Chapter 3

Exploring Energy-Saving Potential for Industrial Sector Using Factory Energy Management System

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Chapter 3

Exploring Energy-Saving Potential for Industrial Sector Using Factory Energy Management System

In this chapter, the applicability of EMS is discussed, focusing more on the energy-saving potential for the industrial sector using factory energy management system (FEMS).

Since the structure of energy consumption in the industrial sector is generally more complicated than that in office buildings and varies a lot among the users, trying to grasp the comprehensive picture of FEMS applicability with only a few samples may be too rough.

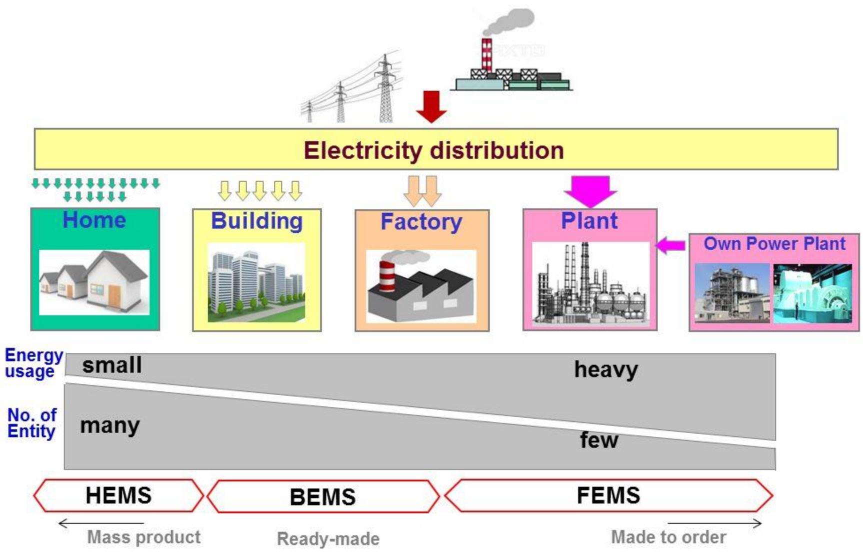
This chapter first discusses the general overview of energy consumption in the industrial sector and identifies the potential of energy efficiency considering the applicability of energy-saving technologies. The assumption of energy-saving potential is then tested through the case studies at the actual sites, and the implications and observations are drawn at the end of this chapter.

1. Applicability of FEMS

As discussed in Chapter 2, there is no difference in the basic functions among FEMS, BEMS, and HEMS but in the size of data and the number of target users. Compared with BEMS and HEMS, which target numerous users, the number of target users of FEMS is much smaller. However, since the size of each target user of FEMS is much larger than that of BEMS and HEMS, the effect of a single user's energy efficiency is huge. Also, since the profile of energy demand varies among users, FEMS is usually provided as a made-to-order product.

On the other hand, BEMS has a larger number of target users and is readily available as a ready-made product. HEMS, which deals with a larger number of smaller users, is a readily available mass product and involves lower price.

Figure 3.1: Applicability of FEMS, BEMS, and HEMS



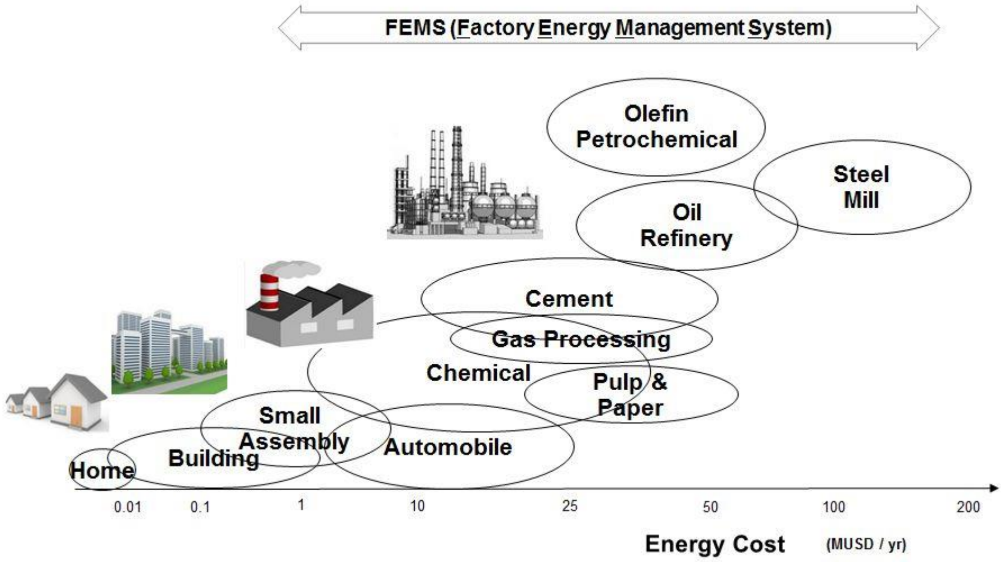
BEMS = building energy management system, FEMS = factory energy management system, HEMS = home energy management system.

Source: Azbil Corporation, 'Introduction of RENKEI Control System, Jointly Promoted by METI –Case Studies for True Energy-Saving Through Utilizing EMS & FEMS'.

The implementation of FEMS helps its users to grasp their energy consumption at ease and to run the cycle of PDCA for energy saving. Moreover, it should be noted that FEMS is a tool for energy saving by optimising the operation of appliances instead of investing huge capital for replacing the existing appliances with more energy-efficient ones.

The following figure plots various types of consumers in the industrial sector according to the volume of energy consumption as the horizontal axis. The target users of FEMS are medium- and large-sized consumers of energy.

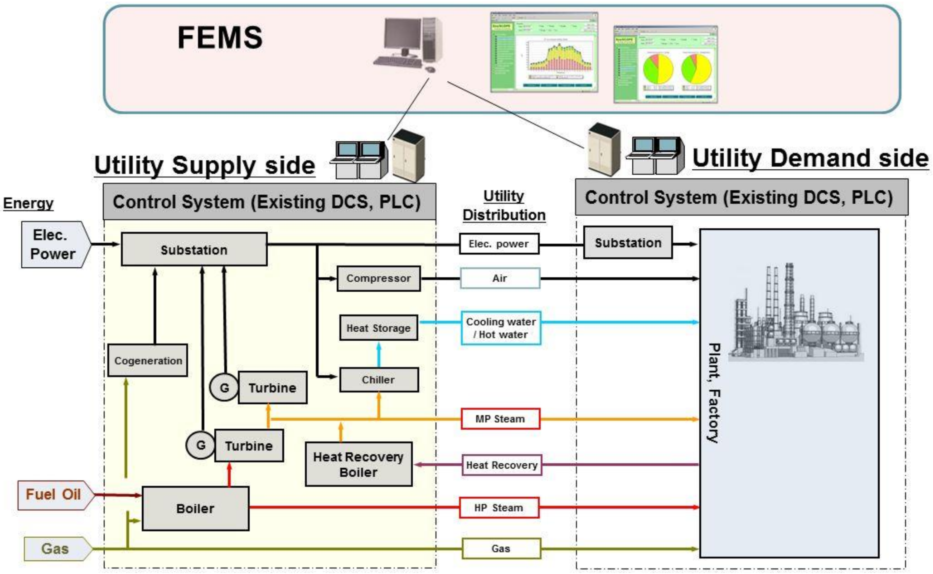
Figure 3.2: Image of Factory Energy Management System Applicability



Source: Azbil Corporation, 'Introduction of RENKEI Control System, Jointly Promoted by METI – Case Studies for True Energy-Saving Through Utilizing BEMS & FEMS'.

Since the facility setup also differs among the industrial consumers depending on the type of industries, FEMS's coverage is customised for each user to deal individually with a combination of various appliances. The following figure illustrates the general overview of FEMS's coverage. Because large industrial consumers are apt to own facilities of utility supply (electricity, heat, steam, hot or cooling water, and so on), FEMS often covers not only the demand-side but also the supply-side facilities of these utilities.

Figure 3.3: FEMS's Coverage of Supply-Side and Demand-Side Facilities



DCS = disturbance control standard, FEMS = factory energy management system, PLC = power line communication.

Source: Azbil Corporation, 'Utility Facility Optimization Package Catalogue'.

2. Energy-saving technologies and industries

By establishing the connection between FEMS and the control system of facilities, their operational data can be obtained in real time, which facilitates the implementation of energy-saving measures.

Of the various energy-saving measures that differ among industrial consumers, the following are the typical energy-saving measures that can be handled from FEMS via the control system.

(1) Optimisation of compressed air system;

(2) Optimisation of combustion and steam supply;

(3) Optimisation of heat-source equipment;

(4) Optimisation of boiler, turbine, and generator; and

(5) Optimisation of distillation tower.

These are energy-saving measures that will be achieved by fine-tuning the control of appliances using FEMS. Energy-saving measures by installing or replacing or both the appliances themselves, such as installing inverters to motors and using LED for lighting and heat pumps, are not taken into account.

The following table is the matrix indicating the relation between these energy-saving technologies and the types of industry where these technologies are applicable. The horizontal axis shows a list of major industries that may require these functions. There may be still other types of industries not shown here but also require similar functions like those in the list.

Figure 3.4: Matrix of Applicable Energy-Saving Technologies and Types of Industry

		Industry																
		Pulp & Paper	Textile	Steel mill	Non-ferrous metals	Oil Refinery	Petrochemical, Olefins	Chemical	Ammonia, Fertilizer	Automobile	Mechanical assembly	Electric, Home appliance	Cement, Ceramic	District cooling system	Water treatment	Medium size co-generation	Food & Beverage	Pharmaceutical
FEMS Function	1 Energy Monitoring, Visualization	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	2 Energy Management, Performance Analysis	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	3 Demand Prediction		O					O		O	O	O		O	O	O	O	O
	4 Operation Schedule		O					O		O	O	O		O	O	O	O	O
Energy-saving buit into FEMS	1) Compressed Air System Optimization	O	O	O	O	O	O	O	O	O	O	O	O				O	O
	2) Combustion & Steam Supply Optimization	O		O	O	O	O	O	O				O	O			O	O
	3) Heat-source Equipment Optimization							O		O	O	O		O			O	O
	4) Boiler Turbine Generator Optimization	O		O	O	O	O		O					O		O	O	
	5) Distillation Tower Optimization					O	O	O	O									

FEMS = factory energy management system.

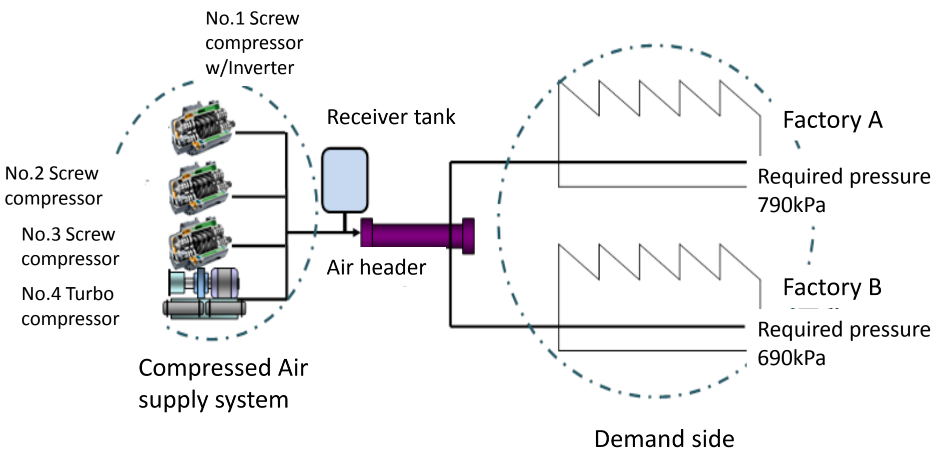
Source: Azbil Corporation (2016), Exhibition material for ‘Sustainable Energy & Technology Asia’.

Each of these five energy-saving technologies is discussed further in the following section.

2.1. Optimisation of compressed air system

Compressed air is used in many factories for general purpose of air use or for instrumentation air use or both. It is apt to be an area of wasting energy where often there is lack of awareness in energy saving, because the outcome of energy use is converted into air that appears to exist by nature. In other words, there often exists a large room for improvement.

Figure 3.5: Example of Compressed Air System



kPa = kilopascal.

Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

When referring to the system configuration of Figure 3.5 as an example of compressed air system, the following three items are considered as the effective approaches for optimising the energy efficiency of the air compressor system (Figure 3.6).

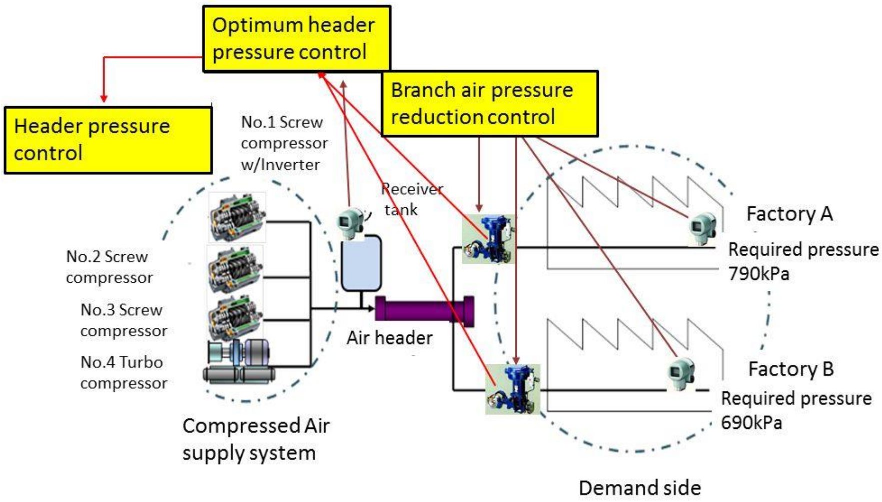
(1) Control of header pressure and the number of compressors;

(2) Adjustment of air pressure at each branch header; and

(3) Optimised control of header pressure.

It is generally observed that 10–30 percent energy saving of the compressed air system can be achieved by applying these measures of energy-saving control.

Figure 3.6: Energy-Saving Control for Compressed Air System



kPa = kilopascal.

Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

(1) Control of header pressure and the number of compressors

In general, air compressors consume less energy for the same volume of compressed air output if the discharge pressure is lower. It is generally observed that the energy consumption is reduced by 8 percent when the discharge pressure of a screw compressor is decreased by 0.1 MPa. Hence, lowering the discharge pressure of the compressors as much as possible contributes to energy efficiency.

If the user simply relies on the on–off control of compressors, the air header pressure may fluctuate greatly within the range of air pressure settings, and to avoid the sudden decline of air pressure, the user is apt to set the average discharge pressure of compressors at a relatively high level, which results in the waste of energy consumption.

For achieving an intelligent energy-saving control, it is recommended to install proportional–integral–derivative (PID) controller, which controls the air pressure of receiver tank, to reduce the fluctuation of header pressure. By doing so, the user can lower the setting of discharge pressure of compressors that results in saving energy.

It is important to note that partial-load, rather than full-load, operation of compressors impairs energy efficiency. Controlling the number of units in operation is performed by PID controller for optimised energy consumption. Partial load to deal with the changes of compressed air demand is managed by inverter-type compressors, while the other compressors operate at full load.

Figure 3.7: Concept of Proportional–Integral–Derivative Control

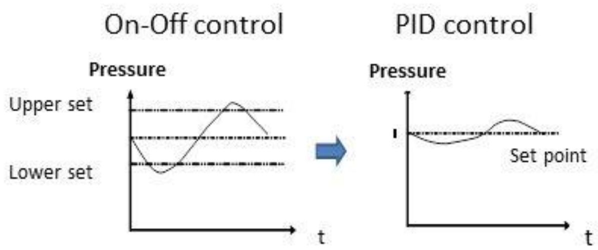
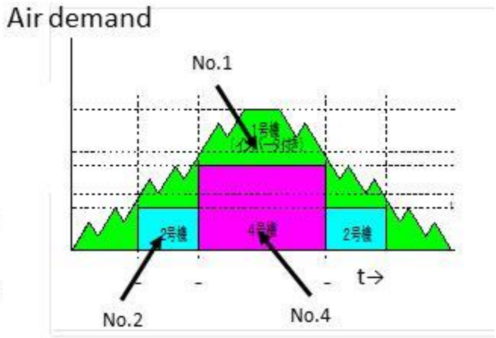


Figure 3.8: Controlling the Number of Units



PID = proportional–integral–derivative.
Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

(2) Adjustment of air pressure at each branch header

In general, air blow (including pneumatic cylinder actuation) and air leakage account for about 80 percent of the total consumption of compressed air, although the situation may vary depending on the sites. These kinds of air consumption and leakage can be reduced by lowering the air pressure at branch headers as much as possible. In addition, there is a potential of energy saving by reducing the air pressure during the time of non-operation, such as holidays and lunch breaks.

The necessary air pressure varies depending on the type of demand. In the conventional system, the compressed air is usually supplied to end consumption at the pressure as high as that discharged by air compressors. By applying the latest energy-saving control system, which installs pressure regulating valves at every branch, air pressure is adjusted at each branch to meet the demand of each site. In this manner, the air pressure of the total system can be reduced in accordance with the actual situation, and this helps in reducing the volume of air blow and air leakage and the energy consumption.

(3) Optimum control of header pressure

In the conventional system, the discharge pressure of compressors is set at a constant level to meet the largest demand of air consumption induced by pat experience. Optimising the control of header pressure contributes to energy savings.

FEMS provides the function of energy-saving control by monitoring the regulatory valve opening of each branch as mentioned in item (2) above. Energy-saving control adjusts the setting of air pressure of receiver tanks so that the PID controller can set the maximum opening of regulatory valves at each branch to the position of nearly full-open.

The optimised control of header pressure adjusts the setting of air pressure as low as possible, in accordance with the volume of current air consumption. By lowering the setting of average header pressure, energy consumption of the compressors can be reduced.

In our experience, energy-saving of about 10–18 percent can be achieved by applying these three energy-saving controls to a compressed air system.

2.2. Optimisation of combustion and steam supply

The following three items are considered to be the effective approaches for optimising the energy efficiency of the combustion and steam supply system: (1) air ratio control, (2) control of exhaust gas temperature, and (3) steam pressure control. It is generally observed that energy saving by 2–5 percent of the combustion and steam supply system can be achieved by applying these three measures of energy-saving control.

(1) Air ratio control

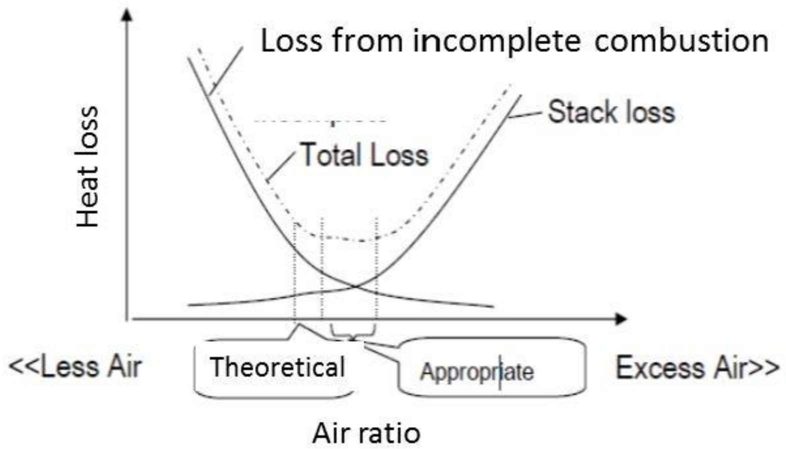
Air ratio refers to the ratio of actual volume of air supply for combustion against the theoretically calculated air supply necessary for combustion. If the air is supplied in combustion exceeding the theoretical requirement, the amount of heat transferred to this excessive air becomes the energy loss. Therefore, the smaller the air ratio is the more efficiently the energy management is achieved.

While the reduction of air supply to lower the air ratio as much as possible is favoured for lessening the energy loss, it should be noted that too much reduction of air supply may cause incomplete combustion. This leads to the discharge of combustible ingredients into the exhaust gas without being burned, and the unburned combustible content results in another form of energy loss.

To minimise the energy loss, the air ratio should be configured so that the sum of the heat loss in excessive air and the loss from unburned fuel would be minimised.

The following figure illustrates the relation between them. The heat in excessive air increases with the increase of air ratio, while the heat loss from unburned fuel increases drastically when the air ratio is lowered to 1.0 or less. The total heat loss from exhaust gas is minimised at a certain air ratio (the point of 'appropriate' in the figure). The optimal air ratio is identified in this approach, but this may vary depending on the combustion facilities, such as the form of combustion chamber and the type of burners.

Figure 3.9: Relation between Air Ratio and Heat Loss



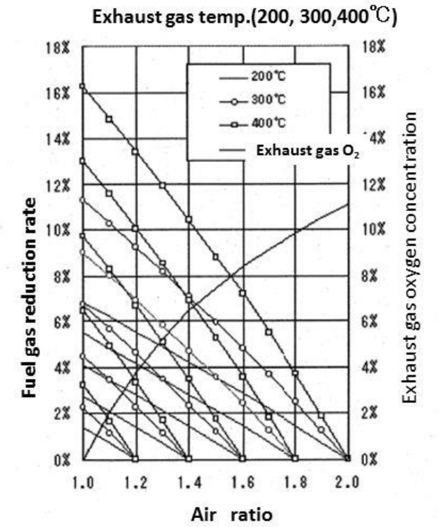
Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

(2) Control of exhaust gas temperature

If the air ratio is high, air that is not used for combustion is simply heated and wasted as exhaust gas. Furthermore, if the exhaust gas temperature is high, more thermal energy is wasted and discharged in the exhaust gas. In Japan, the government provides a guideline of normative reference value and target value of exhaust gas temperature.

Recovering heat from exhaust gas is needed to lower the exhaust gas temperature, and an economiser is usually used for this purpose. An economiser serves for exchanging heat between exhaust gas and feed water.

Figure 3.10: Air Ratio and Exhaust Gas Temperature



Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

(3) Steam pressure control

The requirement of steam pressure is different among the types of production, but in a conventional system steam is supplied at pressure as discharged by the boiler.

Reduction of steam header pressure can be effectively achieved by utilising the latent heat of the steam on demand side and, thus, reducing heat leakage and steam drain. The total thermal loss can be reduced in this manner.

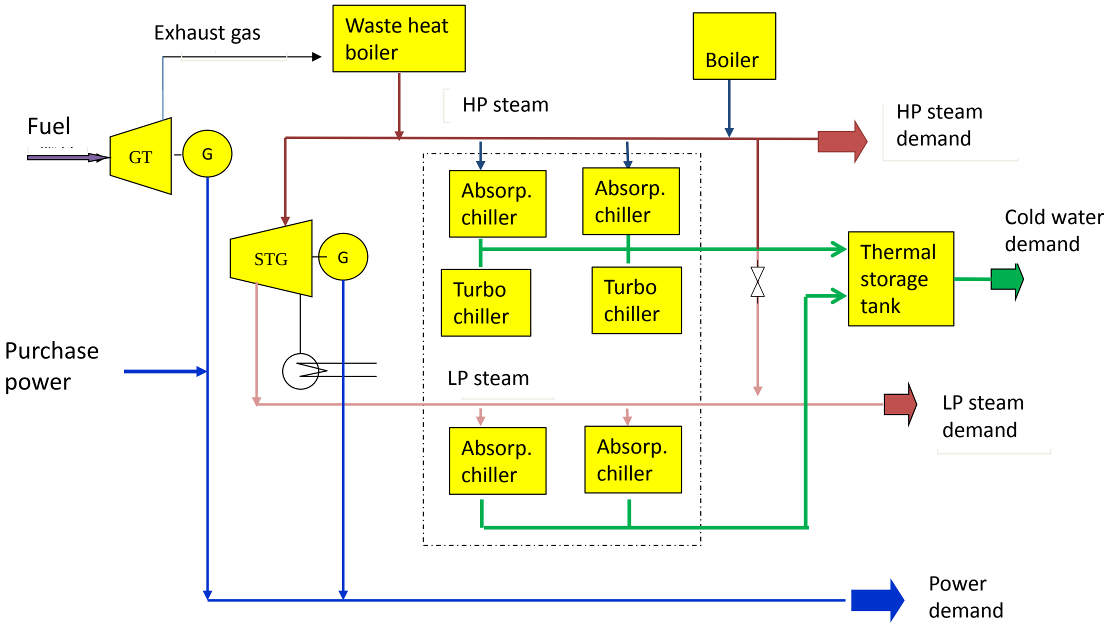
Using energy-saving control, pressure regulation valves installed at every branch can adjust the pressure at the branch to meet the pressure requirements. Reducing the steam pressure in accordance with the actual requirement of each branch helps reduce the total thermal loss.

2.3. Optimisation of heat-source equipment

Figure 3.11 shows a sample diagram of heat-source system, which supplies cold and hot water to the production process.

In this example, there are two turbo chillers using electric power and four absorption chillers using steam as the energy source. Electricity supply is partially generated by captive gas turbine, partially by captive steam turbine, and the remainder is supplied from the external grid. Steam supply from the steam turbine can be used for the demand of low pressure steam.

Figure 3.11: Overview of Heat-Source System



GT = gas turbine, HP = high pressure, LP = low pressure, STG = steam turbine generator.

Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

The following two items are considered as the effective approaches for optimising the energy efficiency of the heat-source equipment.

(1) Optimised operation and

(2) Trade-off solution.

It is generally observed that 3–7 percent energy saving of the heat-source equipment can be achieved by applying these measures of energy-saving control.

(1) Optimised operation

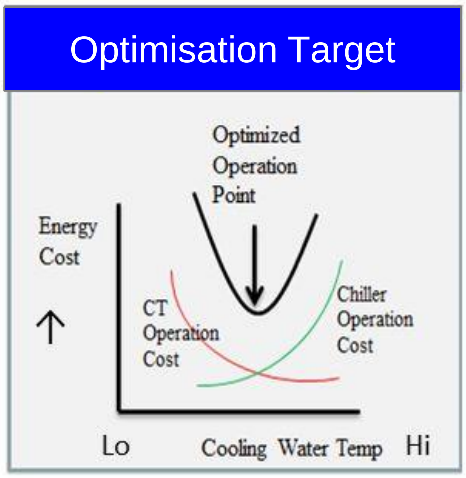
During the peak hours when the price of power purchase from the grid is high, use of absorption-type chillers using steam is of high priority; during the off-peak hours when the power price is low, use of highly efficient turbo chillers is of high priority. This leads to reduction of energy costs.

Cold water is stored in a storage tank during off-peak hours, and the stored cold water is used during peak hours. It is not easy for the user to determine which appliance to use under which conditions, and to determine the load allocation for optimising the operation.

(2) Trade-off solution

There are various trade-off issues in actual use, such as the relation between the temperature setting of cooling water and that of cooled water. If the temperature of cooling water is low, energy consumption of the cooling tower increases, but chillers work more efficient. If the temperature of cooled water supply is low, the efficiency of the chillers is worsened, but energy consumption of the conveyance pumps decreases.

Figure 3.12: Cooling Water Temperature



CT = cooling tower.
Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

The aforementioned issues, i.e. optimum operation to deal with how many units of appliance to operate and how to allocate the load among them, and the solution to trade-off, can be solved in real time by using the operation optimisation provided by FEMS.

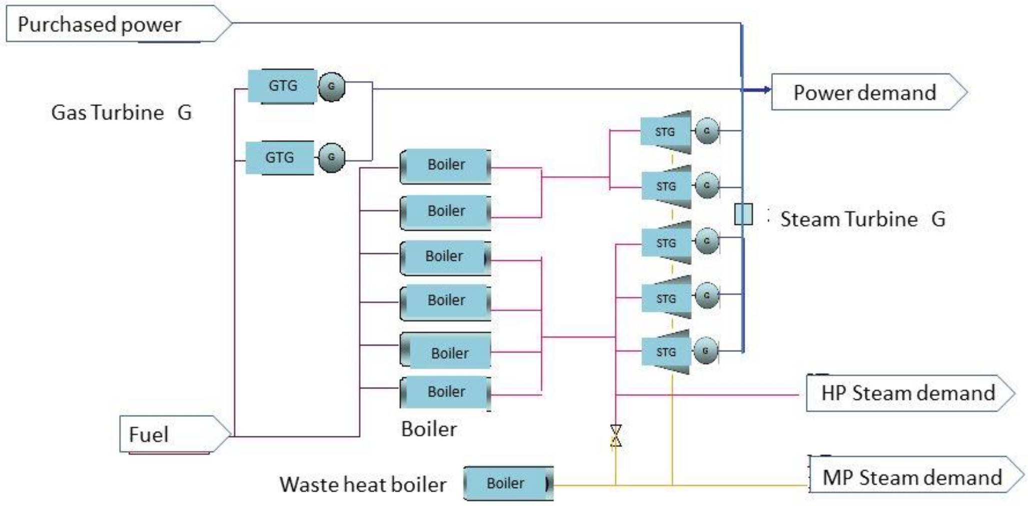
The operation optimisation system solves the optimisation and trade-off issues under various conditions. It minimises the total expense of electricity purchase from the grid and the cost of fuel and contributes to energy efficiency.

2.4. Optimisation of boiler, turbine, and generator

Figure 3.13 shows a sample diagram of utility facilities for oil refinery. Electricity is supplied by captive gas turbine generators, captive steam turbine generators, and also from the external grid. Steam supply from the steam turbine can be used for the demand of low pressure steam.

Steam for operating steam turbine generators is supplied from the steam boilers. Steam demand on the process side is supplied by heat recovery boilers or obtained from steam turbine generators.

Figure 3.13: Boiler and Turbine Generator Cogeneration System



HP = high pressure, MP = middle power.

Source: Japan Electronics and Information Technology Industries Association (JEITA) (2016).

It is not easy for the user to determine how to operate the utility equipment at the minimum cost of electricity and steam, which changes conditions at every moment. By using the online operation optimisation system, these complicated issues can be solved in real time.

The number of operating boilers and their load allocation is decided according to the steam demand and the efficiency of each boiler. The volume of steam to be extracted from each steam turbine generator is determined according to the demand of electricity and process steam, considering the different characteristics of each turbine.

It is generally observed that energy saving by 2–3 percent of the boiler turbine generator system can be achieved by optimising energy-saving control.

2.5. Optimisation of distillation tower

(1) Distillation tower

Advanced process control (APC) technology, based on the multivariable-model predictive control, has been adopted by many oil refinery and petrochemical plants for improving the yield of output and for stabilising the quality.

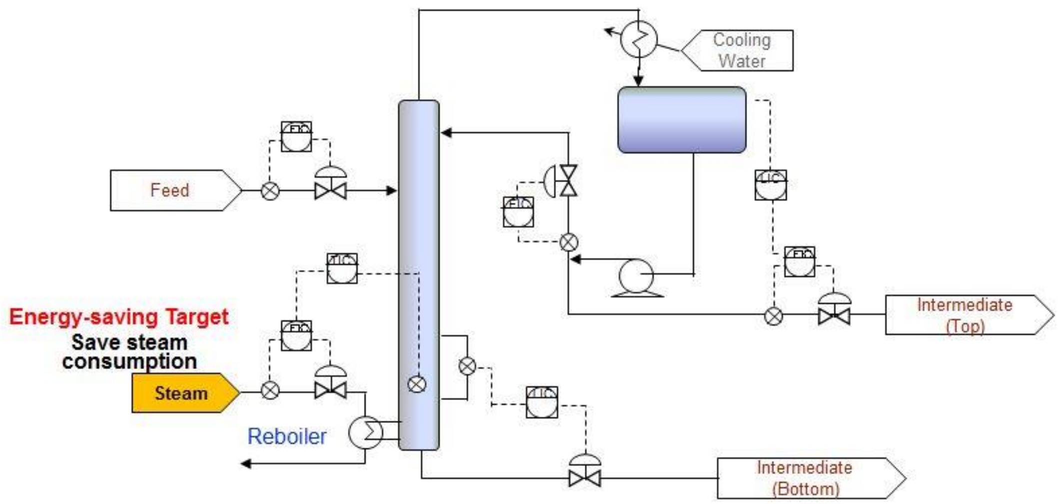
APC has also been recognised as a useful tool for energy saving. The following are its advantages, compared with the conventional control system.

(1) Excellent controllability and

(2) Elimination of control variable interference.

The following diagram, which is an example of distillation tower, shows energy-saving control using APC.

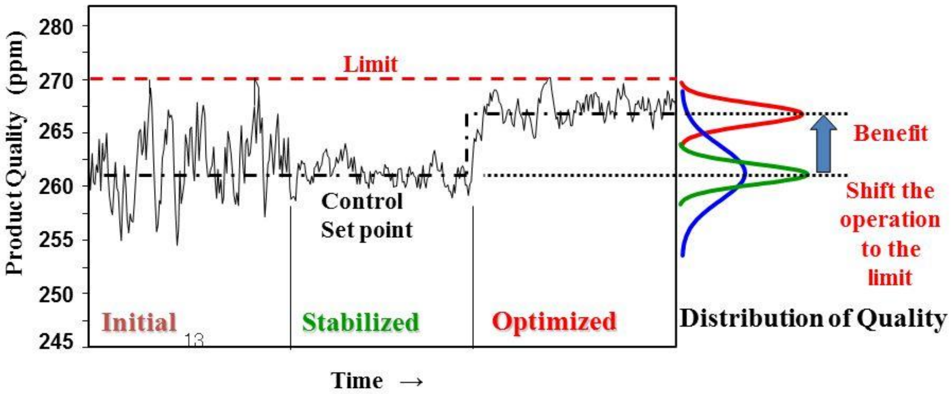
Figure3.14 Distillation Tower System



Source: Azbil Corporation (2016), Exhibition material for 'Sustainable Energy& Technology Asia' 2016.

APC stabilises the variance in impurity concentration compared with conventional PID control. This helps reduce the reboiler steam flow and the reflux flow, thus resulting in energy efficiency, by shifting the operation point closer to the upper limit of product impurity.

Figure 3.15 Product Quality Control



Source: Azbil Corporation (2016), Exhibition material for 'Sustainable Energy& Technology Asia 2016'.

It is generally observed that energy saving by 5–8 percent of the distillation tower system can be achieved by optimising energy-saving control.

3. Selection of Case Study Sites

To confirm the applicability of energy-saving technologies discussed in the previous section, case studies were conducted at sites: (i) Cogeneration plant operated by GPA, Singapore and (ii) Air compressor system at Proton City, Malaysia. These two sites were selected considering their relevance for the study and the site owners' willingness to accept the site survey.

The table below locates the position of these two sites on the matrix of energy-saving technologies for each type of industry. It shows that 'compressed air system optimisation' and 'optimisation of boiler, turbine, and generator system' are commonly used by various types of industry. In terms of types of industry, automobile and food and beverage are among the industries that widely exist in Southeast Asia.

Figure 3.16 Positioning of Case Study Sites in the Mapping of Energy-Saving Technologies

Proton (Malaysia)

GPA (Singapore)

			Industry																
			Pulp & Paper	Textile	Steel mill	Non-ferrous metals	Oil Refinery	Petrochemical, Olefins	Chemical	Ammonia, Fertiliz	Automobile	Mechanical assembly	Electric, Home appliance	Cement, Ceramic	District cooling system	Water treatment	Medium size co-gene	Food & Beverag	Pharmaceutical
FEMS Function	1	Energy Monitoring, Visualization	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	2	Energy Management, Performance Analysis	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	3	Demand Prediction		○					○		○	○	○		○	○	○	○	○
	4	Operation Schedule		○					○		○	○	○		○	○	○	○	○
Energy-saving buit into FEMS	1)	Compressed Air System Optimization	○	○	○	○	○	○	○	○	○	○	○	○				○	○
	2)	Combustion & Steam Supply Optimization	○		○	○	○	○	○	○				○	○			○	○
	3)	Heat-source Equipment Optimization							○		○	○	○		○			○	○
	4)	Boiler Turbine Generator Optimization	○		○	○	○	○		○					○		○	○	
	5)	Distillation Tower Optimization					○	○	○	○									

FEMS = factory energy management system.

Source: Azbil Corporation (2016), Exhibition material for 'Sustainable Energy & Technology Asia'.

It is worth noting also that gaining acceptance by the site owner of the site survey was a big hurdle unlike in the case study for buildings. As for the building sector, power utility companies in Indonesia, Thailand, and Viet Nam, the members of the Working Group of this ERIA study, offered their own buildings as the case study site and willingly provided data for the survey. These are public utility companies and are less reluctant to disclose their own data for promoting energy efficiency.

The case study for the industrial sector, on the other hand, had to negotiate with the site owners who are not the stakeholder of this ERIA study and were generally reluctant to disclose information about their operation. However, some of the owners of these two sites were very cooperative and provided the information for the survey as much as they could, which kind support the team greatly appreciated.

The following Sections 4 and 5 discuss the result of the case study on GPA (Singapore) and Proton (Malaysia), respectively.

4. Case Study 1: Green Power Asia Pte Ltd Cogeneration Plant, Singapore

4.1. About the case study site

Green Power Asia Pte Ltd (GPA) is an energy service provider based in Singapore. According to its website, the company provides the following various services.

(1) Onsite generation for electricity, steam, chilled water, and gases supply;

(2) Utilities supply and distribution services environmental asset and risk management;

(3) Performance guaranteed operation management;

(4) Environmental portfolio management;

(5) Carbon and renewable energy projects development;

(6) Power scheduling and settlement;

(7) Demand management integration with energy efficiency improvement; and

(8) Liquefied natural gas or compressed natural gas and natural gas supply management.

At the case study site, GPA is the provider of utility services, i.e. electricity and steam, using its own cogeneration plant. This cogeneration plant is located within the premises of Fuji Oil (Singapore) Pte Ltd, Senoko Road, Singapore, which is the manufacturer of vegetable oil.

Fuji Oil and GPA signed a build–operate–transfer contract in which GPA supplies electricity and heat to Fuji Oil for 15 years from 2011 using this cogeneration plant, and thereafter the ownership of the plant is transferred from GPA to Fuji Oil.

Figure 3.17: Case Study Site

Source: Author. (using map data from freevectormaps.com).

4.2. Observations from the survey

(1) Overview of the cogeneration plant

The site survey, which consists of the interview on plant operators and walk-through, was conducted on 25 of July 2016.

The capacity of this cogeneration system is 6.4 megawatt (MW) gas turbine for electricity and 30 tonne/hour for 13 bar gauge (barG) steam. All the exhaust heat from the gas turbines is recovered by a heat recovery steam generator. The natural gas used as fuel is purchased from Keppel Gas.

Figure 3.18: Cogeneration Facility Overview

Figure 3.19: Gas Turbine

Source: Site survey at Green Power Asia Pte Ltd (GPA) and Cogeneration Plant (25 July 2016).

Before the installation of this cogeneration system, Fuji Oil purchased electricity from the grid, and the steam was supplied by its own boilers. According to GPA, the introduction of the cogeneration system contributed to the reduction of annual energy costs by 31 percent. Currently, the main challenge for GPA is to further minimise operation costs and to maximise profit while satisfying the demand of power and steam.

(2) Operational profile

Besides the cogeneration system consisting of gas turbine (6.4 MW) and heat recovery steam generator (HRSG) as the main system, gas engine (mono-generation, 2 MW) and auxiliary boilers (two units) are installed on the site as backup for the maintenance of the main system.

Usually the gas turbine generator is operated constantly at maximum load. The power demand of Fuji Oil is, in general, 4.5 MW or less, hence, there is an excessive power generation over the demand. Since GPA is a licensed power wholesaler, it sells the excess of power generation to the grid. The excessive power generation is simply sold to the wholesale market at a spot market price called 'uniform Singapore energy price'. GPA has no long-term contract of power wholesale with an external counterpart, hence, GPA has not taken measures for hedging the price volatility. According to GPA, the wholesale price is not sufficiently high to recover the fuel cost. However, operating the cogeneration system at full capacity and selling the excess to the grid is better than adjusting the output to meet the demand in real time to avoid excessive generation considering that operating at partial load may impair the efficiency of power generation.

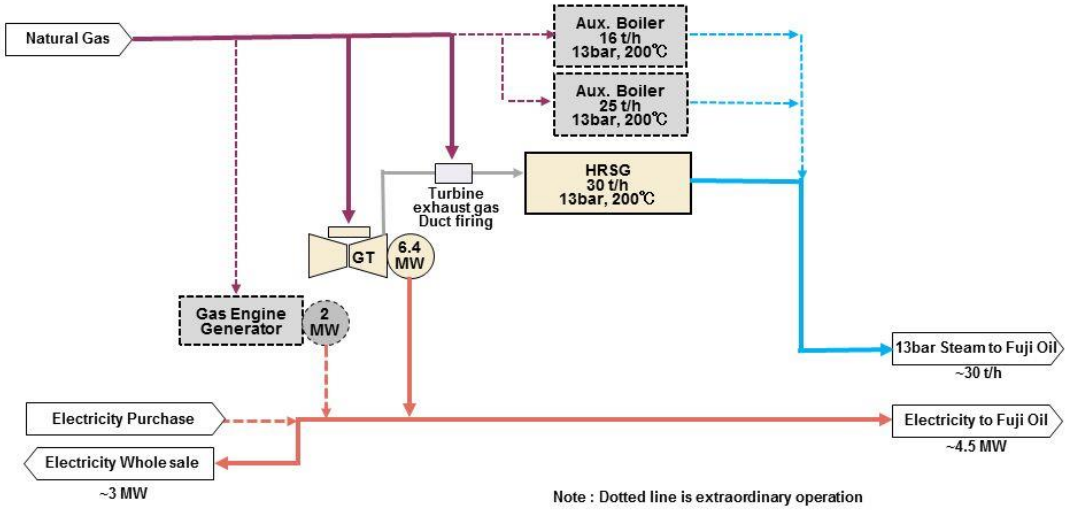
Steam is produced by HRSG. If the steam from HRSG is not enough to cover the demand, duct firing is used to increase steam generation.

GPA sets up an operational plan of the cogeneration plant by receiving from Fuji Oil its plant operational plan and making forecast of electricity and steam. Based on this, GPA calculates the necessary volume of natural gas to be procured from Keppel Gas. To have a benefit of preferential price, GPA is requested to inform Keppel Gas of the planned natural gas consumption three days ahead. In exchange for the favourable gas price, GPA is bound to a 'take-or-pay' contract. That is, in the case of consuming more gas than planned, the penalty has to be paid for the excessive consumption, and in the case of consuming less than planned, the cost of gas for the initially reserved volume, including the unconsumed, has to be paid. Therefore, when the steam load is lower than planned, the amount of duct firing is reduced, and surplus of gas is consumed in the gas engine generator (mono-generation) and generates more electricity to be sold to the grid.

This constraint of gas procurement contract is another reason GPA prefers operating the cogeneration system constantly at full capacity rather than adjusting to the actual demand. When the actual steam demand is lower than expected and the cogeneration system is not able to consume the full volume of gas supply of the day, the surplus gas is consumed by the gas engine generator to generate electricity to be sold to the grid.

It is also noteworthy that GPA is an external supplier of electricity and steam for Fuji Oil. It is only requested to supply these utility services to meet the demand of Fuji Oil and has no authority to adjust the demand side for optimising the cost of these services. The study team also contacted Fuji Oil to try to grasp the details of demand-side facilities and to discuss the potential of energy efficiency through optimised plant operation, but was declined because Fuji's operational data are confidential.

Figure 3.20: Diagram of Green Power Asia Pte Ltd's Cogeneration System



GT = gas turbine, HRSG = heat recovery steam generator, MW = megawatt, t/h = tonne per hour.

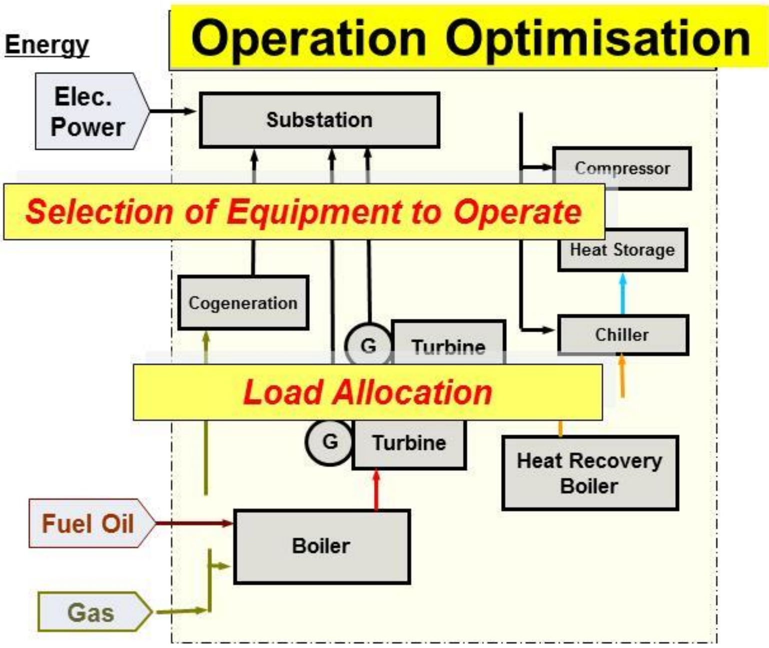
Source: Author.

4.3. Discussion on possible solutions

(1) Application of operation optimisation system

This study assumed to propose the application of operation optimisation system (Figure 3.21) to deal with the challenge of GPA for improving energy efficiency and profitability.

Figure 3.21: Operation Optimisation (sample)



G turbine = gas turbine.

Source: Author.

However, for this case assumptions should be extended beyond the actual situation in proposing the solution. Although FEMS may be able to deal with the optimisation of supply-side operation only, the optimisation would be achieved more effectively by analysing thoroughly the comprehensive system covering both the supply side and the demand side and applying the adjustment, as illustrated in Figure 3.3. In the case of GPA, the operators are separated between the supplier of utility services and the user, and the supplier (GPA) is only requested to provide these services to meet the demand, i.e. it has no authority to intervene into the operation of the demand side. Details about the demand-side operation in this case are not available and if the analysis is confined to the supply side, the structure of GPA's utility supply system using cogeneration system and its operational pattern are rather simple that there is little space for adjusting its configuration for optimisation. In addition, its operation is also bound to constraints, such as the inflexible contract of gas procurement, hence, GPA's gas turbine generator is operated at maximum load and the excessive electricity generation is sold to the grid. Despite these constraints observed from current situation, this study assumes that there is a potential of improving the energy efficiency by optimising the operation of the entire system covering both the supply side and the demand side holistically.

One thing to note about the current system is that the steam is supplied to the demand through one supply line at 13 bar gauge (barG). It is conceivable from general practices that the necessary pressure of steam varies depending on the types of demand. There is also a possibility, in this case, that lower steam pressure may be sufficient for some parts of the demand.

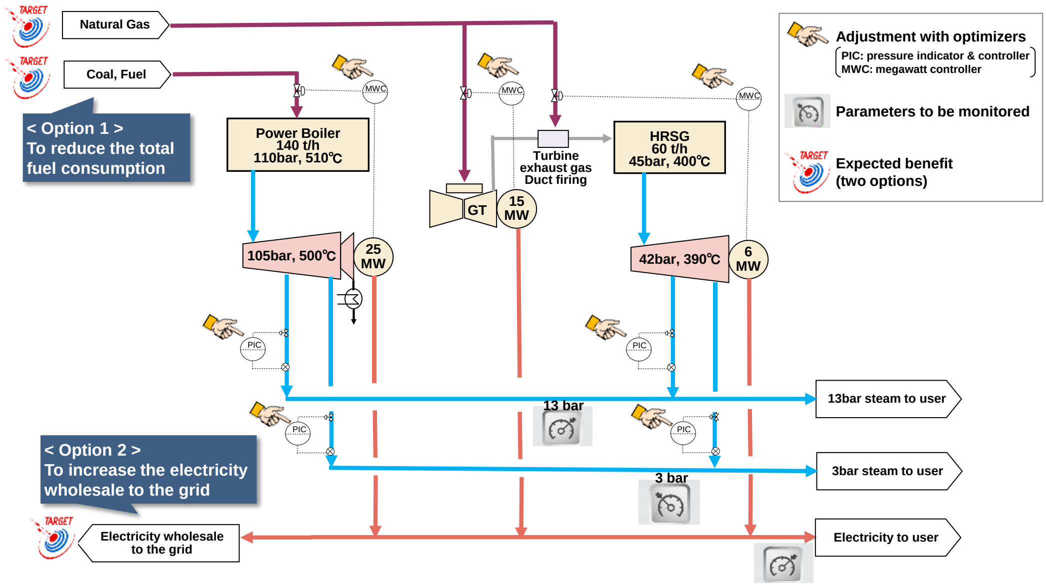
Hence, this study proposes to divide the supply of steam into two lines, i.e. newly installing a low-pressure line (3 barG) besides the existing medium pressure line (13 barG). Compared with the supply with a single line with medium pressure (13 barG) only, the addition of low-pressure line is expected to achieve the reduction of steam supply, i.e. the reduction of energy consumption for producing the steam.

Because the demand of low-pressure steam and medium-pressure steam changes from time to time, it should be monitored real time. Utilisation of pressure indicators and controllers helps maintain the optimised balance of supply between these pressure levels. In combination with megawatt controllers, the balance between electricity generation and steam production can be adjusted.

(2) Estimation of energy-saving potential and revenue-increase potential

There are two options to benefit from the reduction of energy consumption for producing steam: (i) to reduce the total fuel consumption in line with the saving of steam production and (ii) to maintain the total energy consumption but to use more for power generation so that the electricity wholesale to the grid can be increased. In the case of GPA, which is bound to a take-or-pay contract of natural gas procurement and will also prefer operating the cogeneration system constantly at maximum load to attain the best performance of efficiency, probably the second option is preferred as far as the wholesale price outperforms the marginal costs of electricity generation.

Figure 3.22: Two Options to Benefit from Reducing Steam Production



HRSG = heat recovery steam generator, MW = megawatt, t/h = tonne per hour.

Source: Author.

In a very rough estimation, the expected effect of energy saving by taking the first option is about 1–2 percent (reduction against the total fuel consumption), and the expected effect of increased revenue of electricity wholesale by taking the second option is about 2–5 percent (increase against the revenue from electricity wholesale to the grid).

5. Case Study 2: Proton Air Compressor System, Malaysia

5.1. About the case study site

Perusahaan Otomobil Nasional (Proton) is a Malaysian automobile manufacturer founded in 1983 with headquarters in Shah Alam, Selangor. Sales of automobiles in 2015 reached 102,175 units. This puts the manufacturer in second place domestically, with a 15.3 percent market share.

Figure 3.23: Proton Perdana

Proton = Perusahaan Otomobil Nasional.

Source: Proton website http://www.perdana.proton.com/

Proton has two major factories near Kuala Lumpur, one is located in Shah Alam near the head office and another in Proton City, Tanjung Malim, Perak, Malaysia. For this case study, Proton City factory was selected. The site area is 1,280 acres (5.2 km^2).

Figure 3.24: Location of Proton Tanjung Malim Sdn Bhd

Proton = Perusahaan Otomobil Nasional.

Source: Author. (using map data from freevectormaps.com)

5.2. Observations from the survey

(1) Overview of the air compressor system

The site survey, which consists of interview on plant operators and walk-through survey, was conducted on 22 July 2016.

Proton has air compressor facilities supplying compressed air to the stamping (press) shop, body (welding) shop, paint shop, trim and final (assembly) shop, and engine plus transmission shop in accordance with their demand for compressed air.

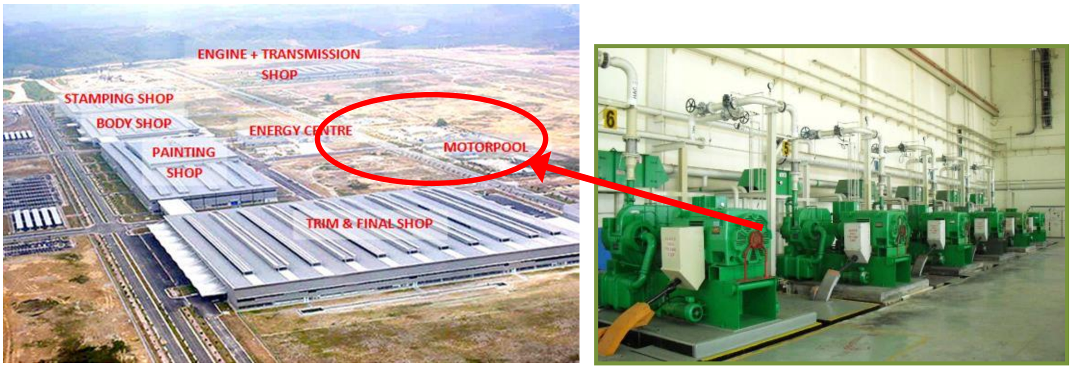
There are two places within the premises where the compressor room is located. One is in the energy centre and another in the engine plus transmission shop. The compressor system in the energy centre supplies to all except for the engine plus transmission shop, while the compressor system in the engine plus transmission shop supplies to its own use. The following are the installed air compressor systems in each room.

(1) Energy centre: 6 turbo compressors, 522 kilowatts (kW) x 6,000 normal cubic metres per hour (Nm^3/h); and

(2) Engine plus transmission shop: 2 turbo compressors, 336 kW x 3,400 Nm^3/h.

In total, these compressor systems generate 700 kilopascal (kPa) gauge of compressed air. Receiver tank is installed at each shop.

Figure 3.25: Bird's-Eye View of Proton Tanjung Malim Sdn Bhd and Its Compressor System

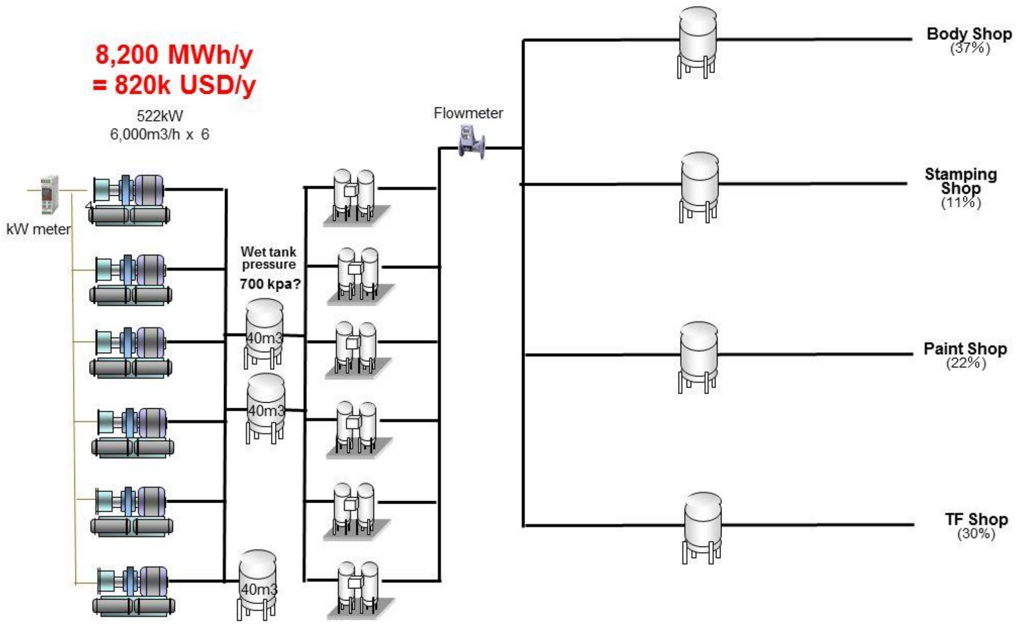


Source: Proton Tanjung Malim Sdn Bhd Compressed Air System Optimisation.

(2) Operational profile

The survey focused on the air compressor system in the energy centre. According to the plant operators of Proton, six units of compressor system in the energy centre in total consume 8,200 megawatt-hour electricity per year.

Figure 3.26: Diagram of Compressed Air Supply System in the Energy Centre



kPa = kilopascal, KW = kilowatt, m^3/h = cubic metre per hour, Wh/y = megawatt-hour per year, USD/y = United States dollar per year.

Source: Presentation material of Proton Tanjung Malim Sdn Bhd, 'Compressed Air System Optimization'.

Since compressors account for 17 percent of energy use for the entire plant, Proton is also aware that energy-saving measures for compressors can contribute significantly to overall cost improvement. According to Mr Abdul Azeem Bin Mohamed Mohideen, energy manager of Proton, Proton has taken initiative, called 'compressed air system optimisation' (CASO), since April 2014. According to Mr Mohideen, CASO initiatives have so far dealt with the following measures:

(1) Air leak repair,

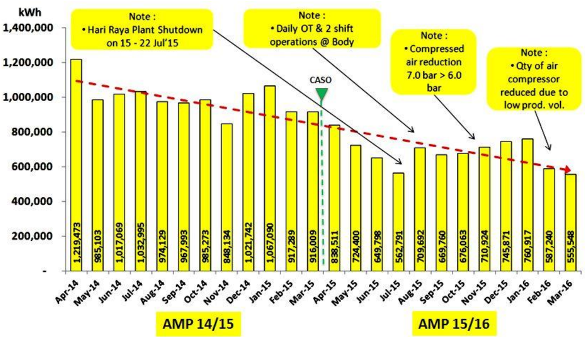
(2) Supply pressure reduction,

(3) Panel cooler improvement, and

(4) Air compressor optimisation.

These energy-saving measures have had the results of reducing the electricity consumption of air compressor system significantly as shown in Figure 3.27.

Figure 3.27: Proton's Energy Savings by Compressor Optimisation



AMP = (fiscal year of) annual management plan, KWh = kilowatt-hour.

Source: Presentation material of Proton Tanjung Malim Sdn Bhd, 'Compressed Air System Optimization'.

5.3. Discussion on possible solutions

(1) Application of compressed air system optimisation

Although CASO initiatives have achieved good results in energy efficiency, this study observed that there are still several energy-saving measures for compressed air systems, especially focusing on the energy saving related to the demand. This study proposed the following measures for further improving the energy efficiency of compressed air system as shown in Figure 3.28.

(1) Apply a group control of air-compressors;

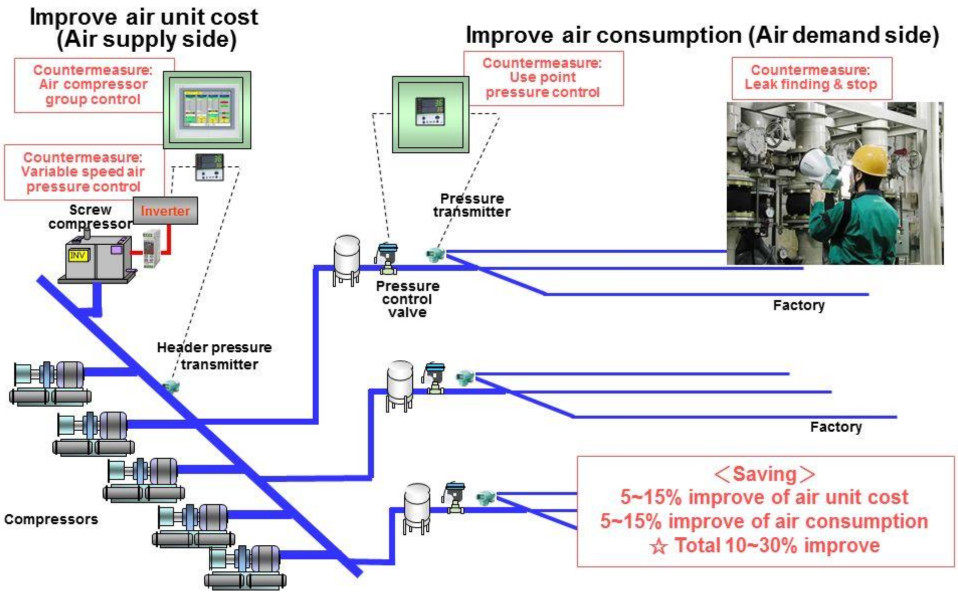
(2) Apply a control of variable speed air pressure;

(3) Install an air pressure control device at the downstream to monitor and control the air pressure also at the demand side; and

(4) Strengthen the leak detection to stop air leakage.

Above all, this study considers that the third item, i.e. installation of an air pressure control device at the demand side, is expected to yield energy-saving effect although certain initial costs may be required.

Figure 3.28: Compressed Air System Energy-Saving Solution



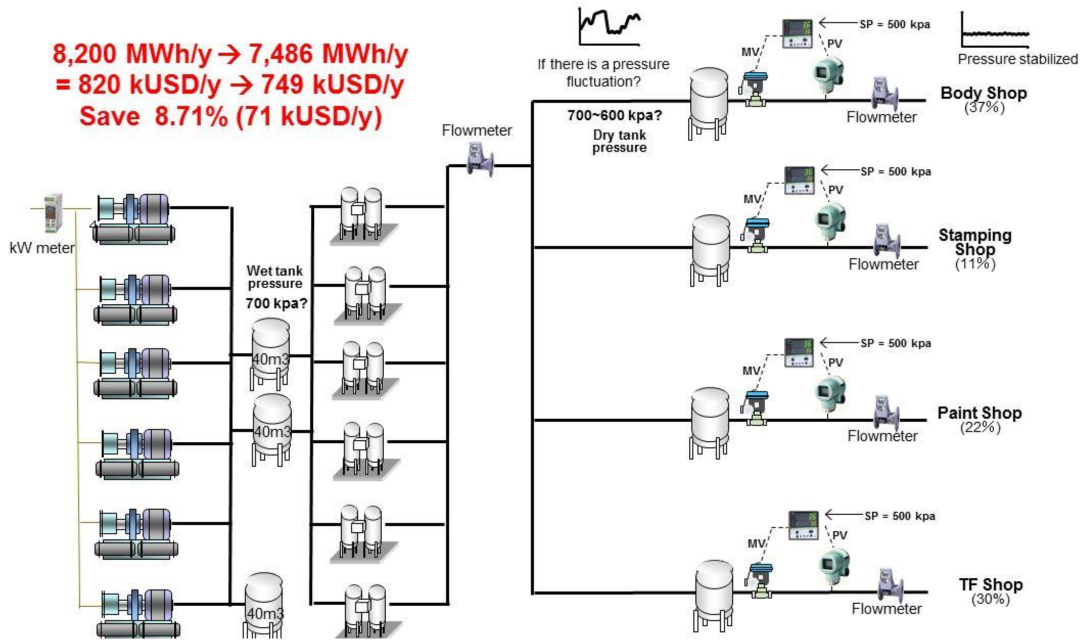
Source: Azbil Corporation (2016), Exhibition material for 'Sustainable Energy & Technology Asia 2016'.

(2) Estimation of energy-saving potential

Here the energy-saving potential of introducing a pressure reduction control device to each receiver tank is estimated.

Figure 3.29 shows the installation of pressure control devices at each of the four branch lines of air supply. If there is a pressure fluctuation at the upstream, the air pressure at the downstream will be adjusted to be constant. By reducing the excessive pressure supply, energy consumption for producing compressed air is expected to be saved.

Figure 3.29: Reduction of Compressed Air by Controlling Air Pressure at Branch Lines



kPa = kilopascal, kUSD/y = thousand US dollars per year, KW = kilowatt, MW = megawatt, MWh/y = megawatt-hour per year.
Source: Author.

This study estimates that if the original supply pressure is 600 kPa and is reduced to 500 kPa, air compressor system energy savings of 8.71 percent is expected.

Figure 3.30 Estimation of Energy-Saving Potential

	Shop	Present			Improvement Estimation							
		Air Consumption (hourly-average)	Annual Air Consumption (Present)	Supply Pressure (Present)	Supply Pressure (Reduction)	Annual Air Consumption (Estimate)	Blow Percent age	Oerating hours	Estimated Air Saving (Improvement)	Estimated Power Saving (Improvement)	Annual Cost saving	Improvement
		(m3/h)	(m3/yr)	(kPa)	(kPa)	(m3/yr)	(%)	(h/day)	(m3/yr)	(kWh/yr)	(MYR/yr)	(%)
1	Body-Shop	5,000	31,680,000	600	500	28,919,751	95	16	1,748,158	205,666	73,011	8.71%
2	Paint-Shop	3,000	19,008,000	600	500	17,351,851	80	16	883,280	103,915	36,890	8.71%
3	Stamping-Shop	1,500	9,504,000	600	500	8,675,925	95	16	524,447	61,700	21,903	8.71%
4	TF-Shop	4,000	25,344,000	600	500	23,135,801	70	16	1,030,493	121,234	43,038	8.71%
5	ETM-Shop	5,000	31,680,000	600	500	28,919,751	95	16	1,748,158	205,666	73,011	8.71%
										total	**247,854**	8.71%
											¥7,435,624	

Conditions		
Net Working-day	264	(days/yr)
Electricity Price	0.355	(MYR/kWh)
Compressor COP	8.50	(m3/kWh)

kPa = kilopascal, KWh/yr = kilowatt-hour per year, m^3/h = cubic metre per hour, MYR = Malaysian ringgit, ¥ = Japanese yen.

Source: Author.

The estimated costs of implementing these measures are US$160,000 (about 533,000 Malaysian ringgit [RM]). Comparing between the estimated costs and the economic benefits (about RM248,000 per year), this study expects that the payback period is about 2.2 years, which shows that the investment for these measures is economically feasible.

6. Key Findings from the Case Studies

As shown in Figure 3.16, this study identified five types of energy-saving technologies that could be widely applicable for the industrial sector. Two out of these five types were chosen for the case study, i.e. optimisation of compressed air system and optimisation of boiler, turbine and generator. Thereafter, the field case study was conducted for each of them to confirm the applicability of assumption, namely Proton's compressed air system in Malaysia and GPA's cogeneration system in Singapore.

Since there are various types of industries, and each uses various types of appliances, conducting only two case studies may not be sufficient to grasp the status of energy consumption of the industrial sector in Southeast Asia in depth. However, as discussed in Section 3, compressed air system and boiler, turbine, and generator are commonly used by various types of industry. In terms of types of industry, automobile and food and beverage are among the industries that widely exist in Southeast Asia. Therefore, roughly speaking, this study considers that these two sites represent the characteristics of energy consumption of the industrial sector in Southeast Asia.

From these case studies, it can be generally implied that the factory appliances are maintained rather well and that the owners are conscious about improving energy efficiency to a certain extent. Another reason may be that the case study sites are located in Malaysia and Singapore, which have rather high income level. It is also worthy of note that the case study sites were chosen upon the suggestion of government agencies of these countries that may be apt to select a good practice of their country.

However, even considering the aforementioned leanings, this study has observed that there is still a space for improving energy efficiency by optimising the system configuration. Following the observations from the site survey, this study raises three issues commonly applicable to the industrial sector in the ASEAN region. Also, dealing with these issues is expected to pave the way for the deployment of FEMS in this region.

The first issue is the practice of detailed measurement. Meanwhile, increasing the points of measurement and adjustment complicates the data analysis and the adjustment of operation, and FEMS is expected to be a tool to provide solution.

The second issue is the process of repeated trial and error. Since the structure and the condition of manufacturing system is different from site to site, the optimum configuration of parameters also differs among the sites, and finding the solution a priori is far from easy. The trial-and-error process of changing parameters is indispensable for reaching the optimum configuration.

On the other hand, facility owners are reluctant of changing the parameters because wrong configuration may affect the productivity of manufacturing and quality control although it may be transitional. These kinds of trial might be more difficult for the case of GPA in Singapore, where the supplier and the user of utility services (electricity and steam) are different, thus, the integrated approach covering both supply side and demand side is not easy. Utilisation of FEMS, which helps analyse the conditions of the entire system, is expected to facilitate the process of identifying the optimum solution without impairing the productivity and quality.

It has to be noted that human capacity development of expertise that versed in energy and statistics is also necessary to handle the huge volume of operational data although the utilisation of FEMS can be a strong tool for data analysis. Since it takes certain time and cost to develop human resources with the aforementioned expertise, it is strongly recommended that appropriate policy measures to promote this, such as qualification system for energy managers and training programmes, should be in place.

The third issue is to establish a commonly acceptable methodology to evaluate the cost and benefit. In general, the percentage of energy-saving potential against the total energy consumption is small for the industrial sector compared to office buildings. In the industrial sector, considerable portion of energy is used for the manufacturing process which is directly related to the products and, thus, is rather easily visible. Whereas at the buildings certain volume of energy, such as air conditioning, air circulation, and lighting, is apt to be used in an unmanned or scarcely manned manner. As explained in Section 2, the expected energy saving is around 5 percent of total consumption or less in many cases. However, because the energy consumption per one site of manufacturing is, in general, far larger than that of office buildings, energy saving per site can be large although the percentage appears to be small.. Therefore, a meticulous methodologies to evaluate the effect of energy saving measures should be established so that the results can be accepted not only by the suppliers of energy-efficiency technologies but also by their users and those who provide financial resources. This helps promote energy-efficiency technologies, including FEMS, and determine policy intervention necessary for their promotion, such as subsidies for initial investment.

Challenges for the deployment of EMS (not only FEMS but also BEMS) in the ASEAN region and a set of policy recommendations for its promotion briefly described in this section are discussed in detail in Chapter 5.