility RENKEI, energy is not limited only to electricity but also including other energy units such as steam, chilled and hot water, etc. There is various methodology of how energy users get involved in the demand side facility RENKEI. As an example, the demand side facility RENKEI with methodology using production planning information is shown below, figure 2-8. The scheme is to enhance the efficiency of the heat source operation and to reduce the peak demand by sharing the production planning information of each production unit incorporating the information for the overall optimum production scheduling.

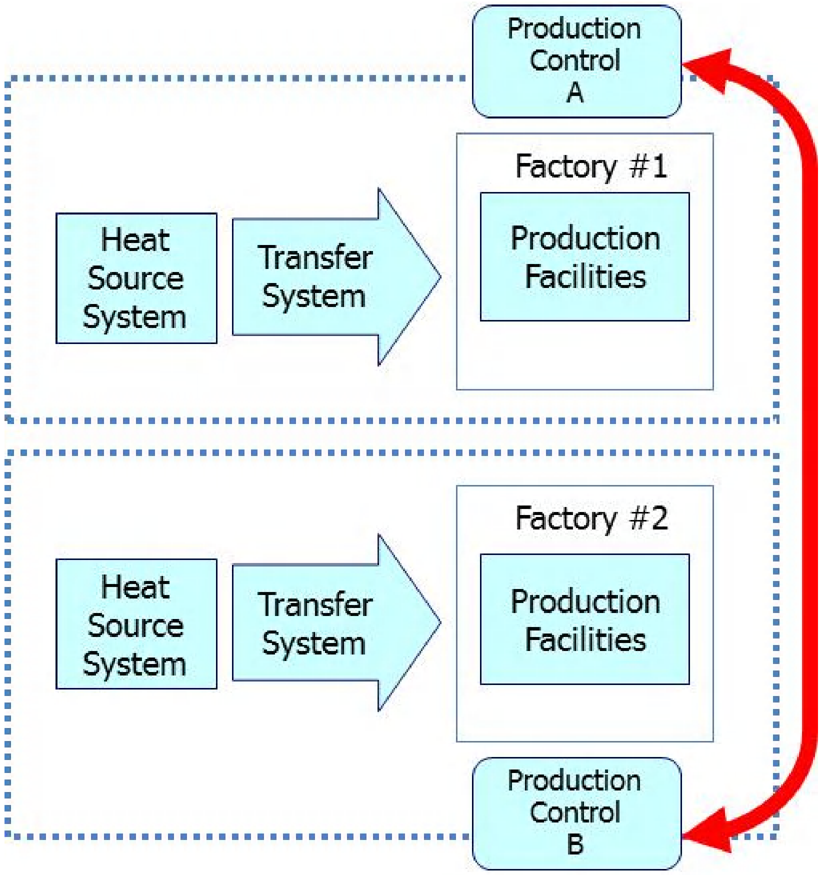

Figure 2-8: Demand side facility RENKEI (Demand side management)

2-4 RENKEI Control Benefits

(1) Economic Effect

Figure 2-9 below demonstrates the investment economic benefit comparison for equipments and energy savings solutions by means of unit cost to achieve CO2 reduction (CO2-reduction unit cost [1]). The vertical axis represents CO2-reduction unit cost. CO2-reduction unit cost is defined as the investment (x 1,000 JPY) spent to reduce 1 ton of CO2. The smaller the unit cost is, more attractive it is as the energy saving method. The horizontal axis represents the amount of CO2 reduction. As it goes more to the right, the reduction is larger. The category "stand alone equipment" (marked as a blue dotted line) is represented by equipments such as transformers and heat source units plotted with equations [2] "the cost difference between the energy efficient unit and the conventional unit divided by the CO2 reduction. The category "RENKEI Control" (marked as a red dotted line) represented with the cost of implementing a typical RENKEI Control system divided by the CO2 reduction. It is said that the average domestic CO2-reduction unit cost is approximately 110,000 JPY / t-CO2, and you can see that the RENKEI solutions are all cost effective being well below the average, and more economical than the stand alone equipment solution. Additional feature is that it does not necessarily require major facility renewal or renovation, only coordinating among the existing facilities with the RENKEI control technology achieving the overall energy consumption optimisation solution.

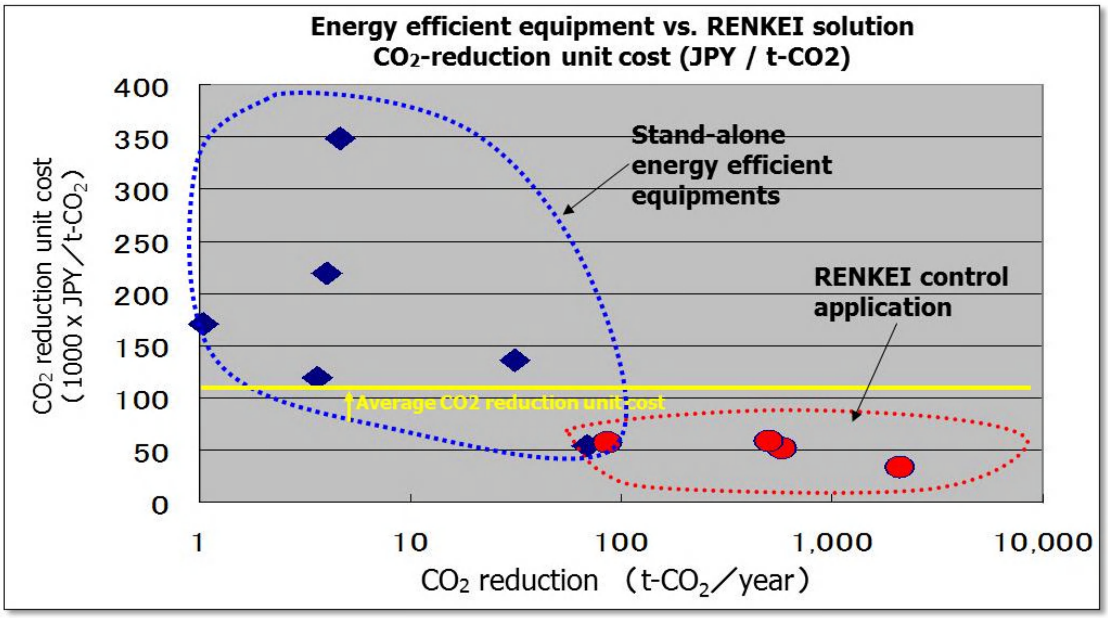

Figure 2-9: RENKEI Control Investment Effectiveness

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[1] "CO2-reduction unit cost" is investment necessary to reduce 1 ton of CO2.

[2] For the case of "stand alone equipment" it was calculated as the cost difference of "the energy efficient unit and the standard unit". Excerpt from the article "BE Building Facility" December 2005 and January 2006 editions.

(2) Benefit Statements

By implementing the demand and supply RENKEI, power peak-cut is feasible. As an example, district heating and cooling application is presented as shown in Figure 2-10, below. It utilises a set of city gas operated absorption chillers and a set of electric operated turbo chillers in parallel so that the electricity does not exceed the power contracted demand when the cooling load demand is at the high end with priority to control the CO_2 emission.

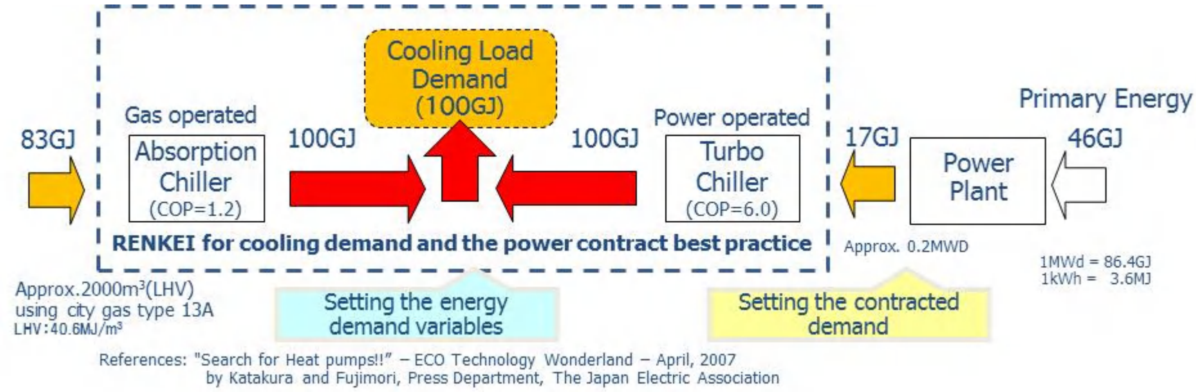

Figure 2-10: RENKEI Control with combined use of Absorption freezer and Turbo freezer

In this application, the two elements (1) the difference of the coefficient of performance (COP: defined as the refrigeration capacity divided by power consumption) for absorption chillers and turbo chillers; and (2) the difference of CO_2 emission at the same chilled water output among the two; have to be considered for intended optimum control using the demand and supply RENKEI methodology.

An example of cooling load demand is exhibited in Figure 2-11 (1), below. The demand is at the highest 100 GJ just after 12 o'clock noon. From the Period of around 7 o'clock in the morning onward, the demand increased sharply and around 8 o'clock in the evening onward the demand decreased gradually showing significant changes in demand.

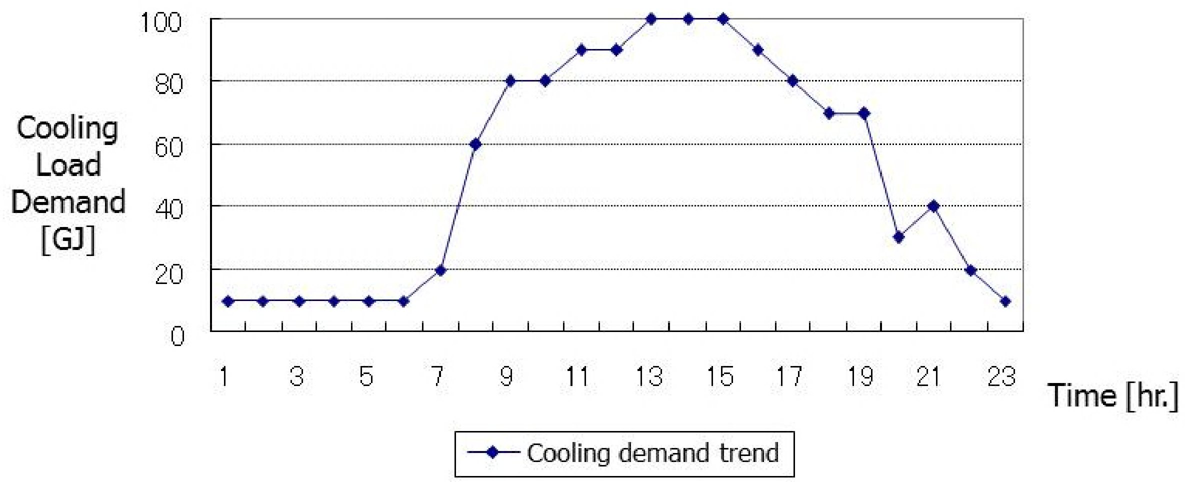

Figure 2-11 (1): Sample of Cooling Load Demand

The system prioritises on the turbo chiller operation powered by electricity for the purpose of minimising the CO_2 emission. However it had to consider the power demand cut-off due to the contracted demand. The power contracted demand 4,000 kW is shown in Figure 2-11 (2) with a green bold dotted line. When the cooling load demand exceeds 86 GJ, the set of turbo chiller operation alone could exceed the power limitation of 4,000 kW. The solution was to combined use of the city gas operated absorption chillers between 11 o'clock and 4 o'clock in the afternoon by incorporating the past cooling demand trend as shown in Figure 2-11 (1) as a forecast information for configuring the RENKEI control. The power performance by implementing the RENKEI control is shown in Figure 2-11 (2) with pink round dots depicting the cooling system is operated well below the power contract demand cut-off 4,000 kW.

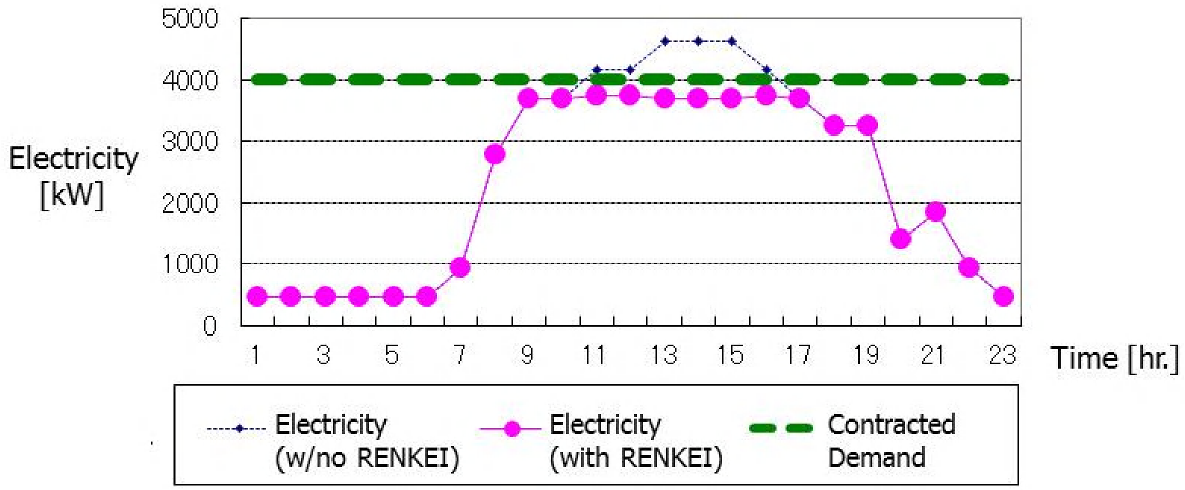

Figure 2-11 (2): Power Consumption Control

On the other hand, the uses of the city gas operated absorption chillers suggest the increase in CO2 emission. Figure 2-11 (3) shows that the period of combined use of absorption chillers (using the RENKEI control) in comparison to the period only using turbo chillers resulted in CO2 emission increase. It demonstrates when using the RENKEI control, the increase is minimised to the least.

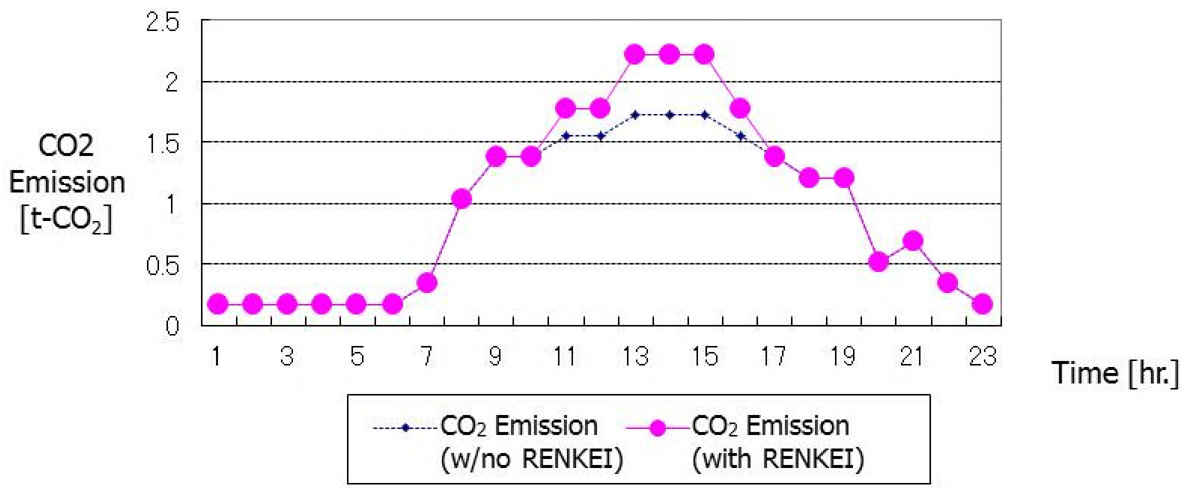

Figure 2-11 (3): Change in CO2 Emission

By introducing the RENKEI control incorporating the demand side cooling load forecasting information; it enables an optimum operation of absorption and turbo chillers of the supply side. From the perspective of recent power shortage crisis in Japan, the controlling aim is to stay below the power demand limitation by the combined use of turbo and absorption chillers, and at the same time minimising the CO2 emission crucial in the environmental aspect.

2-5 Overview of RENKEI Control Introduction and Verification

In order to materialise the introduction of RENKEI control, especially when implementing the demand and supply RENKEI control, it requires not only to overcome the technical issue of performing the high level engineering task at minimal cost but also requires an intimate collaboration work between teams of supply and demand sides from the organisation. Additionally, the important factor in implementing RENKEI control is to form a constructive teamwork with the energy management solution providers, namely the RENKEI control vendors. In developing effective RENKEI control system best suited for the energy user organisation, it requires common understandings and perspectives towards the control requirements among the user and the vendor teams. The relationship between user and vendor is exhibited in Figure 2-12, below. In introducing the intended RENKEI control system, the user side needs to establish a project team to estimate the RENKEI control investment and returns in order to gain endorsement by the stakeholders, namely the members of the top management team. After the project is approved, the project team takes the responsibility for related reporting such as the energy saving result, etc. to the stakeholders. For the "estimate" and "report", the vendor support becomes very important.

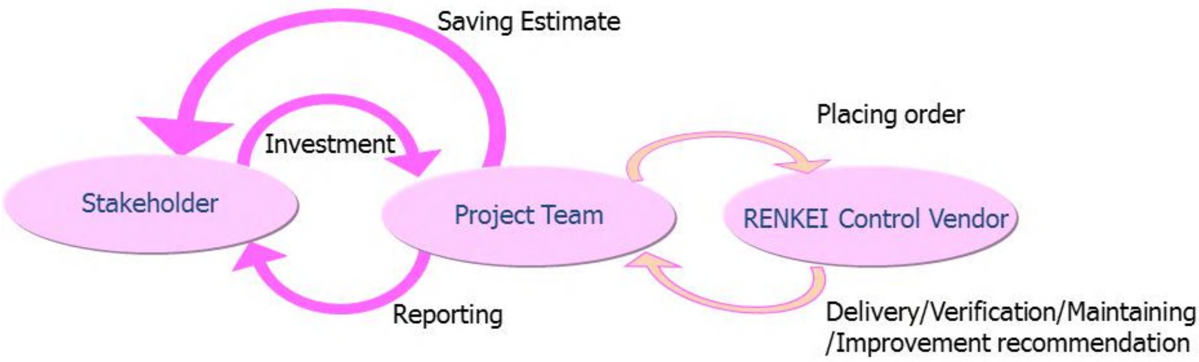

Figure 2-12: User and RENKEI Control Vendor Partnership

In the next chapter, "five steps in introducing the RENKEI control" is introduced, and the relationship between the business operator (energy user) and the vendor is explained. The introduction steps are covered in the next chapter however to in deriving "estimates", the user and vender need to share information to appreciate the mutual benefits. In Chapter 4, the methodology of energy saving verification is provided required to complete the "report" as mentioned in the previous paragraph. For the RENKEI control concept, since the energy saving scope becomes wider than that of the stand-alone, the prior examination of verification methodology at the earliest possible stage is essential and important.

3 Guideline in Introducing RENKEI Control

3-1 Introduction Procedure

When introducing RENKEI control system, unless having necessary information with a good reference prior to implementation, generally a feasibility study is carried out to estimate the benefits of having the system. Once the investment was justified and the decision was made, the implementation officially starts.

The procedure, five steps in introducing RENKEI control, is demonstrated in Figure 3-1, below.

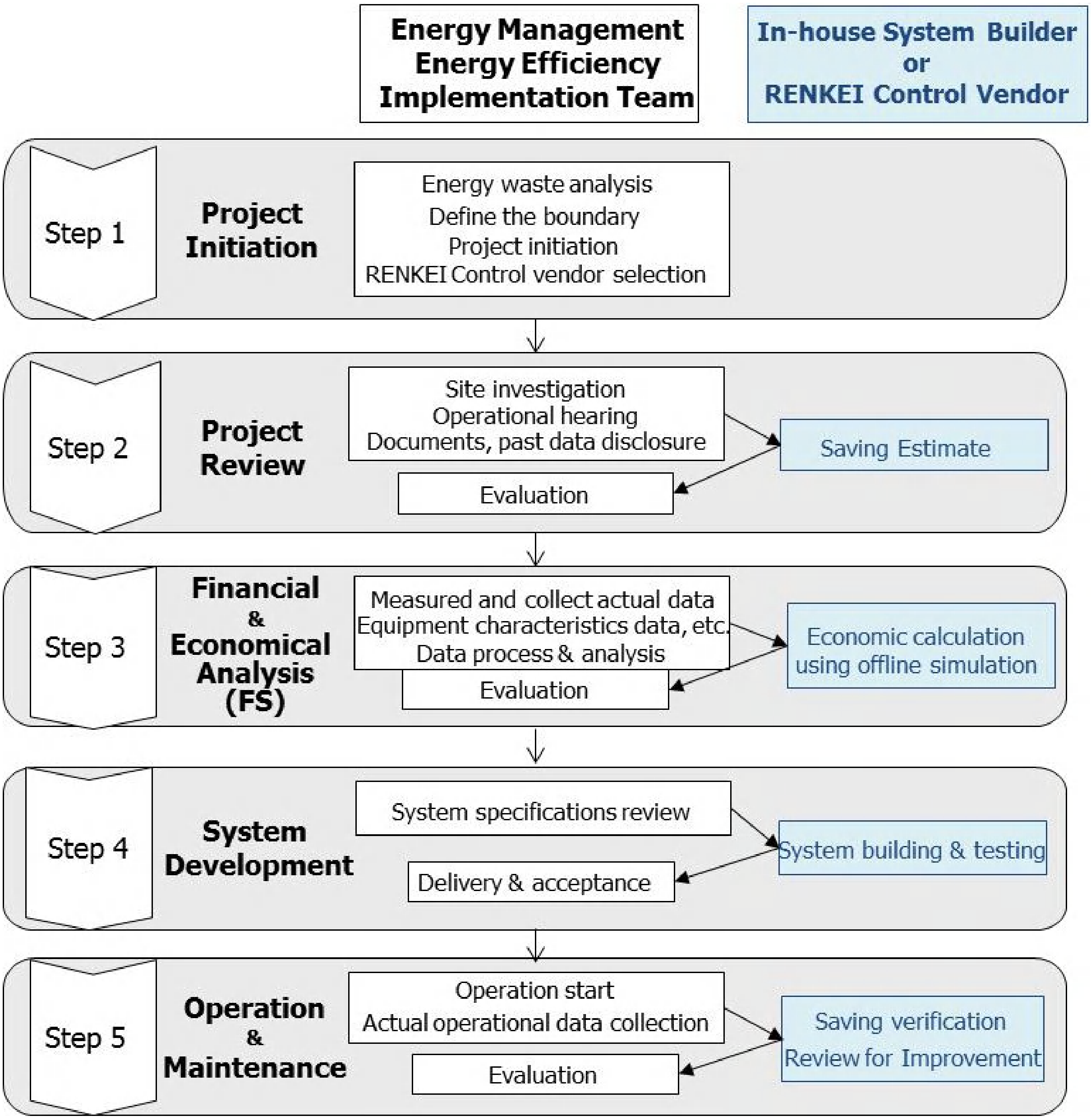

Figure 3-1: 5-step Procedure in Introducing RENKEI Control

(1) Step 1 Project Initiation

This step is to analyse the energy use data and the operational data to identify efficiency improvement factors once the RENKEI concept is applied among equipments and facilities. Once the factors are identified, evaluate the scope of equipment and facility and deciding the type of RENKEI control to implement. If the identified RENKEI control system involves multiple departments in the organisation, establish a project team involving relevant departments and functions. Evaluate the in-house resource capability in making the decision if the RENKEI control system is to be developed in-house or by energy saving solution vender (hereinafter refer to as "vender").

(2) Step 2 Review of Project (Benefit Projection)

This step is to review the specifications of facility and equipment in the scope together with interviewing the facility operators and the relevant department members to come up with appropriate RENKEI control concept and rough energy saving estimate. If the facility situation is relatively complex or requiring high level of control solutions, consider asking the RENKEI control vender to perform a site survey (e.g. a half day session) to obtain recommendations.

(3) Step 3 Feasibility Study (Provisional Financial estimate and economics)

As a result of "Step 2" review, if the payback of investment is worth pursuing the opportunity, further detailed analysis using real time energy and operational data for accurate and fine tune estimates. If the real time energy and operational data are not available, installing temporary meters to gather necessary data as scoped an alternative approach.

If the review was done with RENKEI vender in "Step 2", work with the vender in "Step 3" as well for the consistency of work. Since the work in “Step 3” requires a significant man-hour involvement, in principle the work is a charged basis. For higher precision in analysis and estimate, more time in data collection and analysis are required, and therefore when using the vender for the feasibility study, good judgement in balancing cost aspects and expected precision[3] is very important.

(4) Step 4 System Installation (Installation & Acceptance)

Once the Investment payback is justified in "Step 3" and the project approved, actions will be taken for the system implementation. After reviewing the existing system status, identify the necessary specifications for the RENKEI control system. If the system is to be out sourced, request vendor candidates for quotations. After receiving quotations, once again evaluate the investment payback situation, and make decision for "go" or "no go". During "Step 3" if the necessary data was not available for estimate analysis and having to using temporary meter measurements, it is highly recommended to consider installing necessary meters and automatic data collection system. The reason is that the data used for the energy saving benefit analysis will also be used for the energy performance measurement, and data will become highly valuable when the energy saving verification is to be performed as well as to evaluate further energy performance improvement aspects in the next procedure "Step 5". Once the vendor is identified, place an order and proceed with the following procedure for the implementation of the system.

- Create basic specifications
- Create detailed specifications
- System designing

[3] For the balancing statement of Cost and Sophistication of FS, refer to Appendix 5

- System construction
- System acceptance test
- Trial run

(5) Step 5 Operation and Maintenance

Once the system operation has started, collect and record the necessary data related to quantitatively verify the energy saving result from the system. Based on the collected data, perform the energy saving quantitative verification. For the evaluation detail, please refer to Chapter 4 "Verification Guideline". If the RENKEI control system was sourced from a vendor, request the saving verification from the vendor as well. Also a maintenance contract is to be made after the implementation. In case of the facility operation changes, the maintenance contract should include system configuration aspects such as control logic review, model review, etc. as well as the regular maintenance such as tuning for the RENKEI control performance consistency, etc. The maintenance aspect is very important to maximise the performance and effect of the RENKEI control functionalities, once the implementation has started.

3-2 RENKEI Control Provisional Financial Estimate and Economics

A feature of the RENKEI control implementation is estimating the financial benefit and its economics as described in the "Step 3" in the introduction procedure of the previous section 3-1. In doing a feasibility study, the following materials regarding facilities and equipments in the defined boundary need to be prepared.

- Process flow diagram
- Specifications and characteristic data
- Functional limitations or operational restrictions
- Operational performance data

  (The data necessary to perform calculation and analysis of energy efficiency index and energy use influencing factors such as operation performance under changes in production outputs, product lines, temperature or weather, etc.)
- Electricity and fuel/gas unit price and contractual information

Feasibility study in general is practiced as indicated in Figure 3-1, in the next page. By taking the past operational performance data as the baseline, it is to compare the key performance indicator (KPI) [4] derived from the RENKEI control application versus the past operational performance prior to implementing the RENKEI control.

[4] Refer to Chapter 4 for the detail of KPI

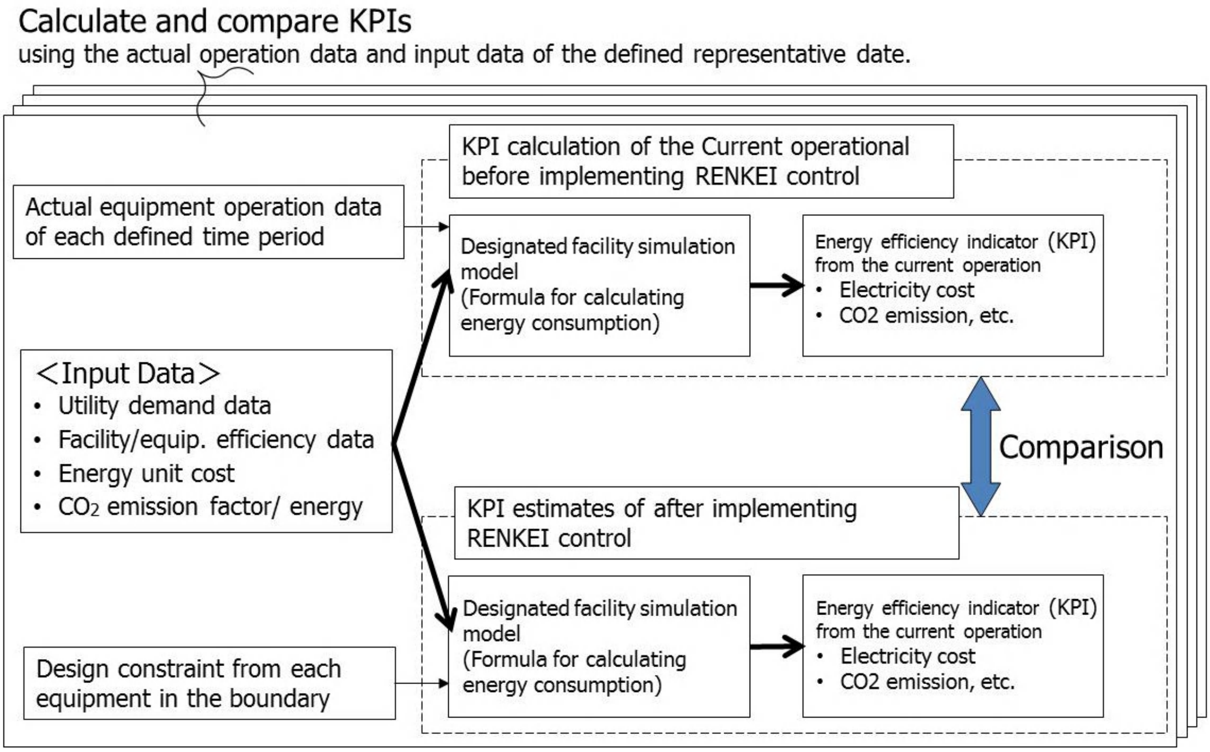

Figure 3-2: Feasibility Study Implementation

The KPI identified during the feasibility study and the KPI identified after the implementation of RENKEI control (see Chapter 4, "Verification Guideline) must be in the common scale for legitimate verification of energy saving benefit. The KPI computation varies depend on the complexity of the RENKEI control and the status of facilities in the defined scope. It can be from a simple excel worksheet computation to a complex computation using simulation models. In order to compare the performance before and after implementation of RENKEI control, it is important to identify factors influencing value of KPI for proper verification. Once identified the influencing factors, choose appropriate data collection period for appropriate KPI comparison in identifying the energy saving benefit. Some of the common factors influencing KPIs are:

- Production load
- Weather condition
- Product line or type of product
- Operation status (weekdays, weekends, holidays, etc.)

In the feasibility study procedure “Step 3”, as well as identifying KPI as mentioned above, ROI and economic effect must be evaluated. In this case, the KPI deriving from the specific energy consumption should be considered, and by integrating the influencing factors as mentioned above as an assumption to estimate energy consumption and energy cost for economic analysis is essential.

When defining the different date classification representing each influencing factor (e.g. If the selected influencing factor is "temperature", the represented date grouping can be days such as summer-weekdays, summer-weekends, winter-weekdays, etc.) for economic analysis, it is necessary to compute the annual energy saving estimate by proportioning to the number of days in each group. When assessing the energy saving benefit of RENKEI control involving production facilities such as “demand side RENKEI” or “demand and supply bidirectional RENKEI”, etc. even if the production is either batch or discrete process, by consolidating the energy and operational data per each patch as an operational status, it can be treated as the same as the continuous process.

3-3 RENKEI Control in Action

3-3-1 Multiple-room Air Compressor RENKEI Control

Following application in Figure 3-3 refers to an overall integrated RENKEI control system with two compressed air machine rooms with two additional independent compressed air machines in operation. Compressors are all screw type with load/unload functionality.

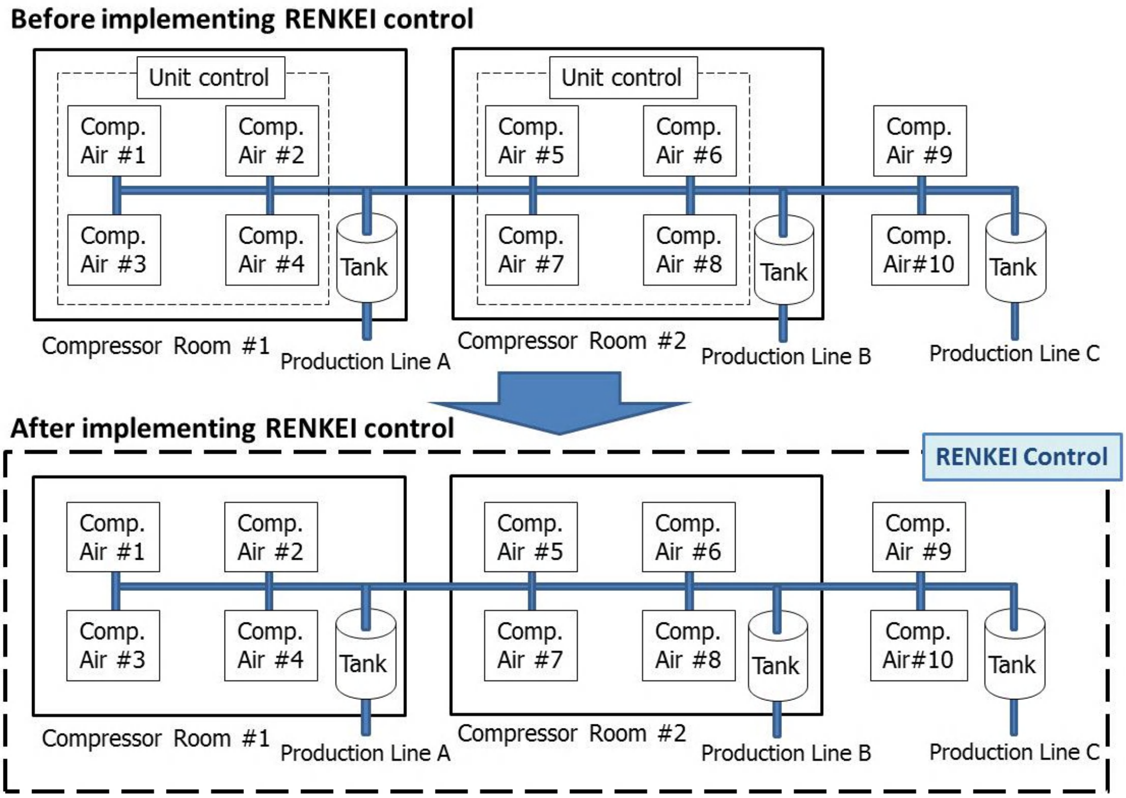

Figure 3-3: Multiple-room Air Compressor RENKEI Control

For the implementation, the energy user provided the RENKEI control vendor with the compressor equipment list and the compressed air system piping diagram. Since there was neither data available on individual compressor operational performance nor to analyse the air volume used, the RENKEI control vendor performed a site investigation. The investigation discovered that even though each compressor was operating with the multi-unit control function, there were several compressors running with unload position. Therefore it was concluded that further energy performance improvement was feasible by introducing the RENKEI control with the category of supply side facility RENKEI methodology.

In order to perform a detailed energy saving analysis, the "Step 3 - Feasibility Study" was carried out and necessary data collected by the RENKEI control vendor. The collected data were consumption current of each compressor and the header tank pressure values obtained through the temporary installed meters. The energy saving was estimated with the data analysis of two patterns; one was data sets of a non-working day with one day before and after, and the other was the data of normal working day.

As the result, it was estimated 10 % energy saving was feasible, and the introduction was implemented. After a year since the RENKEI control implementation, it was verified that the saving was achieved as estimated during the feasibility study.

3-3-2 Factory Utility Operation Optimisation System Feasibility Study

Evaluating that the factory's large energy load demand was due to the air conditioning purpose, a feasibility study was carried out on the utility facilities that supply chilled/hot water to the manufacturing side. The utility facilities include boilers, co-generation facility, absorption type chillers, turbo chillers, steam heat exchangers, hot water storage tank, etc. as shown in Figure 3-4, below.

Since the air conditioning load was the main consumer, the energy demand largely being affected by weather conditions such as temperature and humidity. Therefore the energy saving verification was done based on one week data best representing the four seasonal periods, spring, summer, fall and winter.

As the result, it was estimated 3 % energy saving was feasible during the feasibility study before the implementation. After implementation, it was verified that the saving was achieved as estimated.

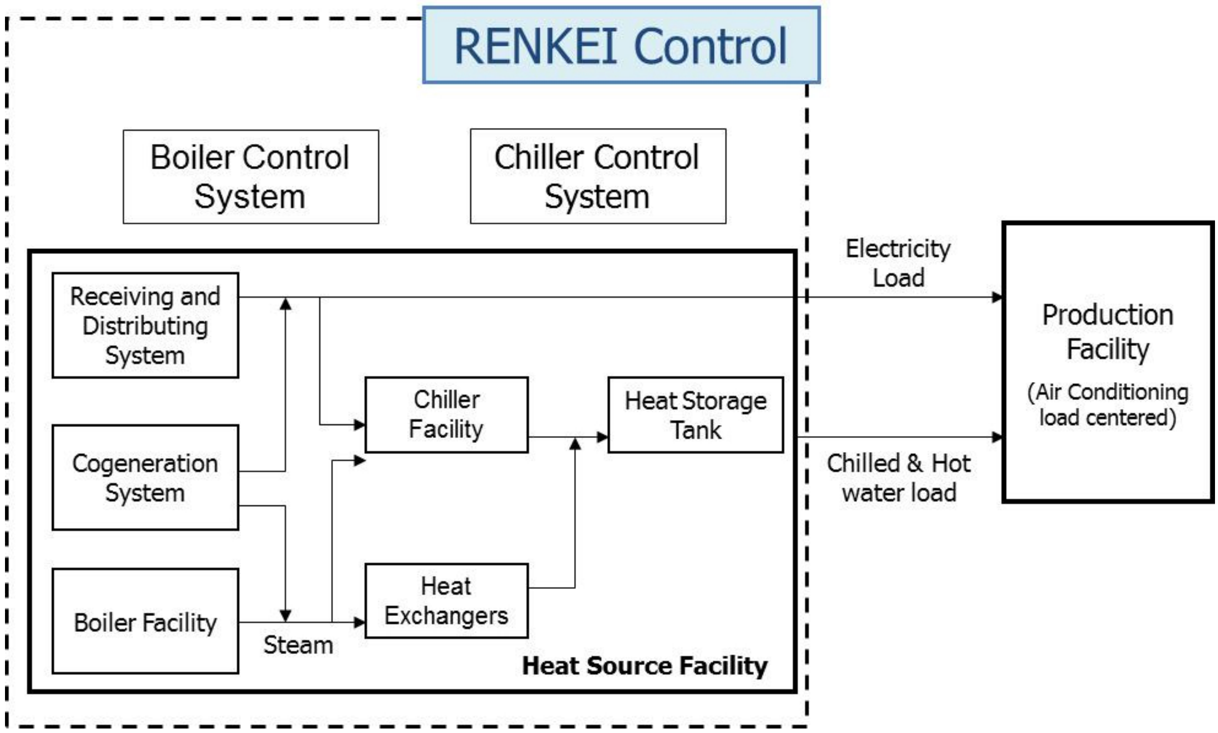

Figure 3-4: Factory Utility Facility Operation Optimisation System

4 Verification Guideline

4-1 Verification Objective

For ensuring the energy saving benefit verification by implementing RENKEI control in improving energy performance, the result has to be specifically verified quantitatively. In order to accomplish this, it requires to determine the method for which boundary, and for which period the energy consumptions are measured and data collected. After determination it requires to identify the scale to which the measured data are properly compared with the baseline in line with the common measurement field. In this chapter, the guideline of how to verify the energy performance improvement is provided.

4-2 Verification Methodology

4-2-1 Energy Efficiency Indicator (KPI)

Energy management related Key Performance Indicators (KPI), defined in the guideline for energy efficiency standardisation under development by the IEC/TC65/JWG14 (Energy Efficiency in Industrial Automation), is principally used as a "scale" for verification. Energy management related KPI with "Specific Energy Consumption" method is typically used in Japan in line with the Act on the Rational Use of Energy. In order to assess the energy saving benefit of using the RENKEI control is comparing the performance of before and after implementation of the RENKEI control with an appropriate identification of boundary and time period as described in sections 4-2-2 and 4-2-3. KPI must be consistent against changes caused by influential factors as well as in continuity. On the other hand, special attention has to be made that for pursuing better and more accurate KPI, it requires more time and effort thus more cost for the verification activities.

Frequently used KPIs with outline description and comparison methodology are shown in Table 4-1, below.

Table 4-1: Energy Management related Key Performance Indicator (KPI)

KPI	RENKEI Control Applicability	Summary	Benefit Verification Method
① Energy total consumption (Simple comparison method)	No	The mass energy consumption volume within the elated boundary and period, using electric energy value or crude oil conversion energy value	Difference of before and after implementing the RENKEI control
② Energy Cost (Simple comparison method)	No	Energy purchasing cost for electricity, gas, fuel, etc.	Difference of before and after implementing the RENKEI control
③ Specific Energy Consumption	Yes	Energy mass consumption volume divided by production volume, revenue, etc.	Comparing the specific energy consumption of before and after implementing the RENKEI control
④ Specific Energy Cost	Yes	Energy cost divided by production volume, revenue, etc.	Comparing the specific energy cost of before and after implementing the RENKEI control
⑤ Specific energy consumption performance (Energy baseline equation modeling method)	Yes	Establish a model equation expressing the relationship between energy consumption and the influential factors	The influential factors of after the RENKEI implementation, are applied to the model equation to calculate the estimated baseline energy consumption subtracted by the actual energy consumption

① Energy total consumption (Simple comparison method)

With the boundary and the time period as defined in sections 4-2-2 and 4-2-3, it is to compare the total energy consumption amount before and after implementing the RENKEI control. If the energy used is only electricity, simply compare the kWh. However if using multiple energy units such as electricity and fuel gas etc., make a uniform heat value conversion such as to crude oil KL or BTU for making comparison. The difference between before and after is the outcome of implementing the RENKEI control. However if there are variances in energy consumption with influencing factors before and after, then some sort of an offsetting measure should be taken to obtain a legitimate result.

② Energy cost (Simple comparison method)

It is to compare before and after the energy cost such as electricity, gas, fuel, etc. However in case if the energy is traded to the third parties, then the comparison is with the energy purchasing cost subtracted by the revenue of energy sales. Since energy unit cost is different from the energy sources and the electricity unit cost may vary with the time of use, and therefore the result may not necessarily be proportional to the result obtained by energy consumption amount described in Item ①.

③ Specific energy consumption

Under the appropriately defined boundary and period, it is comparing the before and after RENKEI control implementation with energy total consumption (energy consumption subtracted by energy sold) is divided by an output such as production volume, sales revenue, attendance, etc. of those closely associated with the energy consumption. If the energy use is multiple such as electricity and other fuels and gases, convert them to a uniform crude oil or BTU heat value. By comparing the specific energy consumption, it eliminates the production volume related influential factors. However even for the specific energy consumption method, if the process with energy consumption not corresponding to the production volume then the benefit of RENKEI control can be underestimated. Furthermore even if the production volume is the same, the energy consumption may vary due to different kinds of products and thus requires special attention for facilities producing a range of different product lines.

④ Specific energy cost

The term “total energy consumption” is replaced by “total energy cost” in the description of item ③, above.

⑤ Specific energy consumption performance (Energy baseline equation modeling method)

If the energy consumption before and after implementing the RENKEI control fluctuates either by external factors such as weather condition, etc. or by internal factors such as production volume, etc., the KPI described in ① (② for using energy cost) would no longer provide legitimate verification after implementing the RENKEI control. Accordingly, a model equation representing the relationship between energy consumption and influential factors was identified prior to the RENKEI control implementation. This was defined as the energy baseline. After the implementation, the influential factors are applied to the model equation to calculate the estimated baseline energy consumption. The RENKEI control benefit is then derived by the estimated baseline energy consumption subtracted by the actual energy consumption.

The baseline model can be expressed as an equation using various statistical models such as multiple regression, etc. More sophisticated is the model more difficult is to handle in practicality. Therefore it is essential to make the model as simple as possible. In practice, it is sensible to prioritise and narrow down to a several factors to generate a multiple regression expressed in linear equation.

As an example, a linear equation derived by energy consumption and production volume is expressed in a graph as shown in Figure 4-1, below. Suppose the verification after the RENKEI control implementation was at production volume "x_1" and energy consumption "y_1". The baseline is expressed as the linear equation prior to the implementation. Then the energy consumption with the production volume "x_1" at the baseline is estimated as "y_0". Such that the difference of "y_0" and "y_1" is the benefit of RENKEI control implementation.

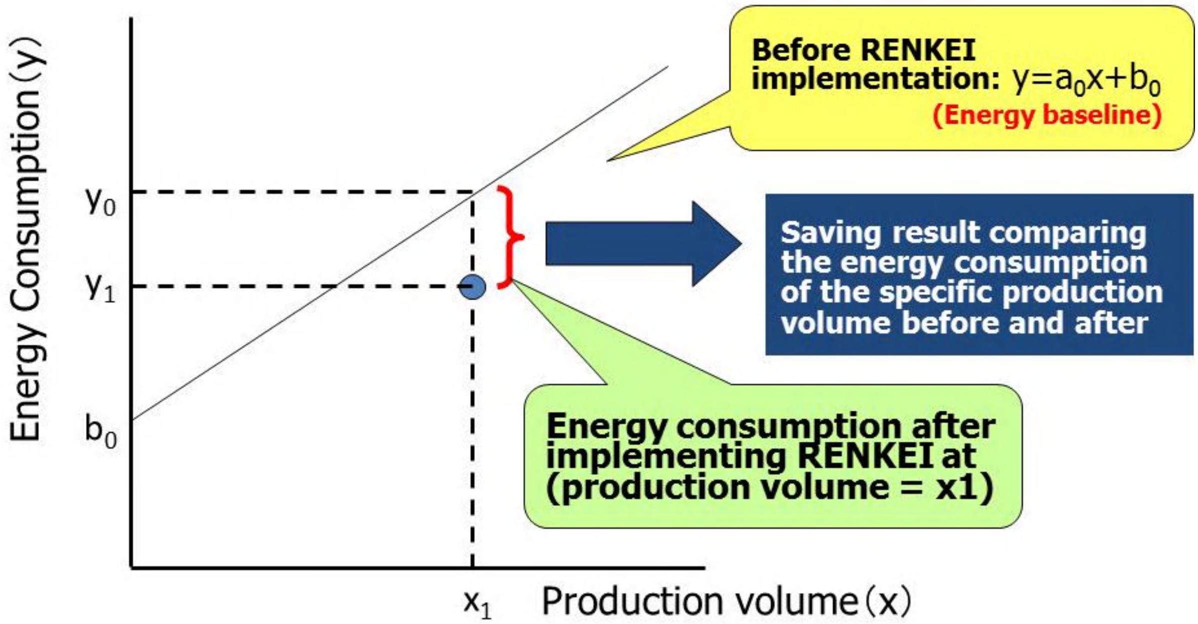

Figure 4-1: Comparison to the baseline defined prior to the implementation

4-2-2 Boundary

It is necessary to define appropriate boundary (equipments/machineries/facilities) in order to measure the energy use for the KPI calculation in accordance with the defined objective. Additionally it is advisable to spell out the thought process of how the boundary is defined. In order to verify the RENKEI control energy saving benefit, it has to include the boundary having the influence of implementing the RENKEI control. Accordingly, eliminating the part not affected by the control would further emphasize the benefit. Samples of how the boundary was established were shown in Figure 4-2, below.

In Figure 4-2, RENKEI control was applied to the Facility System 2. In case (a), although the RENKEI control was not applied to the System 1, there existed some intervention (influence) such as flow rate changes, etc. Therefore it must include the System 1 to the boundary in comparing the KPI before and after implementing the RENKEI control. On the other hand, in case (b), the boundary was only with the System 2 since it is independent of the System 1. Two cases were demonstrated show even if the facilities were the same; the boundary for verification can be different due to the system configuration.

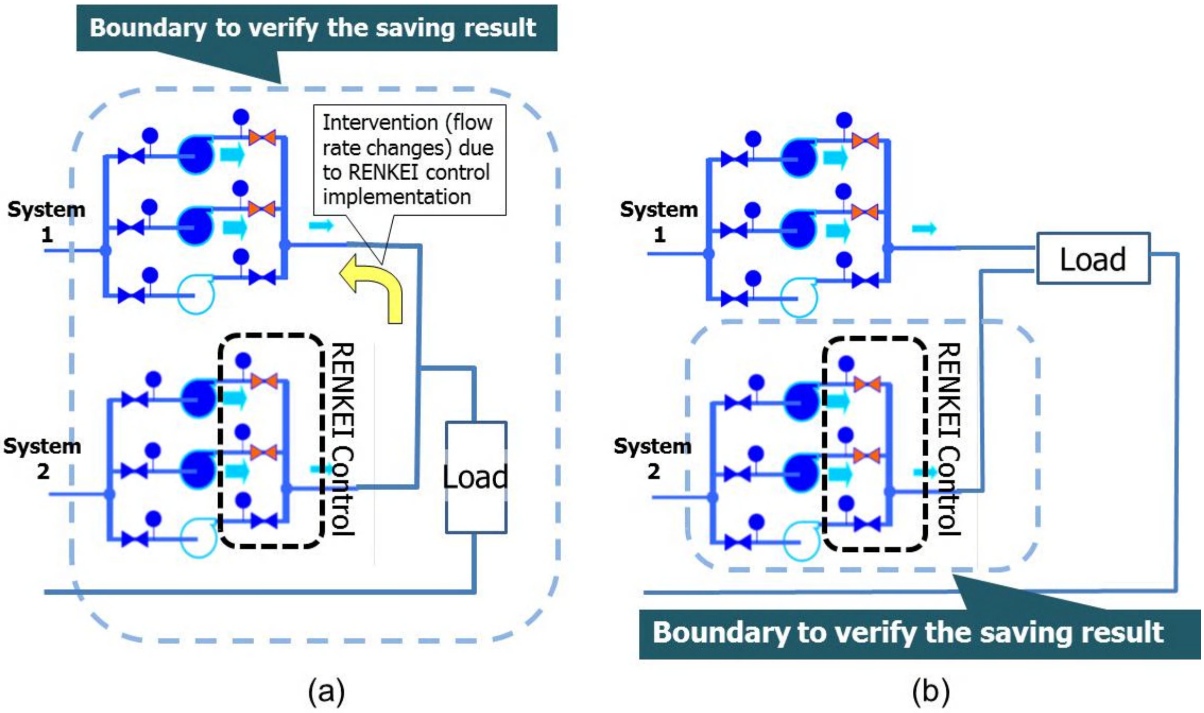

Figure 4-2: Samples of boundary established in verifying the RENKEI control benefit

4-2-3 Verification Time Period

For identifying the evaluation period for verification, it is preferable as much as possible to eliminate periods with factors (weather condition, process/operation pattern, product line, etc.) influencing the facilities implementing the RENKEI control. To make that possible in principle, the overall period must extend to at least a year. For the reason that the data collection and analysis for verification would impact cost and time spent for the work, in accordance with the magnitude of the benefit and necessity, a practical selection of periods from the following examples is recommended.

① A day of a typical energy consumption pattern

② A continuous one week period

③ A representing day in each season

④ One year

⑤ Several years (It does not have to be continuous, and can trace the periods indicated in ①-④ above)

If the energy saving benefit must be verified shortly after the implementation, the KPI should be derived with the data period of either ① or ②. Using these periods, estimate the saving of one year, by making compensation considering all necessary influential factors throughout a year and applying appropriate averaging method such as weighted average, etc. to the original data period used.

4-2-4 Data Collection

For the facilities subject of the RENKEI control, the applied (consumed) units of energy such as electricity, fuel, heat source, etc. should be measured separately per facility as much as possible. The corresponding data such as weather condition, production volume, product line, etc. must be collected at the same time. Automatic data collection is always convenient but if not it can also be done by manual meter reading at a given period of time. For the frequency of data collection in continuous process, on the hour or average of accumulative amount should be appropriate. However this depends on the facility that may require a different frequency than one hour frequency such as from 1 minute to a day frequency appropriate to the nature of the facility.

More precise energy saving benefit statement can be obtained and enhanced energy saving opportunities or limitation can be identified by comparing the KPIs based on the status as described in Appendix 1 and 2.

In order to calculate for the benefit verification, the data prior to implementation of RENKEI control must be collected. However if the past data is not fully available, it is necessary to plan a data collection period using the existing control method before introducing the RENKEI control. If neither of these is feasible, then the remaining option is a parallel operation together with the old control system to collect the comparison data after implementation of the RENKEI control. When the RENKEI control is implemented with a complete renewal of facilities or with introduction of new energy efficient equipments such as inverters, etc., then only the RENKEI part can be assessed with the overall energy performance improvement verification. Figure 4-3 in the next page demonstrates the total savings made by combined RENKEI and facility renewal versus the differentiating savings made solely by RENKEI part.

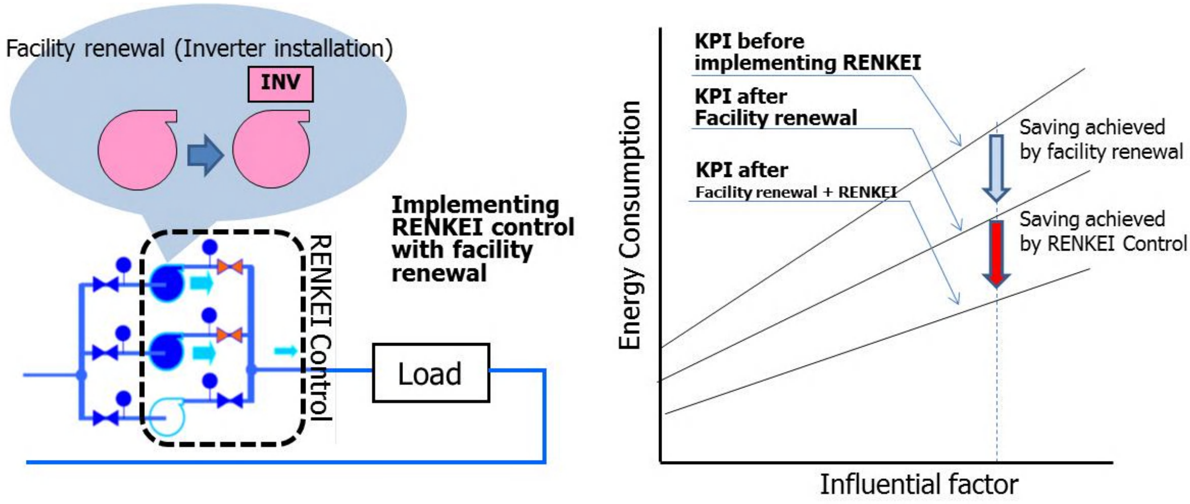

Figure 4-3: Differentiating savings by RENKEI Control from facility renewal

Collected data may contain unexpected value (outlier) or missing value[5]. Normally a set of data (e.g. day data) containing these values, they shall be excluded. For some special reason that the exclusion is not appropriate, then a data adjustment process can be exercised by interpolating the unexpected or missing values with the neighbouring values considered to be most appropriate. In such case, the data adjustment process should be limited to the special case.

4-2-5 Responding to errors generated in collected data

There are more than a few error exists in collected data due to the instrumentation tolerances. For electricity, authorised supply meters are guaranteed tolerances with standard meter (up to 500 kW) ±2 %, precision meter (500 kW up to 1,000 kW) ±1 %, special precision meter (1,000 kW or up) ±0.5 %. For non-supply general meters used for energy management purpose have wider tolerance ranges. Other meters such as gas flow meters in general the error expectancies are inferior to that of electricity. In the case of zero drift bias, by taking the difference of before and after the RENKEI control implementation, the error can be offset. Other errors can be due to linearity, hysteresis, temperature characteristics, etc., however in practice no corrective measures are taken in calculating the savings for these errors. For collected data, it needs to specify the method of data collection and the accuracy of meters used. Furthermore, it is recommended to carry out the calibration of instruments in order to verify the savings with a superior accuracy.

[5] This often is caused by the facility abnormality or inspection routines. Actions such as to take only data generated during production period may be appropriate as suggested in Appendix 2, "Definition of EMU Status".

4-2-6 Expressing Verification Result

For the final result, it demonstrates the KPI of before and after the implementation at the established boundary and time period. Furthermore as required, the time variation such as hourly by the day, daily by a week, monthly by a year, etc., can be expressed with tables and graphs in order to clarify the background of generating the savings. Figure 4-4 below demonstrates the daily savings and the specific energy consumption by a graph. With this graph, it is clear that the saving patterns are different between weekdays and weekends.

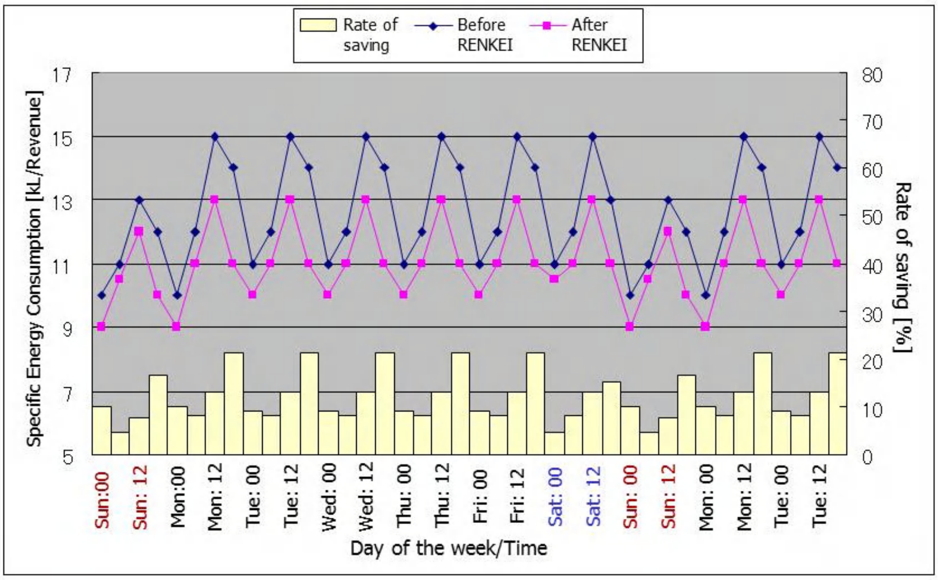

Figure 4-4: Sample of expressing Verification Result (Identifying KPI improvement by time during introduction period)

For the energy baseline comparisons, plotting influential factors on the x-axis and energy consumption (cost) on the y-axis will identify the baseline equation, and by plotting the actual values after the RENKEI control implementation, the energy saving benefit can be observed visually at once. Figure 4-5 below demonstrate its sample.

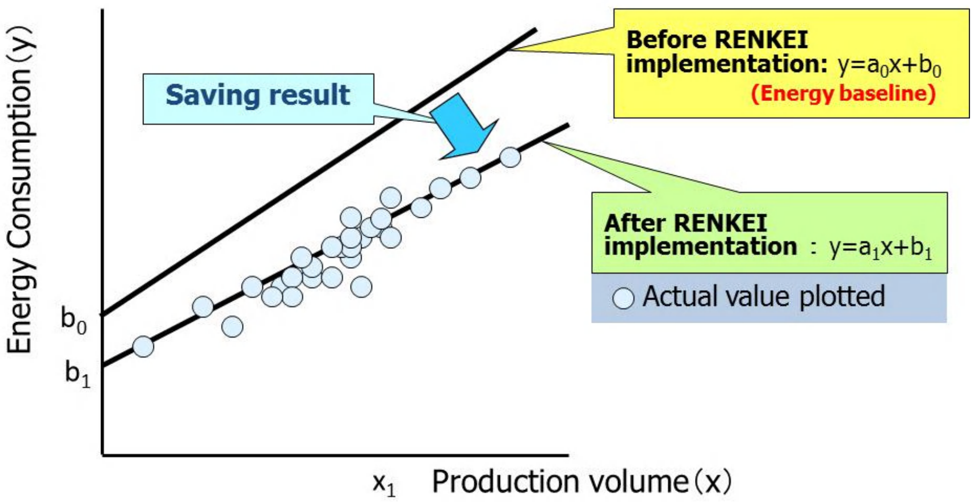

Figure 4-5: Sample of expressing Verification Result (Comparison to the baseline defined prior to RENKEI implementation)

4-3 On-line Automatic Control System and Guidance System

For the RENKEI control implementation and its method of operation, there are two types of execution. One is to execute with on-line automatic control, and the other is to execute using operators who follow the instruction of the guidance system as well as their personal judgement. Operator skill and competency are influential factors to the savings when using the guidance system with operators. In this case, in order to properly measure the energy saving benefit of using the RENKEI control, it is recommended to record the system's indicated values as well as the actual values operated by operators for the benefit analysis.

5 Energy Optimisation Approaches

In this chapter, two useful sets of guide are provided. One is the evaluation method of defining the best control boundary in designing RENKEI control solution and the other is the method in obtaining energy use optimisation that is best suited for the characteristics defined control boundary. Additionally, in the chapter, an approach to the evaluation index (KPI) suitable to the RENKEI control to be installed is provided.

5-1 Energy Management Beneficiary and Energy Type

The RENKEI control is applicable for the most of energy use facilities in commercial buildings and factories (for both continuous and batch [6] processes). Comparing to the individual control concept, much greater energy saving can be expected from the RENKEI control. Hereinafter, samples of energy use method in the RENKEI control applications and the implementation of energy management are outlined.

(1) Commercial Building

There are several patterns in energy supply method for commercial buildings such as receiving primary energy and transforming to usable energy by the in-house utilities for use within the building, receiving heat energy produced and delivered by the district heating/cooling system and transforming to usable energy forming a hybrid structure with other transformed energy, etc. The basic conceptual flow with hybrid concept can be outlined as shown in Figure 5-1, below. Energy required by commercial buildings such as electricity and fuel, etc., is led into the utility facilities, and energy required by the building occupants such as electricity, cooling/hot water, etc., is produced (converted to secondary energy) and supplied by the utility facilities.

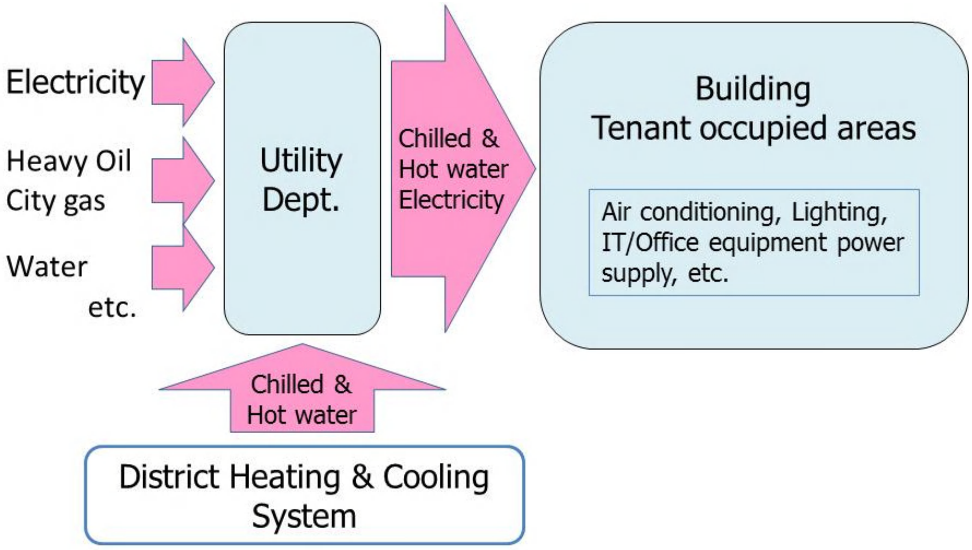

Figure 5-1: Basic Energy Flow Concept (Commercial Building)

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[6] A discrete process is classified as a batch process.

A typical RENKEI control as shown in Figure 5-2 can be seen in the application of integrated operation of multiple heat resource facilities for the HVAC purpose.

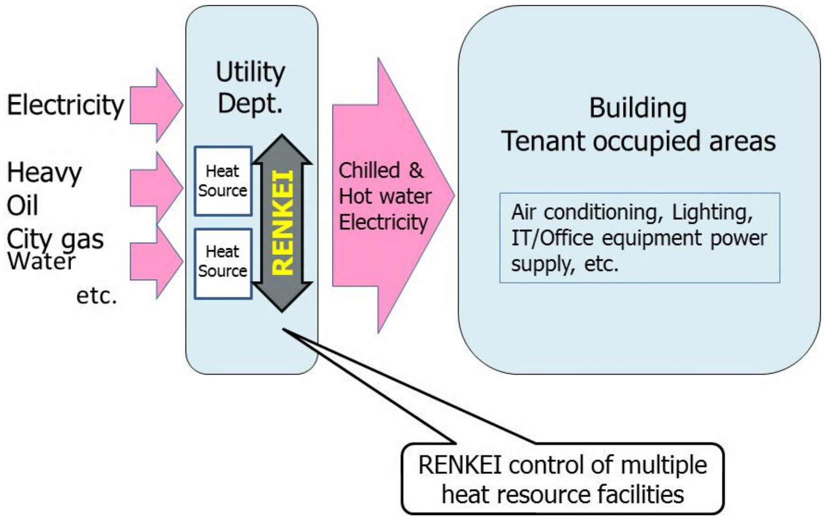


Figure 5-2: Typical RENKEI Control Application (Commercial Building)

(2) Factory

Similar to the commercial building case, several patterns exist also for the industrial applications in energy supply method. Typically they can be categorised by the type of production process. One is a continuous process (Raw material is continuously supplied, processed and made into a product such as petroleum refinery, etc.) and the other is a batch process (Raw material is intermittently supplied, processed and made into a product such as assembly food, pharmaceutical factory, etc.). However in actual factory operation, the situation is not as simple as the categorised description. The operation is typically structured with diversified processes such as continuous process, batch process or combined hybrid process, etc. integrated within a single manufacturing process line.

■Paper Mill Factory

As an example, a paper mill factory is depicted in Figure 5-3 below for further explanation.

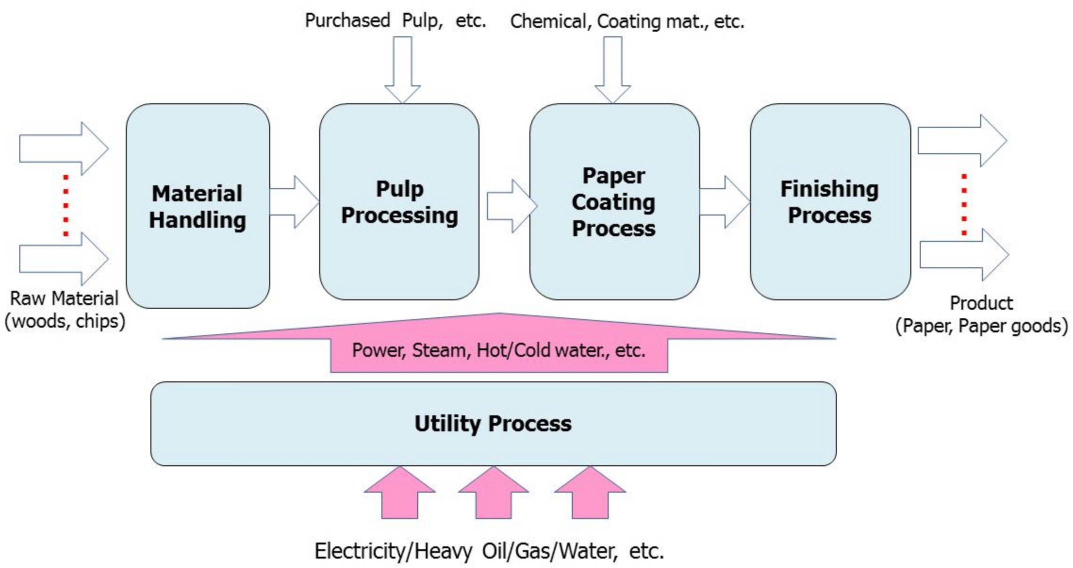


Figure 5-3: Paper Mill Factory Model

The pulp production process after the raw material receiving and handling process can be described as a continuous process when focussing on the continuous digester process. However the each chemical solution injected in respond to material input is batch process. Additionally within the paper making and coating processes, the paper machine operation itself is continuous whereas the coating and chemical injection processes need to follow the recipe specified to the product line and thus regarded as a batch process. Moreover the outputs of the paper making process are wound up in rolls using "reel" unit and sent as batch to the following finishing process.

As shown in Figure 5-4 below, RENKEI control can be a collection of various types of specific RENKEI control, such as responding to the demand intensity among two processes, responding to energy demand during the "paper break" time as a completion cycle within the paper machine or coating processes, and etc.

The facilities in each process operate intermittently as opposed to continuous, thus the associated energy consumption is constantly changing in accordance with the facility movement. For this reason if the saving verification of RENKEI control implementation is simply carried out without considering the process characteristics, deviations is likely to occur and it creates compatibility of the assessment in terms of accuracy and impartiality.

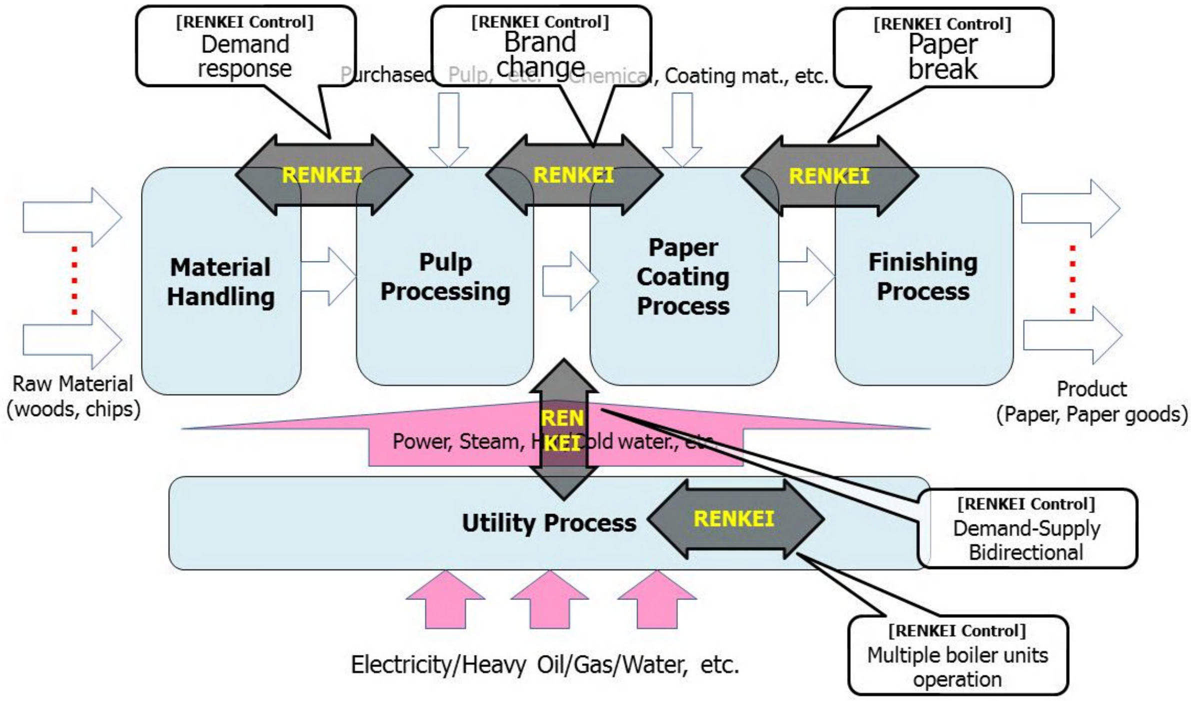


Figure 5-4: RENKEI Control Application (Paper Mill Factory)

■Automotive Plant

For the automotive plant shown in Figure 5-5 below are mostly constituted with batch processes such as from part assembly, painting processes to body assembly, etc.

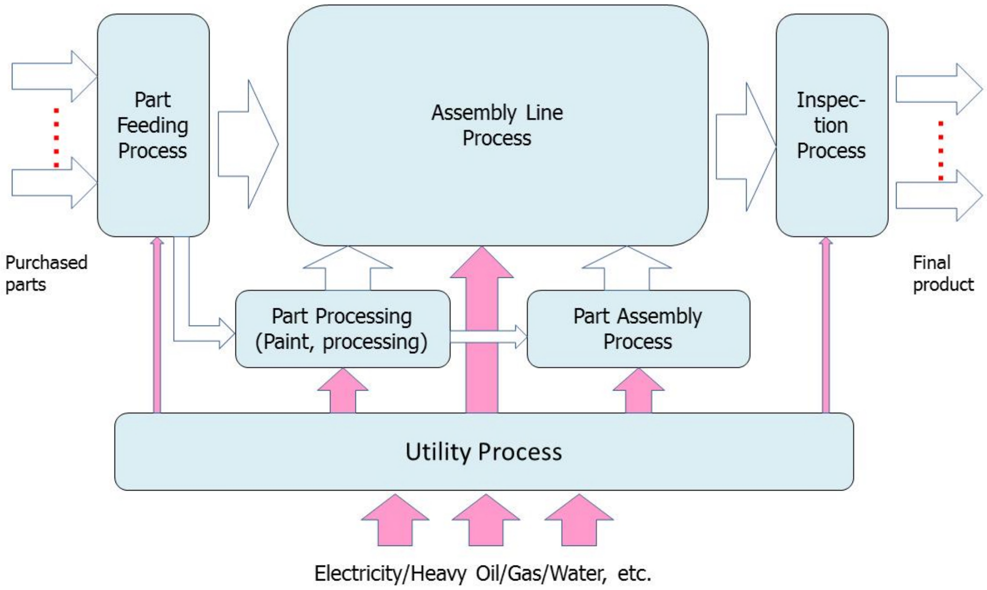


Figure 5-5: Automotive Plant

One of RENKEI control applications in automotive plant is outline in Figure 5-6, below. As the same as the paper mill factory case, there are various patterns such as controlling within a process or among two processes. In the case of automotive plant, each process as categorised as batch process has a wide range of time factors from batch process in seconds to batch process in hours, and thus cannot simply treat batches as the same unit. Therefore in order to properly assess the energy saving benefit of REKEI control, it requires to separate processes of similar time factors in several groups and apply the appropriate time axis to the defined groups for evaluation. (Refer to Appendix 2)

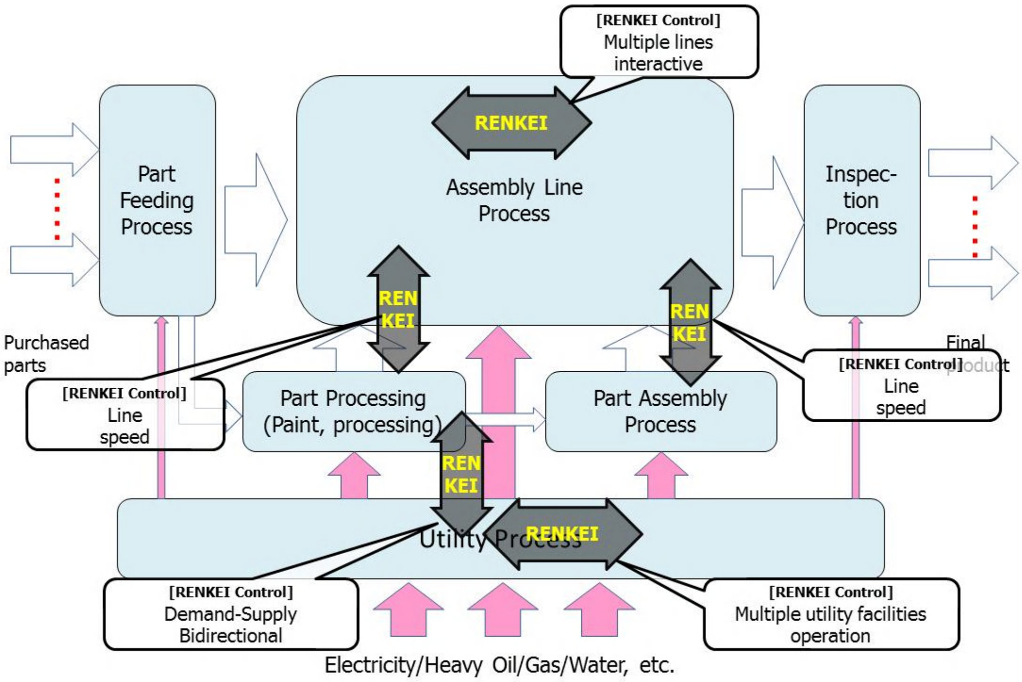


Figure 5-6: RENKEI Control Application (Automotive Plant)

■Energy Efficiency Management with the Control Boundary and Time Axis

In order to apply RENKEI control consistent to the diversified patterns of processes, it is recommended to define the applied scope of RENKEI control to be the boundary, and to manage all facilities, machine and equipments within the boundary as a whole. For such management method, observe the relationship between the energy use and the variables closely influencing the energy use, and to confirm if the boundary is operated at adequate energy use efficiency and how much energy saving benefit is generated. In order to implement energy management smoothly, it is sensible to define the areas containing items of significant energy use and containing energy saving opportunity items represented as an energy management boundary, and to convert into the Energy Management Unit (EMU) as described in Appendix 1 in managing the boundary as one uniform unit.

EMU is a management method in assuming a simplified model of material input using variety of energy for processing and generating the outputs for the next manufacturing process, and to quantify material inputs, generated outputs, the difference (output minus input), and the energy used during the same period. Furthermore, to upgrade the accuracy of quantification, there exists a method to define each status of process and operational conditions of inputs and outputs generated within the EMU (refer to Appendix 2). The facilities in a factory contain process statuses such as preparation, in operation, stop, etc., and depending on the status, the input, output and the energy consumption can vary significantly, and the facilities operate independently as such that often case the correlation between the energy consumption and the production volume can be irrelevant. For this reason, it is sensible to evaluate the correlation of energy consumption and production volume of each status in EMU. By doing so, the production and energy use relation, seemingly complicated at the first glance, can now be described as a simple model with additional feature of forecasting energy use. For this reason, it becomes important to evaluate and analyse the obtained data with appropriately selected time axis.

By observing the energy pattern with a long time axis, for example by month or by year, it can obtain the data that go beyond the differences of processes such as continuous and batch processes to appreciate the long term energy use trend. However in order to identify specifically the energy performance improvement opportunities, it is more appropriate to evaluate the data with a short time axis. It has been said that it is important to select the most appropriate time axis for effectively evaluating the achievement of the objective and target as the result of energy management operation.

5-2 Energy Use Optimisation

In the previous section, a method was explained to assess the energy saving benefit using appropriate time axis and status after identified input and output by defining the boundary as the implementation scope of RENKEI control to be the Energy Management Unit (EMU).

By using this method, effective evaluation can be achieved by splitting up the entire site into multiple EMUs for efficient implementation of energy management and performance improvement. In this section, tips for the energy use optimisation are provided. For systems having different time axis such as continuous and batch systems would normally proceed in distinctive ways of using facilities and carrying out operation. For this reason, a system containing continuous process and a system containing batch process are explained in this section.

5-2-1 Optimisation Consideration (Common subject)

A point to observe in optimisation is initiating the area of evaluation with facilities or processes having significant energy use, and controlling the use of energy in the area most appropriate in respond to the demand (or production volume). If there is fixed energy use independent of the production output, every effort has to be made to reduce this, or to examine how to relate the fixed part to the production input. For example, if the cooling water for production purpose is constantly consumed independent of production volume, examine the subject facility to consume the cooling water only when it is in operation (interlocking the fixed value with production volume).

The next point to observe is in the utility facilities in which the energy is supplied to the demand side, and to see if the supply side energy is capable of adjusting to the energy demand volume (or forecasted volume) by optimally orchestrating the operation of various facilities on real time basis. RENKEI control is to provide a superior control method in generating a large scale improvement result with small scale investment. Provided with the accurate measurement information, the control featuring control algorithm that is incorporated with elements such as operation know-how, forecasting functionality, etc. enables to operate the supply side facilities optimally in response to the demand side operating conditions. It further performs supply volume control in response to the demand condition yielding further reduction of waste.

5-2-2 System Optimisation with Continuous Process

Typical continuous processes can be represented by facilities such as heat sources used in HVAC application for buildings and factories, steam generation utilities, petroleum and chemical plants, etc. These facilities typically operate continuously over the period of time, and likely to identify improvement opportunities when considering optimisation approaches through the viewpoints listed below.

- Operating in response to the demand requirements

  For the continuous process facilities, in many cases, during which the demand is declining, the capacity of the facilities are unable to throttle within a fixed value range. In some instances, even you are able to throttle one facility; it still does not provide the overall energy use reduction. In some instance, when the capacity is throttled, the expected quality level of output can be no longer maintained. For this reason, when examining ways to operate the facility optimally in response to the demand, it is sensible first to know the energy use characteristics of the facility at average load condition in securing the required quality level.

- Improving facility's effective utilization ratio

  Improving facility's rate of operation, in another words to improve facility's effective utilization ratio will upgrade the energy use efficiency. For the continuous process facilities, significant time is required for the preparation prior to the operation cycle and similarly for the preparation in terminating the operation. For this reason, to find the areas where energy is used without contributing to the actual production (demand) such as the time and numbers of start-up and shut-down periods required for each facility, etc., and use this information to examine the effective operation methods minimising energy use that goes in waste. Furthermore, it is desirable to pay attention in maintaining the achieved energy use efficiency by implementing effective facility maintenance programmes such as preventive maintenance system, etc.

- Evaluating the appropriateness of material used

  The difference in material (including raw material, fuel, etc.) can affect significant use of energy and its efficiency, and thus it is sensible to consider various options.

5-2-3 System Optimisation with Batch Process

Typical batch processes can be represented by food/pharmaceuticals, chemical products manufacturing, assembling of parts and finished goods such as automotive and electronic device, etc. The characteristic of batch processes in comparison with the continuous processes can be described as elements such as the process time of each facility in operation is short, the manufactured products can change in a relatively short period of time, etc. For this reason, to identify improvement opportunities when considering optimisation approaches through the viewpoints listed below can be beneficial.

- Monitoring and understanding energy consumption of each facility and examine if more "stop" statuses can be incorporated in the process.

  In many instances, energy consumption can be varying significantly with the operating statuses of the facility. For this reason, it is sensible to see how energy consumption can change with each operation status such as start-up/run/shut-down/stand-by/receiving/dispatching, etc. During this time, useful tip for optimisation is considering not only the energy consumption of each operation status but also the feasibility of incorporating the "stop" statuses by carefully examining consequences drawn by the operation status related to changes such as extra time required, additional work, influential factors and limitations related to the facility.

- Adjusting the capacity of facility to be considered

  When using a facility having larger capacity than the actual demand, it is sensible to consider if the capacity can be reduced. If it is not feasible to reduce, it can be replaced with smaller multiple facilities providing flexibility to the change in production volume.

- Comprehending the relation between product line and energy consumption

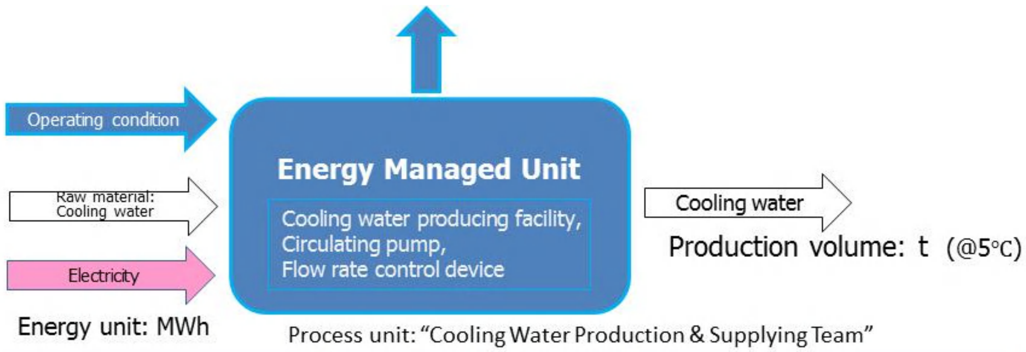
  Processing details of facilities can change significantly depending on which product line (recipe) is processed. In response to the change in processing details, in many instances energy consumption would change. If the information regarding energy consumption of each product type is available (theoretical calculation is acceptable), it enables to analyse the difference between the expected and the actual consumption. This analysis leads into implementing the optimum production scheduling per product type. Additionally, with the best practice scheduling, it enables to control against the unauthorised peak demand situation (Electricity cost reduction).

5-3 Optimisation Yardstick

When implementing energy saving measures (Introduction of RENKEI control or replacement of a facility), it is sensible to adopt an appropriate yardstick, in another words, to define an appropriate evaluation criteria (KPI). With the yardstick, it allows forecasting the energy savings before implementing the measure, and by using the same yardstick to evaluate after the implementation, it enables to identify action items for continual improvement. There are various concepts in KPI, and in this section, the KPI concepts typically used for the RENKEI control implementation are provided.

In Section 5-1, a method to implement and manage improvement measure by dividing the entire site for appropriate EMU. However, for implementation of RENKEI control, it is recommended not only to evaluate the KPI within the defined EMU forming the baseline but also to evaluate the KPI which would demonstrates the benefits generated by the RENKEI control from the perspective of the total optimisation.

For example, after implementing energy efficiency measure such as demand and supply RENKEI, etc., a method as shown in Figure 5-7 below, illustrates how to verify the energy savings benefit. When identifying the energy consumed to produce and dispatch a ton of cooling water after RENKEI implementation, the yardstick is used carrying the scale of baseline to calculate how much energy would have been used to produce and dispatch an identical ton of cooling water during the defined baseline period before the REBKEI implementation. With this methodology, the energy saving benefit is verified by identifying the difference between energy consumed after and before the RENKEI implementation.



	Production volume (t)	Energy unit (MWh)	Specific Energy Consumption (MWh/t)
Baseline	1,000	7,000	7.0
After implementation	1,000	5,000	5.0
Difference	0	▲2,000	▲2.0

Figure 5-7: Implementation Benefit Verification using Specific Energy Consumption

An attention has to be drawn that for some EMU cases, energy is consumed even if there is no production. In those cases, energy consumption estimation calculation formula has to be revised to "fixed energy consumption + production related energy consumption". (Refer to Appendix 4)

Furthermore when EMU operation comes to a "stop", there exist the periods that energy is consumed while the production is zero such as "shut-down" and "start-up" periods. If such situations occur frequently or the portion becomes significantly large, the accuracy of the calculation for energy consumption estimation would get worse. To counter this, such time period can be segregated as an exception, and to evaluate without this portion or to evaluate by assigning specific calculation formula for energy consumption to each period which was identified as an exception. In this way it provide clearer picture of the situation providing better accuracy in evaluation. (Refer to Appendix 2)

5-3-1 Performance Index within EMU that forms the base

In this section, examples of the EMU performance index for system containing continuous process and system containing batch process are outlined. In the complicated cases of EMU that containing both processes, EMU is divided into systems containing continuous process and batch process. Identify performance index distinctively for each system, and for the EMU as a whole, define the overall performance index by combining the performance indexes identified from both systems. With this methodology, energy consumption situation becomes highly visible in the complicated cases of EMU containing both continuous and batch processes.

(1) System with Continuous Process

It can be said that for the continuous process, the frequency of changing material and product lines is relatively low. Accordingly, it is recommended to grasp the EMU as a whole in large scale, and to use specific energy consumption derived by energy consumption against the specific production volume as KPI or to use energy efficiency of facility classified as KPI with significant energy use. In this case, the evaluation accuracy can improve if the energy consumption during operation shut-down and start-up can be excluded or evaluated as exception.

(2) System with Batch Process

It can be said that for the batch process, the possibility of producing multiple types (brands) of product are relatively high. Among the batch process, in the case of the discrete process[7] the frequency of adding new products or terminating the products for obsolescence is relatively high. If the energy consumptions are significantly different by product types, it is recommended to define the KPI with specific energy consumption of one time batch unit from the facility with significant energy use. On the other hand, if the energy consumptions are similar among the product types, by grasping the EMU as a whole, it is recommended to define the KPI as a simple method by deriving specific energy consumption with statistical approach. However in this case a special attention should be placed that the amount of work in process can be an influential factor to the specific energy consumption. When facing with this situation, it can alleviate the influences by using statistical techniques such as a long term moving-average method, etc. Energy tracking is another important method to use in understanding energy consumption accurately on the real time basis. Lastly, for the discrete processes, it is also possible to assign the KPI per a piece of production.

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[7] A discrete process is classified as a family of batch process in this guidebook.

5-3-2 Performance Index demonstrating RENKEI Benefit

In this section, examples of performance index demonstrating energy saving benefit obtained by the demand and supply RENKEI are outlined. In principle, the performance indexes are common irrespective of the 5 types of the RENKEI control defined in Chapter 2.

In the demand and supply RENKEI, the requirement is to control the supply amount in response to the requirements of the demand side. For example, the performance index for the demand and supply RENKEI of cooling water for production purpose can be defined as shown in the following sub-section.

(1) Specific Energy Consumption Method (Relative Comparison)

To produce and transport 1 ton of cooling water is defined as the cooling water significant energy consumption (SEC) and to evaluate the energy saving benefit by comparing the SEC of before and after implementing the RENKEI control.

- Before RENKEI Cooling Water SEC I_{base} =
  Cooling Water Energy Consumption E_{base} / Cooling water transport Q_{base}
- After RENKEI Cooling Water SEC I_{rep} = E_{rep} / Q_{rep}
- Improvement Rate R = $(I_{base} - I_{rep}) / I_{rep} \times 100$ (%)

Note that the subscript "$_{base}$" indicates the result value of the baseline period, and the subscript "$_{rep}$" indicates the result value of the reporting period. Furthermore, the "baseline period" indicates the data period used to define the baseline KPI, and the "reporting period" indicates the data period used to define the performance KPI.

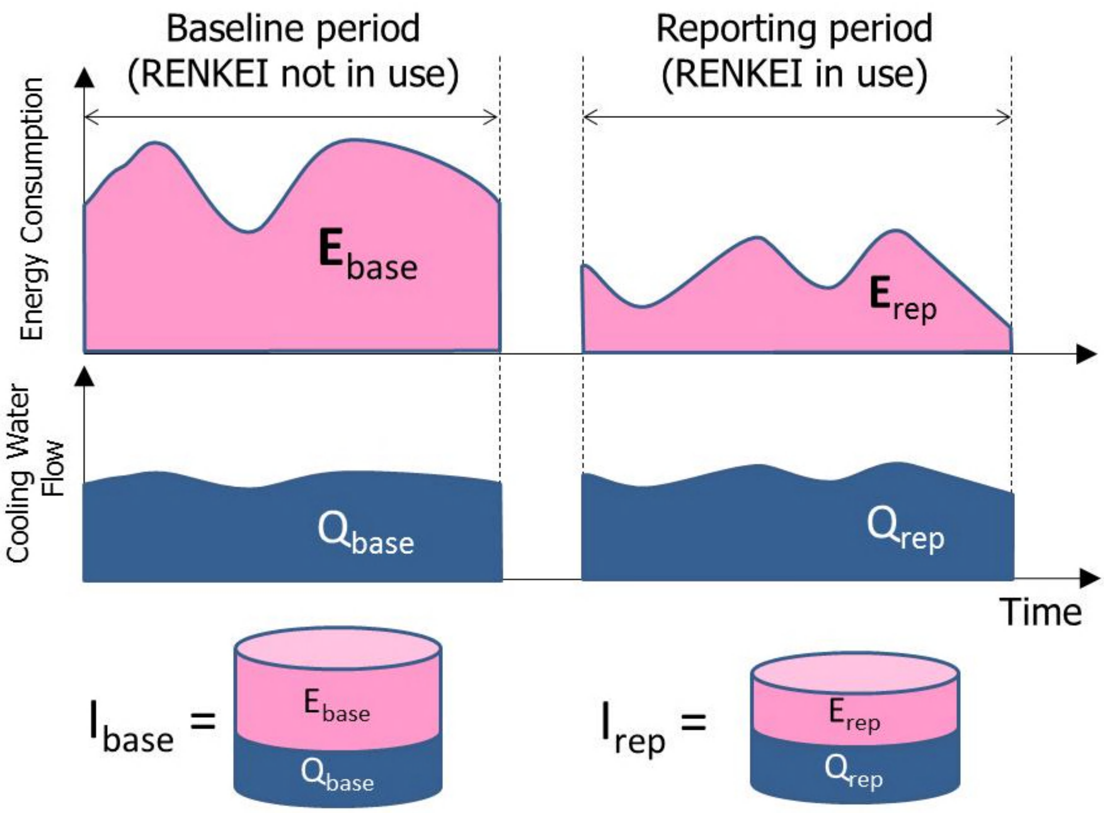

Figure 5-8: Specific Energy Consumption Method (Reporting and Baseline periods)

(2) Energy Total Consumption (Energy Baseline Model Method: Absolute Value Comparison)

For absolute value comparison, the baseline model is created with the required energy to transport cooling water. After the RENKEI control implementation, the actual cooling water transport quantity measured is applied to the model to estimate the baseline energy consumption. The estimated baseline consumption is then compared with the actual energy consumption to verify the savings.

- Before RENKEI model (e.g.): Energy consumption E $=$ I_{base} × Cooling water transport Q
- Estimated energy consumption E_{rep_est} = Ibase × Actual cooling water transport Q_{rep}
- Saving $\Delta E = E_{rep\_est} - E_{rep\_act}$

Note that the subscript "$_{base}$" indicates the result value of the baseline period, and the subscript "$_{rep}$" indicates the result value of the reporting period. The subscript "$_{est}$" indicates the estimated value, and the subscript "$_{act}$" indicates the actual value. Furthermore, I_{base} indicate the cooling water specific energy consumption before implementing the RENKEI control. The relation is depicted as Figure 5-9, below.

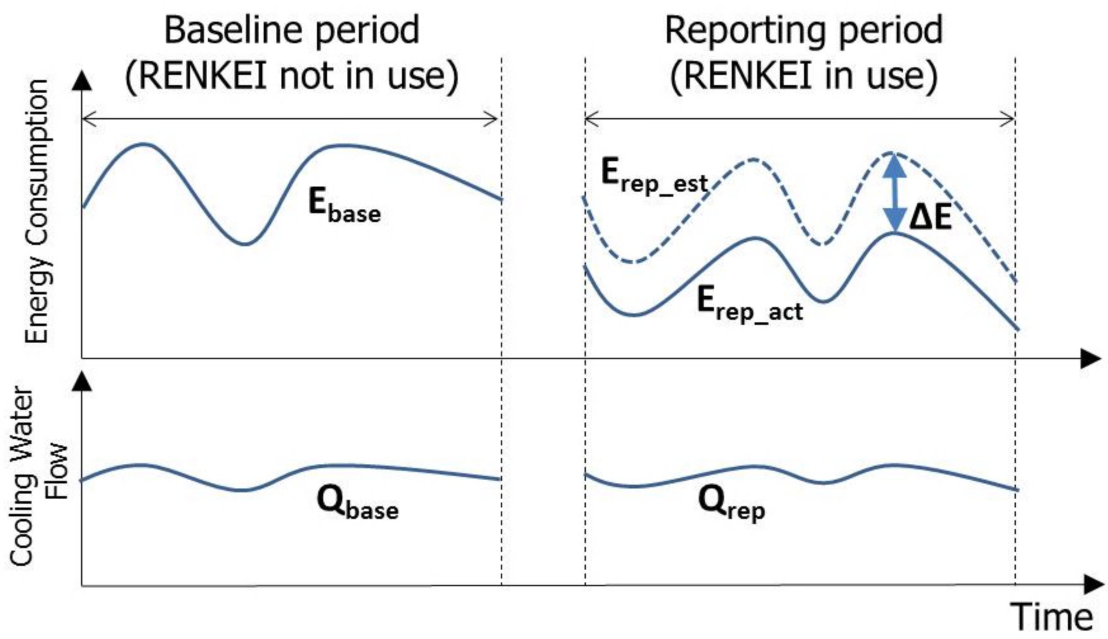

Figure 5-9: Energy Baseline Model Method

The index provides the energy saving implementation benefit of using energy absolute value, and the benefit easily can be converted to the cost value, which provides the economic effect information as well. Additionally, it has the benefit of easily related to the evaluation for carbon emission and trade purposes. Needless to say in order to use the above mentioned model (baseline model), it requires assuring appropriate accuracy for the model itself. For the simple system demonstrated as an example above can be applied as it is. However for applying to the more complicated system such as to include the batch process, it requires to compose a model having acceptable accuracy using the technique defined in the Appendix 2. In this case, for composing and maintaining the model, it requires additional time and effort in analysis work, so that a special attention should be placed on the fact that it requires additional cost in implementation.

6 Future Prospects

For the purpose of energy security and cost reduction, use of renewable energy and energy storage facility in the existing operation is expected to accelerate from now on. In order to maximise the use of such energy, the RENKEI control concept will enlarge its scope. Furthermore with the development of smart grid technology, the company operation site typically classified as an energy user may now be positioned as energy supplier. So far the typical use of RENKEI control is focussing control facilities for better energy efficiency. However in the coming years it is likely the scope will expand towards integration with enterprise management aspects such as accounting, ordering, billing systems, etc.

Additionally in Japan, the tight power demand and supply situation arisen from the Great East Japan Earthquake and associated nuclear power plant accidents remains unchanged which makes the situation that the power load levelling is ever more important. Act on the Rational Use of Energy (Energy Conservation Act) of Japan is taking an aggressive stand to implement and provide evaluation incentives for the peak load coverage. RENKEI control provides ideal optimisation solution that can be comfortably incorporated in the peak load coverage. The peak load management is the area where RENKEI control would like to aggressively pursue in developing solutions for the power demand and supply issues that Japan faces.

7 Ending Remarks

The RENKEI control has attracted many for its viable control technology solution focussing on balancing the disproportionate situation of energy demand and supply situations to minimise the energy waste. It is entering the prevailing period for its superiority as a proven energy management methodology. RENKEI does not require significant investment of having to build or replace a complete new facilities thus provides positive economic effect. Additionally it can initiate implementation within an affordable scale, and gradually expand in to a full optimisation. Once the teams of energy demand side (e.g., production unit) and the energy supply side (e.g., utility unit) manage to collaborate with each other towards the direction of the overall optimisation, the implementation of RENKEI control with gradual development are not as difficult as it sounds. Energy cost hereafter is bound to go up and each organisation requires pursuing further energy savings. For the further energy saving approach in the saturated situation, it requires a step further solution such as the RENKRI control concept. We sincerely hope that this guidebook serves your purpose of obtaining solutions in your future energy performance improvement effort.

Appendix 1.   Energy Managed Unit (EMU) Model

Considering energy management and verification method as a unified concept, there is a method[8] to define the concept into a model by combining all related status as shown in Figure A1-1. The objective is to verify if the model is operated under adequate energy efficiency by analysing the correlation between the energy usage of facilities and equipments within the defined boundary or boundaries in the model as well as by analysing the variables closely associated with the energy use. Additionally, the model aims to forecast the energy consumption of the implemented phase as precise as possible for the purpose of estimating the energy saving benefit. For the stated model, we call it "Energy Managed Unit" (EMU).

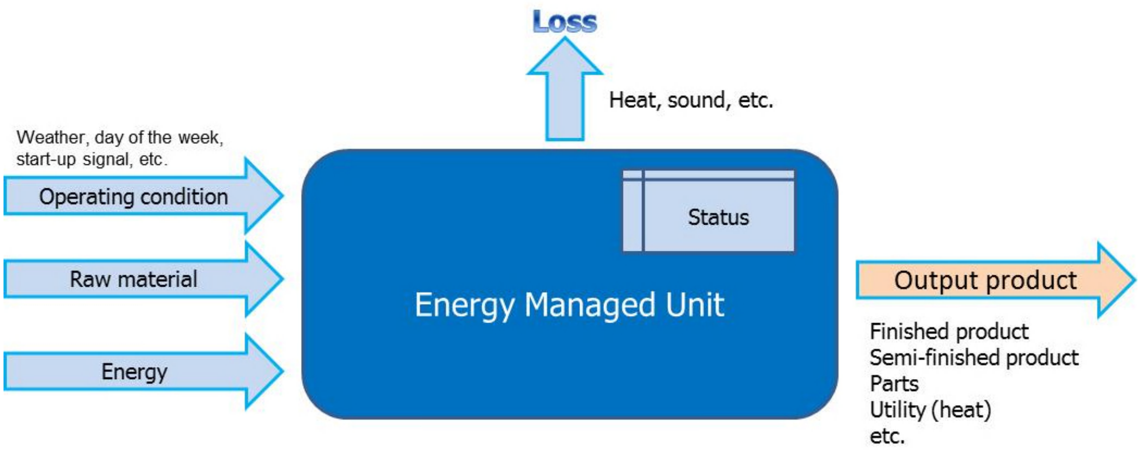

Figure A1- 1: Energy Managed Unit (EMU)

The model composing the EMU is defined by inputs and outputs. The difference of output and input is treated as a "loss". For inputs principally are supplied energy and raw materials supplied into the boundary. Raw materials can be classified as the materials for production or outputs from the previous process (parts, in-process goods), etc. Outputs of the model are final goods, goods in process, or energy output from utilities such as steam, hot-chilled water, etc.

In order to compare the performance on the similar condition before and after introducing RENKEI control, inputs treaded as the operating condition should identify factors that can largely influence the energy performance of the model. Examples of inputs are production condition in determining model's operational setting, lot type, operation on/off of main facilities/equipments, seasonal/weather factors, etc.。

Hereinafter, the EMU concept is demonstrated based on actual application with the boundary defined for the RENKEI controls using the commercial building and paper mill factory cases in the section 5-1.

8 This is a concept of which being discussed under the IEC/TC65/JWG14. The excerpt was taken from the technical report IEC/65/480B/DC(2011/5)

■Commercial building

For the cooling water supply process of the commercial building as shown on Figure A1-2, the output is the cooling water and the inputs are the electricity and water to produce the cooling water.

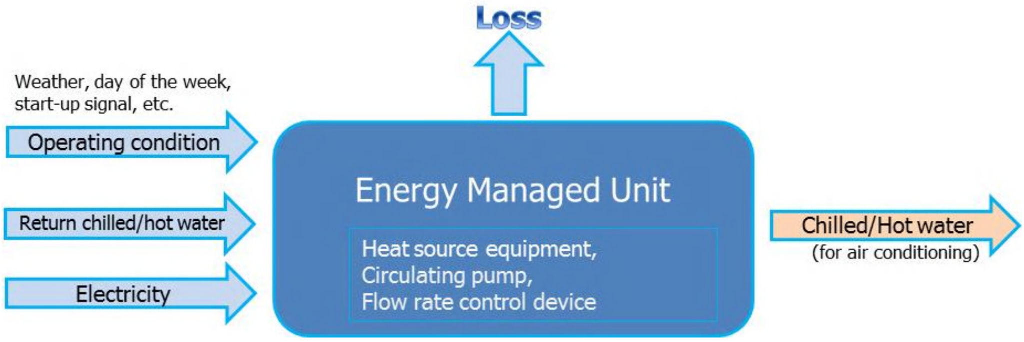

Figure A1- 2: EMU of Commercial Building (Heat-source system)

Electricity is used for multiple purposes such as lighting, IT equipments and others, however in this case it is important to focus the electricity use in the scope with identified as aspects related heat source system. In considering operating condition for the commercial building application, it needs to integrate the factors such as outdoor temperature, on/off of equipments due to schedule/day of week, and other related factors.

■Factory and plant

Figure A1-3 demonstrates the RENKEI control EMU concept during the brand change in paper mill factory.

The scope of RENKEI control during the brand change is to optimise control of the pulp flow rate ratio, input amount of dyes and chemicals at the time of changing the recipe of a paper machine incorporating the expected time lag generated during the change.

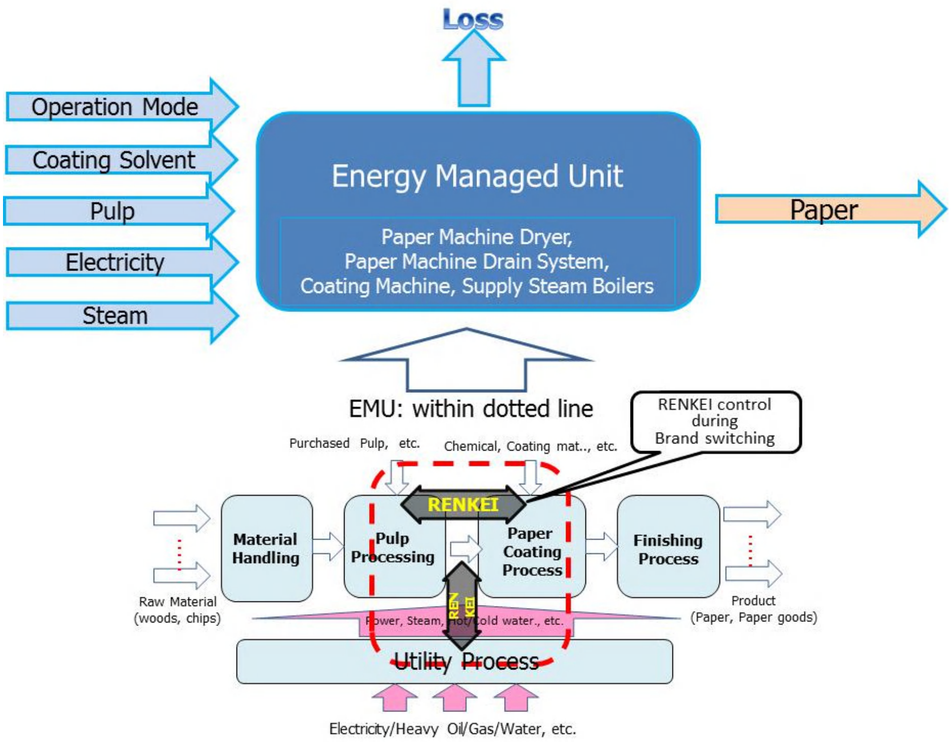

Figure A1- 3: EMU of Paper Mill Factory (RENKEI Control in product line change period)

In this case, the water used as solutions for pulp, dye and chemical is treated as one of input materials. The energy used to operate the machine is listed as electricity and compressed air. The output is defined as the paper produced by the paper machine through the blended process of above mentioned input materials. As for the operating condition elements, on/off timings of the defined facilities and machines, and specification changes of recipe may be considered.

As one can see the boundary set in accordance with the objective to improve and verify energy efficiency can now be defined as EMU in place of the boundary.

Appendix 2. EMU Status Definition

In order to assess the improvement of energy use efficiency as accurately and impartially as possible and to further improve the result by using the RENKEI control, it is useful to apply the concept of "status". As well as the normal operating status, EMU bears other statuses such as standstill, start-up, stand-by, etc. Through those statuses, the energy use characteristics can change significantly. One way to maintain the assessment stability, an example can be to eliminate measurement results of the statuses other than the normal operating status. Another example is to utilise the demand-side facility status as a control element for the "demand and supply RENKEI" control in further improving the efficiency and to stabilise the control function.

In Appendix 1, the operating condition was defined as an element to greatly influence the outcome of EMU. However, looking at factories such as paper mill and automotive where their whole day operation faces various statuses such as preparation, machine failure, recipe changes, etc. over the normal operation status. With the combination of statuses, the energy consumption patterns can vary significantly. Furthermore, for the most of the factories, the time spent on each status can vary day to day. To be precise, a factory operating pattern varies day to day.

For the commercial buildings, the situation is similar. From the statuses such as working hours, tenant business hours, lunch period, closing time etc. can change energy consumption significantly. Even when conditions such as outside temperature, day of week, office hour, etc. are similar, the energy performance indicator (EnPI) such as energy consumption, specific energy consumption, etc. and vary significantly if the statuses play a big part in EMU..

If the improvement activity is measured by comparing the current EnPI to the defined baseline without taking the statuses in consideration, the comparison practice itself will lose its significance. This would make identification of energy performance improvement opportunity more difficult and also to face danger in heading toward wrong directions for improvement activity. It is important to practice continual assessment in order to define a competent EnPI for performance improvement. Therefore operation status must be clearly identified and incorporated when defining the EnPI.

EMU status concept is based on ISO 22400, the International Standard for "automation systems and integration -- Key performance indicators for manufacturing operations management -- ". The ISO 22400 sets the guideline in defining various key performance indicators (KPI) for different business sectors. It also defines various operating conditions for different facilities and equipments related to manufacturing (Time model). In this guidebook, each operating condition is expressed as "status" following the IEC/65/480/DC, technical report "Energy Efficiency in Industrial Automation (EEIA)"

Typical example representing the EMU status is shown on Figure A2-1 in the next page demonstrating the energy consumption pattern versus each pattern using a discrete type assembling factory as a sample. From the figure please note that the time scale is based on the relations of each status vs. energy consumption pattern on time ratio, not expressed as the real time.

[Definition]

・POT (Production order time/ order duration): Production time schedule that was defined in the production plan.

・TPT (Throughput time/ Execution time): Period of time spent on supplying energy within the boundary and to implement production activity.

・BT(Busy time): Period of time spent on producing one lot. (Lot production time)

・PCT (Process time): Operation time of facilities used for the production activity, regardless of output.

・PDT (Production time/ Main usage time): Period of time spent on production to output products.

・ESUT (Effective setup time): Period of time spent on setting up facilities to execute production.

・TT (Transportation time): Period of time spent on transporting between facilities or from warehouse to designated point.

・WT (Wait time/set aside time): Period of time spent on setting aside in-process item or the stand-by items to be transported to the subsequent process.

・DeT (Delay time): Period of time during which facility is put to stop due to failure of defect.

[Correlation formula]

・TPT =Σ (BT + TT + WT)

・BT = PCT + DeT

・PCT = PDT + ESUT

The relationship between energy status and energy consumption can be examined as shown in Figure A2-1, below.

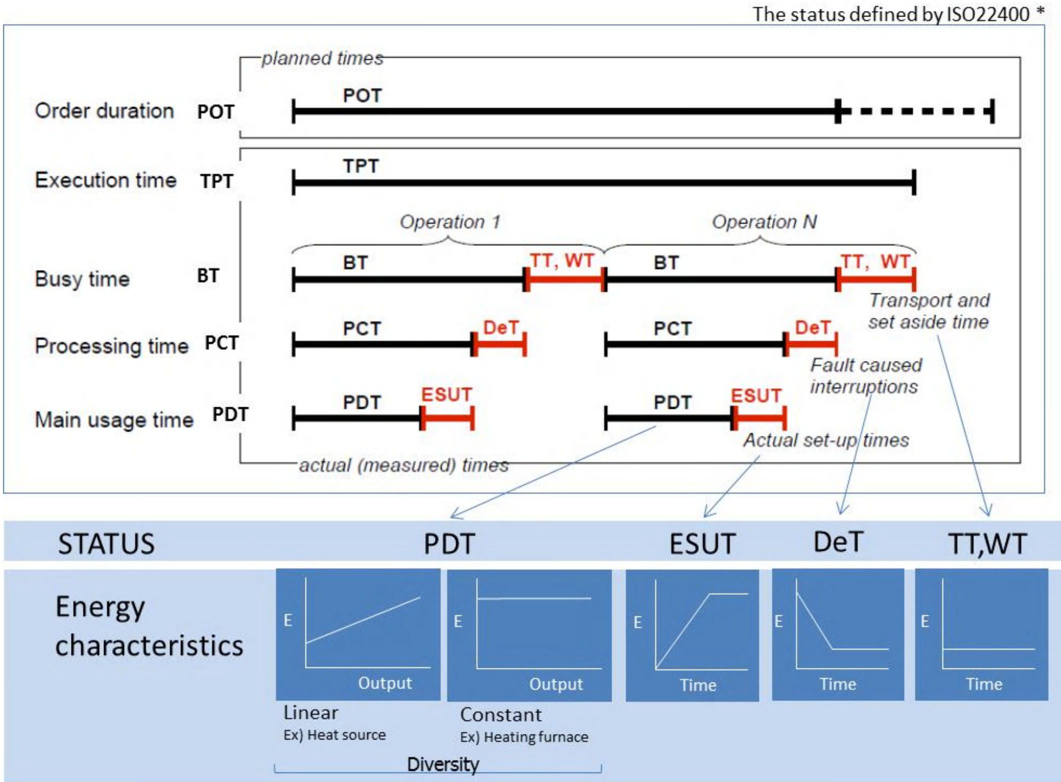

Figure A2- 1: EMU Status vs. Energy Characteristic

During the production time (PDT), energy consumption can vary in response to the EMU characteristics. Energy consumption can vary in proportion to the production volume (such as heat source equipments, etc.) or can practically stay uniform (such as heating furnaces, etc.). Effective setup time (ESUT) of equipment is the status of the period from the stop position to start up the facility until the consumption stabilises. The sample in Figure A2-1, in the previous page demonstrates that the energy consumption increases as time elapses. The Delay Time (DeT) is the status when you stop the equipments as the result of breakdown or defect. When this occurs, the energy consumption decreases as the time elapses, and ultimately the consumption stays uniform as a standby period. The Transportation time (TT) and the Wait Time (WT) are the statuses of a period for preparing the production for other production lot demonstrating the continuation of the standby energy consumption mode.

As you can appreciate from the previous explanation, with different status, the energy consumption characteristics can change significantly due to production, elapse time or other influencing factors.

When actually applying the status management, each status demonstrated on the Figure A2-1 should not be treated explicitly. You will get more effective result by defining [9] a status of its own for optimum purpose in accordance with the boundary set with the scope of RENKEI control. As an useful and convenient method, by dividing the production time (PDT) of the facilities (in a group) and other statuses set into two groups as two statuses can provide precision improvement for the baseline models described in Chapter 5 "Energy Optimisation Approaches".

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[9] For the actual facilities (in a group), there are cases such as upon breakdown when all facilities are stopped, and then gradually to recover one by one, or upon changing the product line, facilities are brought down to halt one by one to change their operation mode. If one attempts to define statuses on all cases, they will become unlimited. Therefore it is recommended to consider the highest end of energy consumption values for each facility to define the status.

Appendix 3. EMU Status Application Example

As the typical example of EMU status, the status related to paper machine and paper/coating process of a paper mill factory is introduced. As shown in Figure A3-1 below, using the paper machine structure and the types of available signals, there are 5 major types of status.

In operation:	status that paper machine facilities are in motion for paper production
Grade change:	status that paper intermediates (out of specifications) are in process during the paper lot change.
Paper break:	status that paper disruption occurs due to some sort of problem, and the paper machine is in operation but not producing paper.
Off specification paper run:	status that “off specification paper” was produced due to the next process handling forcing the normal paper to be discarded.
Normal paper run:	status that paper forwarded to the next process is produced as the normal paper product

In Figure A3-2 shown in the next page demonstrates a sample of an energy consumption pattern in relation to the defined paper machine status. The key energy used in the paper machine is listed below:

- Electricity: Paper machine, various pumps, motors, infrared drying equipments
- Steam: heat source for the dryers to dry paper
- Hot water, cold water, HVAC and lighting for the paper machine facility building

In the sample case, the operation by each status can be described as below:

(Please refer to Figure A3-2 in the bottom depicting the energy consumption pattern to each operation status.)

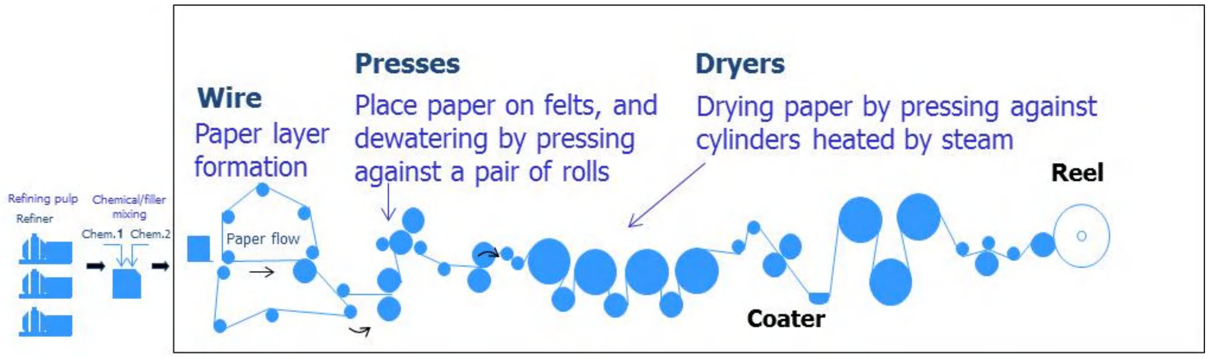
(1) Normal production status forms the basic energy consumption.

(2) A specific coating process requiring extra coating machines has begun, and motors related to the coating machines and the infrared dryers energised, and thus increased in energy consumption.

(3) During the production due to some factor a paper break occurred, and the paper machine continued to operate however the drying process reduced the use of steam without paper, and thus decreased in energy consumption.

(4) For trouble shooting, the paper machine was brought down to a stop. Accordingly the energy consumption reduced by a large amount however some auxiliary units operating independent of the paper machine, and the building required certain energy so the energy consumption would never become zero.

As you can appreciate that it is very useful and important to define the most appropriate status within the established boundary in implementing effective energy management. In this sample case, in order to produce the output with minimal energy consumption, in other words, to improve the specific energy consumption performance, it is not only to pursue the efficient production method but also to pursue the indirect factors such as to reduce the number of paper breaks, to shorten the time of brand change, etc., which will provide additional fine-tuned improvements. Furthermore by using identically defined KPI assigned for each status enables to verify the savings for the long term.



No	Signal name	Signal Output Procedure
1	Paper machine on	Operation status of raw material transferring pump (ON during operation)
2	Trial run	Operator input (ON during trial run)
3	Paper break	Photoelectric installed between processes (ON during paper break)
4	Good paper	Reel rotation counter in operation (ON during operation)
5	Brand change	Operator input (ON during change)
6	Coating on	Coater ON signal (ON during coating run)

No	Status name	Condition
A	In operation	(1)ON& (2)OFF
B	Grade change	(1)ON& (2)OFF& (5)ON
C	Paper break	(1)ON& (2)OFF& (3)ON& (5)OFF
D	Loss paper run	(1)ON& (2)OFF& (3)OFF& (4)OFF& (5)OFF
E	Normal paper run	(1)ON& (2)OFF& (3)OFF& (4)ON&(5)OFF

Figure A3- 1: Status of Paper Making Process

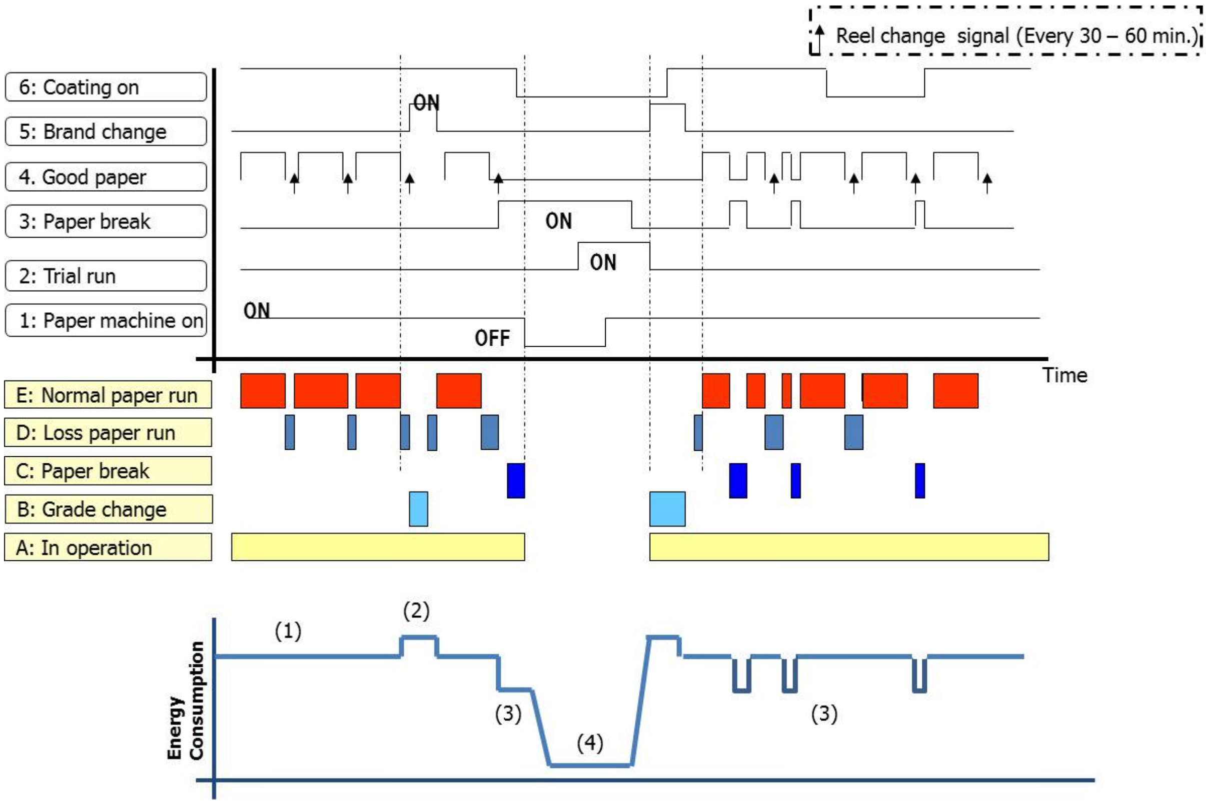


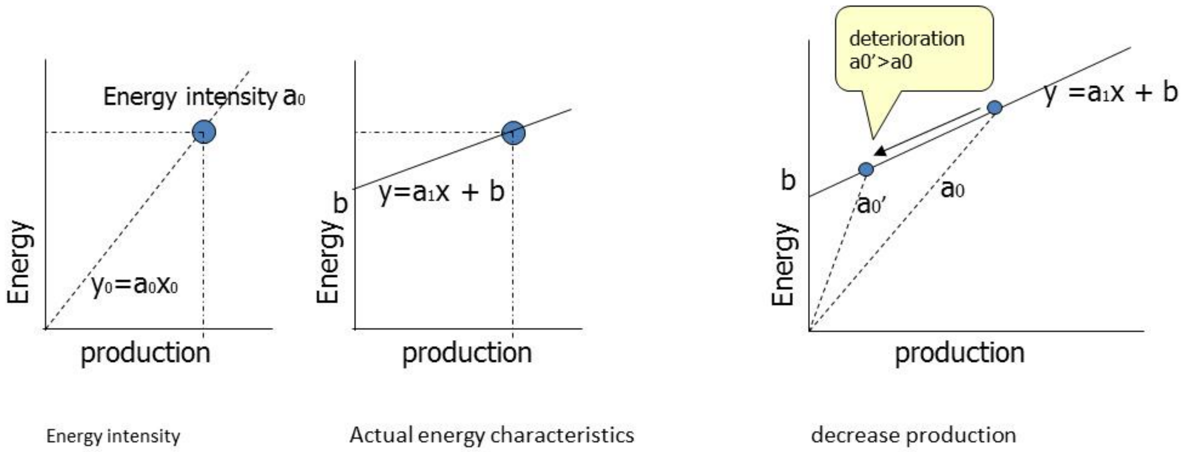
Figure A3- 2: Sample of Status Changes in Paper Making Process and Energy consumption

Appendix 4. Specific Energy Consumption Management: Point of Attention

For production facilities, process lines and factories in general, even when the production is zero, the base energy (indirect production related energy) still is consumed, and therefore to manage energy performance with specific energy consumption is not simple energy consumption divided by production outputs.

When there is a base energy, even the energy efficiency is unchanged, with the decline in production; it appears as though the specific energy consumption performance has also declined. By placing a special attention to this fact it is recommended to form indexation by implementing a relative value management approach in analysing energy efficiency improvement. The practical approach is to integrate the base energy value into the specific energy consumption field to express the index as the formula y= ax + b.

Figure A4- 1: Specific Energy Consumption Management: Point of Attention



Appendix 5. The Cost and Level of Sophistication of Feasibility Study (FS)

The cost of FS is influenced by the sophistication of the model and the amount of case study employed. In order to increase the sophistication of the model, it requires more work units (man-hours) in establishing the model as well as in calculating and evaluating time per unit of energy saving analysis performed. The cost of FS can be expressed as below.

Cost of FS = (Cost of establishing models)

+ (work-unit cost per case study) x (Number of case studies employed)

It is difficult to judge if the model is equipped with appropriate accuracy for proper evaluation. For the influential factors to the model accuracy can be examples such as "model error" generated by using linear model against equipment having non-linear characteristics, degree of consideration in "design constraint" in actual operation, "measurement error" in the actual data, etc.

For the "model error", by comparing the actual value with the simulated value by the model using the actual operation data will provide to some extent acceptable quantitative evaluation result. For the "design constraint" it is essential to perform comprehensive hearing session with the operators of the subject product model (brand), and to evaluate under the closest design constraint situation of the actual operation. For the measurement accuracy with respect to the actual data, it is suggested to implement calibration of metering devices resulted in generating questionable data, and to confirm what level of tolerance can be allowed.

For the "Number of case studies employed", to evaluate the annual savings by simulate 365 days is not economically practical for its costly work unit implication. In general, it is to select representing days that serve the best evaluation purposes (e.g. if influenced by weather conditions, to select representing days from summer, winter and intermediate periods), and deriving the annual savings by analogical reasoning is regarded as appropriate evaluation method.

Appendix 6. Relation to the Annual Report requested by Energy Conservation Act

Act on the Rational Use of Energy (Energy Conservation Act) of Japan specifies to use the specific energy consumption unit as described in section 4-2-1 "KPI" when submitting the annual report. However the principal of Energy Conservation Act aim is to encourage use of various measures such as in facilities, operation, use of control, etc. in reducing the mass energy consumption focussed originally in fossil fuels shortage. It therefore requires special attention that the Energy Conservation Act performance index is not necessarily appropriate in evaluating the energy saving benefit for the facilities implementing RENKEI control. Specific points to be noted are indicated below.

(1) Within the energy consumption, the recovered energy from the wastes, natural energy such as wind, solar, etc. are exempted from the scope of Energy Conservation Act. For RENKEI control implementation when evaluate the saving result from the demand side facilities, all energy must be evaluated, and thus the ones exempted by Energy Conservation Act need to be included.

(2) For the numerator used for specific energy consumption, the energy consumption that was not used directly for the actual production used to be deducted from the total consumption. However after the recent revision of the Energy Conservation Act, the deduction was ruled out. From this aspect, the energy consumption discussed in section 4-2-2 after defining the appropriate boundary, the method of deducting the non-production related energy consumption to improve the accuracy of saving verification may not conform to the guideline defined by the Energy Conservation Act for the annual reporting procedure.

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3. IEC/65/480B/DC Energy Efficiency through Automation Systems, 2010-05-13, IEC/TC65/JWG14
4. ISO 50001-2011 Energy Management System – Requirements with guidance for use (JIS Q 50001:2011 Energy Management System – Requirements with guidance for use)
5. "Search for Heat pumps!!" – ECO Technology Wonderland – April, 2007 by Katakura and Fujimori, Press Department, The Japan Electric Association

Terms and Definitions, Acronyms

No.	Terms/Acronyms	Definitions	Section
1	primary energy	Electricity, gas, fuel. etc.	2-1
2	secondary energy	Steam, chilled/hot water, compressed air etc.	2-1
3	Visualization "Miyeru-ka"	Verifying the actual use of energy to promote energy management activities.	2-1
4	RENKEI Control	The concept to provide an optimum control as a whole by orchestrating energy demand and supply facilities in order to reduce the waste due to the mismatch of demand and supply or waste generated between the multiple energy supplying facilities.	2-1
5	demand and supply RENKEI	A method to eliminate waste by operating energy supply facility in respond to the demand.	2-1
6	supply side RENKEI	A method to eliminate waste by performing combined use optimisation within energy supply facilities.	2-1
7	supply side equipment RENKEI	To provide control for efficient operation of devices within the supply facilities by reflecting specific characteristics that each device bears.	2-2
8	supply side facilities RENKEI	A method to control neighbouring supply side facility connected operation.	2-2
9	demand and supply bidirectional RENKEI	A method to control the supply side facility responding to the energy demand of the demand side facility, and additionally to restrict demand side facility when the demand exceeds the capacity of supply side facility.	2-2
10	demand side facilities RENKEI	A method to control energy demand by directing production systems of the demand facility to collaborate each other in considering the capacity of supply side facility.	2-2
11	district heating and cooling (DHC)	A system to supply heating media such as hot water, steam, chilled water, etc. through pipes to multiple of buildings or to defined buildings and facilities grouped as a district.	2-3
12	demand side management	To realise the overall most economical power supply system as with participation of energy users for the planned operation of power systems that were conventionally performed solely by power utility companies.	2-3
13	demand response	In response to the demand in power system, it is for the power utility operators to control the consumption by energy users.	2-3
14	absorption chiller	A chiller using city gas as source of energy.	2-3
15	centrifugal chiller	A chiller using electricity as a source of energy.	2-3
16	coefficient of performance	Performance factor: defined as "refrigeration capacity / power consumption"	2-3
17	business owner	Energy user	2-5

No.	Terms/Acronyms	Definitions	Section
18	energy saving solution vendor	Vendors who supply energy saving solution. Among the vendors who are supplying RENKEI control are called RENKEI control vendor.	2-5
19	Key Performance Indicator	A key indicator that evaluate level of achievement to the defined business objective	3-2
20	energy efficiency indicator	Quantitative energy efficiency value defined by organisation	3-2
21	energy intensity or specific energy consumption	Calculated value "energy consumption (numerator)" divided by "value closely associated with the energy consumption (denominator)".	4-2
22	energy baseline	Quantitative benchmark value that provides basis of comparing energy efficiency. They are expressed as numeric value, model or others. A model (expressed as formula, etc.) with comparative relation to elements influencing energy use subject of comparison is termed "Energy Baseline Model"	4-2
23	multiple regression model	A linear formula (linear function) expressing a state of relationship when a chosen variable behavior is influenced by other variables.	4-2
24	heat source facilities	Facilities producing chilled water and hot water. (Cool or heat the water as a heating medium to the set temperature)	5-1
25	utility facilities	Facilities supplying energy such as electricity, steam, compressed air, chilled water, hot water, etc.	5-1
26	continuous process	Manufacturing process typically used in petroleum refining to continuously process supplied raw material transforming to the final produce.	5-1
27	batch process	Manufacturing process typically used in assembly and food, pharmaceutical factories with processes that raw materials are supplied intermittently and transforming to the final product.	5-1
28	continuous cooking	A lean and long vertical cylindrical vessel that chips are introduced from the top, and heated with chemical to boil, and extracted continuously from the bottom of the vessel.	5-1
29	paper machine	A machine to produce paper. The forming section, the slurry of fiber is filtered out to form fabric. The press section where the wet fabric passes between rolls loaded under high pressure to squeeze out water. The drying section where the sheet is pressed against a series of steam heated drying cylinders to complete the process as an output paper.	5-1
30	coater process	Process to coat paint material on the paper. Some process includes the blending of paint material and other function.	5-1
31	Energy Managed Unit	The unit implementing energy management. Energy Managed Unit.	5-2
32	intermediate load	Facility that is in the load situation below the rated capacity.	5-2
33	peak demand	The highest point of electricity demand or other energy.	5-2

No.	Terms/Acronyms	Definitions	Section
34	energy tracking	An evaluation method to track when and how much energy was used at each production process per unit of defined component of product, and to sum up the use of energy.	5-3
35	baseline period	The period of collected data to define evaluation criteria for KPI.	5-3
36	report period	The period of collected data to evaluate performance improvement.	5-3
37	Production cooling water	cooling water for production equipment	5-3
38	ISO 22400	Automation systems and integration -- Key performance indicators Manufacturing operations management --	A-2
39	POT (production order time)	Production time schedule that was defined in the production plan.	A-2
40	TPT (throughput time)	Period of time spent on supplying energy within the boundary and to implement production activity.	A-2
41	TT (transportation time)	Period of time spent on transporting between facilities or from warehouse to designated point.	A-2
42	WT (wait time)	Period of time spent on setting aside in-process items or the stand-by items to be transported to the subsequent process.	A-2
43	BT (busy time)	Period of time spent on producing one lot. Lot production time.	A-2
44	PCT (process time)	Operation time of facilities used for the production activity, regardless of output.	A-2
45	DeT (delay time)	Period of time during which facility is put to stop due to failure or defect.	A-2
46	PDT (production time)	Period of time spent on production to output products.	A-2
47	ESUT (effective set up time)	Period of time spent on setting up facilities to execute production.	A-2

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Energy use optimisation technology by Green IT

RENKEI Control Guidebook

－From Introduction through Saving Verification－

August, 2012

Publisher:

Japan Electronic and Information Technology Industries Association (JEITA)

http://www.jeita.or.jp

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