SPECIAL ASSISTANCE FOR PROJECT IMPLEMENTATION (SAPI) TO IDENTIFY THE MEASURES TO REDUCE AND/OR MANAGE GHG EMISSION FOR MAJOR COAL-FIRED THERMAL POWER PLANTS IN VIETNAM

FINAL REPORT

June 2011

Japan International Cooperation Agency (JICA）

CHUBU Electric Power Co., Inc.

Japan Coal Energy Center (JCOAL)

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Abbreviation

ADB	Asian Development Bank
BAU	Business as Usual
CCS	Carbon dioxide capture and storage
CCT	Clean coal technology
CDM	Clean Development Mechanism
CER	Certificate Emission Reduction
Chubu EPCo	Chubu Electric Power Company
CIF	Cost Insurance & Freight
COP	Conference of the Parties
d.a.f	Dry Ash Free Base
Eff.	Efficiency
ECBM	Enhanced Coal Bed Methane
EOR	Enhanced Oil Recovery
ESP	Electrostatic Precipitator
ET	Emissions Trading
EVN	Vietnam Electricity
GHG	Green House Gas
HGI	Hardgrove Grindability Index
IE	Institute of energy
IEA	International Energy Agency
IGCC	Integrated coal gasification combined cycle
Ig. Loss	Loss on Ignition
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent power producer
JI	Joint Implementation
LULUCF	Land Use, Land Use Change and Forestry
NEDO	New Energy & Industrial Technology Development Organization
OM	Operation and maintenance
SC	Supercritical
Trans.	Transportation
UNFCCC	United Nations Framework Convention on Climate Change
U.H.V..	Useful Heating Value
VINACOMIN	Viet Nam National Coal & Mineral Industries Group

Chapter 1 Introduction

1.1 Background of the research

In Socialist Republic of Vietnam (hereafter Vietnam), demand for electricity has been increasing significantly along with the country's rapid economic growth. Coal-fired thermal power plants constitute about 10 percent of the nationwide power plants, but in northern Vietnam which has coal resources, coal-fired power and hydraulic power are the region's main power resources. In the Power Master Plan VI developed in 2007, the development of coal-fired power in both northern and southern regions in the future has also been adopted as a basic policy. JICA has also been providing support for the development of electric power in Vietnam. It has so far provided assistance for the construction of coal-fired thermal power plants under a yen loan scheme, including Pha Lai, Nghi Son and Thai Binh thermal power plants.

On the other hand, reduction of the environmental burden from coal-fired thermal power plants is required on a global scale. From the standpoint of measures for climate changes, the curbing of greenhouse gas emissions in the energy sector is needed. Also in Vietnam, the efficient operation and management of existing thermal power plants, awareness-raising on environment and the development of concrete environmental measures have become important issues.

Against such a background, a research will be carried out with Vietnam Electricity (hereafter EVN), a counterpart organization, in order to examine comprehensive and appropriate measures in terms of both economy and technology to curb greenhouse gas emissions from coal-fired thermal power plants, which are regarded as sources of comparatively large volume of greenhouse gases. It is expected that introduction of the measures for curbing greenhouse gas emissions presented in this research into the coal-fired thermal power plants that were built under yen loan projects will be examined, and the measures will contribute to the reduction of the environmental burden of these plants.

1.2 Purpose of the research

The research aims to investigate, analyze and examine appropriate measures for curbing greenhouse gas emissions from coal-fired thermal power plants in Vietnam from short-, medium- and long-term perspectives, and make proposals for most appropriate Measures to Curb Greenhouse Gas Emissions from Major coal-fired thermal power plants.

Results of this research to be delivered according to the above-mentioned purpose are as follows:

(1) Verification of measures to reduce greenhouse gases in the future

A long-term roadmap plan (closure of low-efficiency power plants, replacement of existing equipment, introduction of high efficiency power plants, etc.) for curbing greenhouse gas emissions from coal-fired thermal power plants in Vietnam will be verified.

(2) Identification of necessary facilities for subcritical pressure steam coal-fired thermal power plants

Facilities required for subcritical pressure coal-fired thermal power plants for which construction is planned in the future will be identified from the standpoint of curbing greenhouse gas emissions

(3) Examination of measures to curb greenhouse gas emissions which are in line with international trends and are feasible in Vietnam.

1.3 Regions to be researched

The research covers whole of Vietnam.

* Based on the site survey for three EVN’s coal-fired thermal power plants, measures to curb greenhouse gas emissions from major coal-fired thermal power plants in Vietnam.was proposed.

1.4 Major implementing agencies of the partner country

(1) Counterpart agency

Vietnam Electricity (EVN)

(2) Relevant government and administrative agencies

Ministry of Industry and Trade (MOIT)、Ministry of Natural Resources and Environment (MONRE)、Institute of Energy (IE), etc.

Chapter 2 Current status of coal-fired thermal power plants and activities related to curtailment of GHG emissions

2.1 Operation of thermal power plants

2.1.1 Operation of thermal power plants and setup for operation management

The target coal-fired thermal power plants (TPPs) are the Ninh Binh, Pha Lai, and Uong Bi plants. Each of these plants is characterized by a high annual operating rate and a plant efficiency rate below the design level. There were some plants commenced operation in the 1970s and consequently have been in service for close to 40 years. In some, the efficiency of these plants was lowered by aged deterioration.

Meanwhile, Vietnam has continued to achieve firm economic growth at annual rates in the range of 6 - 8 percent since 2000. Along with this growth, it is being faced with a serious power shortage due to the expanding demand. As a result, there are many planned outages, which are having a major impact on the national life and corporate production activities.

In light of these circumstances, a few power plants side tends to place priority on assurance of output, and cannot shut down plants for long durations to conduct proper maintenance.

The setup for operation of these plants consists of three alternating groups for each unit. Each group is divided into subgroups for electrical facilities, turbine facilities, and boilers. It is also the general practice in Vietnam to have a division between electrical and machinery personnel even in the control room.

The plants are operated in three shifts, and the workers are divided into groups corresponding with facility type, i.e., electrical facilities, turbine facilities, and boiler facilities.

The plants have instituted an organizational unit especially for management of operating performance, called the "safety technology department" or "technical department". They also have units assigned exclusively to analysis of fuel (coal) composition required for efficiency calculations.

Based on these data, the assigned units sample operating data on a daily basis, calculate efficiency, and make reports to the EVN.

Although some of the data are recorded by a so-called "operation log device", almost all are from readings taken by operators by themselves every hour, on the hour.

2.1.2 Analysis of the current status of boiler facility operation

Figure 2.1-1 is an explanatory diagram of factors decreasing boiler efficiency. One of these factors is the adherence of scales made of iron, copper, or other substances on the inner walls of evaporator tubes along with aged deterioration. The scales lower the thermal conductivity of the boiler proper. Similarly, grime on the inner walls of heat transfer tubes and corrosion by drainage in low-temperature parts can impede heat transfer and lower the heat exchange rate in air heaters.

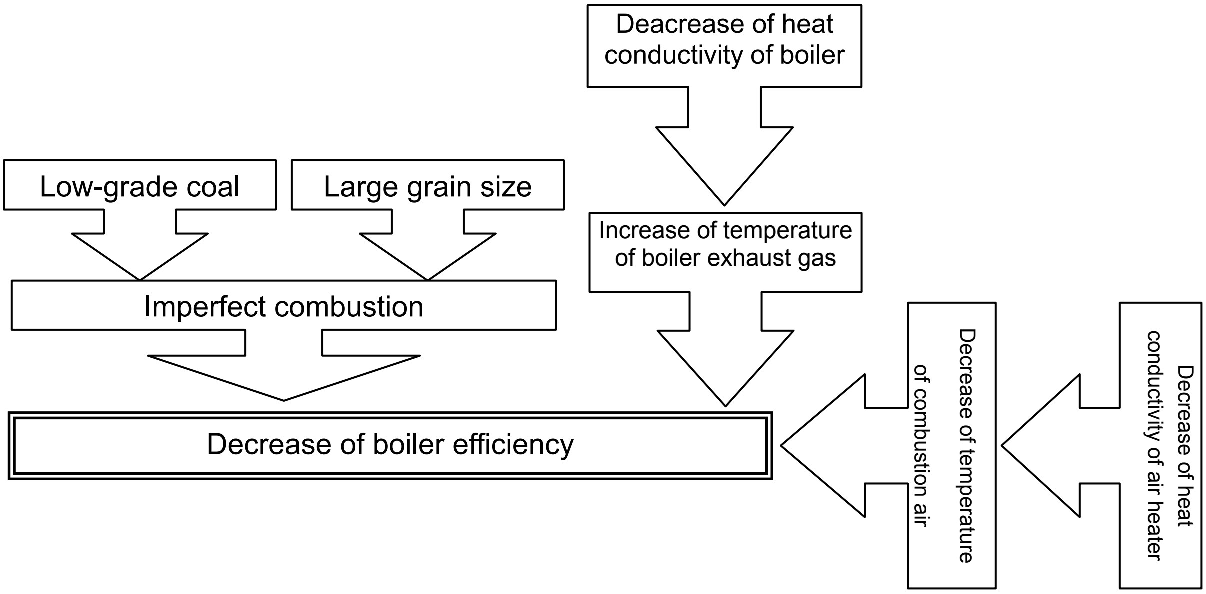


Figure 2.1-1 Outline of boiler efficiency decline

At some of the plant facilities covered by the study, the temperature of exhaust gas from the boilers and air heaters are higher than the design level. This phenomenon indicates a trend of decrease the effectiveness of heat exchange.

Generally speaking, the superior coal produced in Vietnam is mainly exported; coal of a somewhat inferior quality is used to fuel for power generation, and this is a major cause of the inability to obtain the full potential output. This influence is particularly in evidence in the case of units 5 and 6 at the Uong Bi plant. At the time of its construction, the plant was designed to use the coal with a calorific value of 6,020 kcal (per kg). The study, however, revealed that the calorific value of the coal actually used by the plant was in the range of 5,200 - 5,400 kcal.

As a result, the main steam pressure and temperature are both far below the design levels, and the boiler efficiency is in the range of 70 - 80 percent, lower than at any of the other plants covered by the study.

Furthermore the influence of useing low-grade coal also appears in the proportion of uncombusted fuel in coal ash. This proportion was high at many of the plant units studied this time, but it was also reduced by certain steps. At the Ninh Binh plant, for example, the reduction was achieved by replacement of the cyclone classirier of coal pulverizer and control of the frequency of the sending coal blower for optimal control of combustion.

2.1.3 Analysis of the current status of turbine facility operation

Like that of boiler facilities, the efficiency of the turbine facilities fell below design levels. This is partly due to the low boilers output because of aged deterioration and the other factors. The turbines themselves, however, are saddled with facilities in bad condition that are additional factors in lower efficiency. These may be exemplified by the decline in heat exchange effectiveness due to grime in condenser tubes because of inadequate cleaning owing to defects in the dust collector, and the suction of air into the condenser due to deterioration with the passage of time.

As in the case of boiler facilities, it is hard to take enough time for proper maintenance because of the situation surrounding power supply in Vietnam. At one plant, it was found that turbines were being allowed to operate at main steam temperatures and pressures below the rated levels, with full knowledge of the resulting decline in turbine efficiency. This was because of apprehensions about equipment breakage due to the stress imposed on pipes, which had deteriorated with age, by high-temperature and -pressure steam.

In addition, the rise in the temperature of river water in summer is another big problem, because it lowers the degree of condenser vacuum, which has the effect of reducing turbine efficiency. All of the plants covered by the study drew water to cool their equipment from rivers in the vicinity. In some cases, the river water temperature rises to about 37 degrees (centigrade) in summer. The higher water temperature unavoidably results in a lower degree of vacuum and, by extension, efficiency.

The problems and issues noted above were generally ascertained through interviews with plant engineer and technicians about such points in this study. Many of these personnel were aware that the plant operation ideally should be maintained at levels approaching the design ones, but said that facilities could not be shut down for periodical inspections in reality, because of the tight power supply.

2.1.4 Analysis of the current status in operation of environmental facilities

(1) Wastewater and industrial smoke

The conscious for environment protections is high in any plant of this country. The utmost efforts have been done to respect the discharge standards of Viet Nam. Measurement protocols for wastewater and industrial smoke have been prepared and the discharge standards were actually respected in each investigated plant. In addition to measurements by themselves company, certifications by ISO/IEC 17025-acquiring organizations have been required for them at regular intervals. Therefore, the accuracy of measurements would be kept also in the routine measurements. In Japan, as it has been evaluated that the discharge standards of the antipollution laws are not enough for large-scale plants like a power plants, the values of “the agreement on environmental pollution control” has been adopted. The values are decided by deliberations between industrial plants and local governments and are stricter than ones of the discharge standards. We show the values of the discharge standards in both countries and values of the agreement on environmental pollution control for one Japanese coal fired plant, below (However, as Japanese values are converted to 5% O_2 level, direct comparisons of standard values on both countries are impossible.).

Table 2.1-1 Standard values for exhaust gas in Vietnam and Japan

Items	The discharge standards in Viet Nam (*1)	The discharge standards in Japan	The agreement on environmental pollution control
NOx	1000 ppm	200 ppm	30 ppm (*2) 15 ppm (*3)
SO_2	1500 ppm	108 ppm (*2, *4) 98 ppm (*3, *4)	28 ppm (*2) 25 ppm (*3)

*1. Actual values adopted in each plant as the standard
*2. An example value for one plant on 700 MW of rated capacity
*3. An example value for one plant on 1000 MW of rated capacity
*4. A value according to “the K value control” which is expressed by $Q=K*10^{-3}*He^2$ (Q; standard value, (Nm^3), K; constant value for each reason, He; height of gas exhaust (m))

Table 2.1-2 Standard values for wastewater in Vietnam and Japan

Items	The discharge standards		The agreement on environmental pollution control (*2)	
	Viet Nam (*1)	Japan	Plant wastewater	Domestic wastwater
pH	pH6 to 9	pH5 to 9	pH5.8 to 8.6	pH5.8 to 8.6
COD	100 mg/L	160 mg/L	10 mg/L	10 mg/L
SS	100 mg/L	200 mg/L	10 mg/L	10 mg/L

*1. Actual values adopted in each plant as the standard.
*2. An example of a plant on 4100 MW in total rated capacity.

(2) Environmentally-related facilities

Plants constructed in recent years have flue-gas desulfurization equipments and electrical dust collectors and are operating these on a routine basis. Additionally, relative small scale and old plants also have extended electrical dust collectors and have renovated the height of chimneys. Thus investments for environmental protection are not so small and the emission of environment pollution substances has been well controlled.

(3) Automatizations for environmental measurements

Plants constructed in recent years have automatic equipments to measure the water qualities. In addition of measurements by these, manual procedures have been also carried out in every 2 hour or every 4 hours. As the reasons of manual measures, there are three matters described below.

- Good measurement conditions for automatic equipments have not been found.
- Accurate measurement values are not detected by automatic equipments because of lack of enough maintenance and of accurate calibrations.
- There is enough manpower for manual measurements.

Now certain plant advocates manual measurements better than automatic measurements but thermal power generation by supercritical pressure, which will be introduced for effective power generation in future, requires stricter water regulations than one by subcritical pressure. Therefore, acceleration of the automatizations is important.

(4) Disposal and recycle of waste products

The managements (how to store, how to penetrate wastewater and so on) of waste products like clinker and fly ash could not be researched in this project because they have been carried to industrial waste companies or recycle companies on the outside of power plants. However, there are some techniques to recover unburned carbon from ash and to utilize ash and calcium sulfate in this country. Thus disposal has been positively converted to valuable resources.

(5) Activities for reduction of the greenhouse gas emission

In Viet Nam, obligation quantities of annual electricity generation have been set for each plant and the violators have to pay a penalty charge. However, the plants researched in this project have not made specific efforts for reduction of greenhouse effect gas. Additionally, there are not laws and regulations for it.

2.2 Status of thermal power plant maintenance

As compared to those in Japan, the two Vietnamese thermal power plants have an extremely large number of employees. Employees number over 1,000 each at Pha Lai and Uong Bi plants. Technical personnel engaged in facility maintenance account for 10 - 20 percent of them. Maintenance management is generally performed by the plant personnel, but external consignments are made for inspections and performance tests requiring special equipment and materials.

2.2.1 Setup for maintenance management at thermal power plants

(1) Setup for routine maintenance

Each plant has both operators engaged in operation and control work in central control rooms and workers who oversee the status of the machinery on the floor. In the event of detection of abnormality in the meter readings for the main machinery constantly monitored by the operators or in operating data collected every hour, or on patrols by workers every 15 - 30 minutes, a report is made to the people in charge in the central control room. If these people see a need for repair based on the report, they contact repair personnel. Although the response depends on the power supply-demand situation, some power plants shut the unit down to perform maintenance about once every three months, if the demand allows. As routine maintenance tests with reserve equipment, the plants regularly make switchovers to this equipment and test its operation while keeping report forms on it. As such, there is currently no problem in regard to confirmation of equipment soundness

The plants do not apply the approach of comparing the cost required for lengthening service life through preventive maintenance and that required for post-breakdown repair, and selecting the optimal policy. As such, there is a need for study in this area.

Technical conferences are held at regular intervals, and studies are made as necessary on issues such as the need for equipment repair. Because output is of paramount importance, the duration of unit shutdown must be held to the minimum requisite.

(2) Setup for maintenance during periodic inspection

The power plants implement a full periodic inspection (check) once every four years, which is the term stipulated by law and recommended by manufacturers, and simple inspections once every two years. The duration varies somewhat with the plant. Up until ten years ago, the plants asked manufacturers to send technicians over to make the inspections, but now they perform them entirely with their own personnel. Requests are made to manufacturers when there is a need for special repairs and inspections.

In the case of units that have been in operation for more than 30 years, the plants basically know the locations frequently involved in equipment breakdown, and the current work method for them has been optimized with respect to the number of technicians and time required for inspection. Units that were placed into operation in 2000 or later have higher levels of efficiency, and it is difficult to shut them down for inspection and repair. As a result, there are many instances of trouble due to decline in performance and the lack of measures to counter it.

The power plants store spares for parts that often require repair. Formerly, they purchased many spares for the purpose of reducing the duration of repairs that suddenly became necessary. At present, however, they are buying in lower quantities because improvement of purchasing methods and channels are facilitating procurement of parts.

2.2.2 Periodic inspection plans and items

(1) Confirmation of long-term periodic inspection plans

Plans for periodic inspection extend five years into the future. Because of the need for arrangements with manufacturers, tenders, and other preparations, detailed studies are made for equipment to be repaired in the next fiscal year. If work must be done on major pieces of equipment, application is made in advance to the EVN, whose approval is required.

(2) Confirmation of the items of periodic inspection

The overhaul (disassembly) checking of equipment in major periodic inspection is implemented every four years, and in simple inspection is every two years. All the equipments are inspected through these periodical inspections.

There is no prescribed interval for overhaul checks of pipes, valves, meters, and other such parts attached to major types of equipment; these parts are grouped so that such checks are done along with those for the major types.

After completion of the periodic inspection, the plant compiles an outline record of the results of overhaul checks of each piece of equipment along with operating data in the form of a booklet consisting of a few volumes. The booklets are kept in storage for as long as the facilities are in use, and the plant is therefore able to investigate the results of all past inspections.

Recent years have seen mounting interest in approaches to environmental problems, partly because of the conditioning of related legislation providing for penalties for environmental violations and clear standards for the cleanliness of air and water. In response, recent modification of power plant facilities is being motivated not only by improvement of unit efficiency but also by concern for the environment.

2.2.3 Analysis of the current status in maintenance of boilers and environmental facilities

(1) Ninh Binh Thermal Power plant

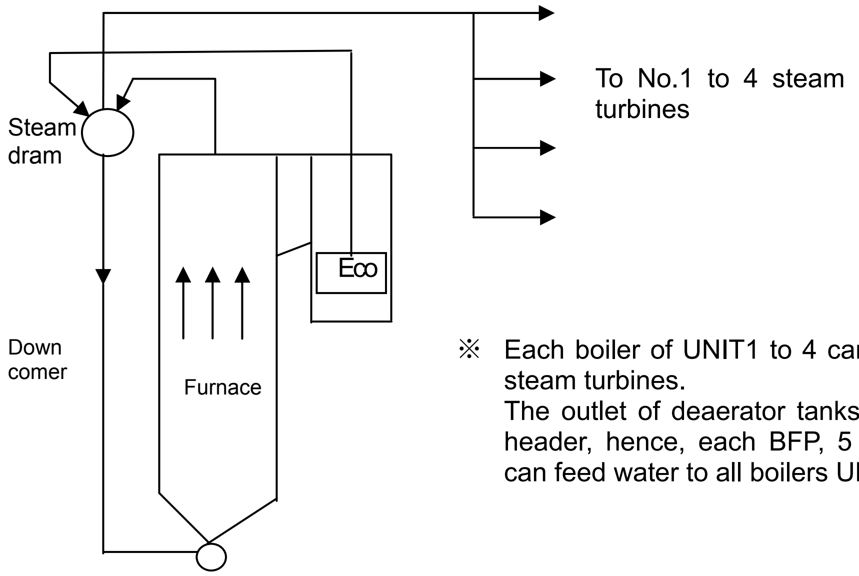
The unit interiors are kept very clean. In addition, the facilities are indoors, and therefore not susceptible to the influence of corrosion due to rains and salt. Their condition is consequently so good that it is hard to believe they have been in operation for more than 35 years.

The following are the major problem points revealed as a result of a visual check of equipment exteriors and examination of the periodic inspection records.

- Boilers

The boilers for units 1 - 4 at the Ninh Binh Thermal Power plant are Chinese-made indoor single-drum natural circulation types that were placed into operation beginning in 1974. Figure 2.2-1 shows the outline structure. The plants are fueled with coal, but there is little trouble with erosion due to powdered coal. This is because the combustion gas flow rate is low, and anti-erosion measures have been taken as a result of past experience of such trouble. Measures have also been taken to combat erosion from past experience, and there is consequently little trouble involving erosion caused by pulverized coal. To reduce the level of uncombusted material in ash (incomplete combustion being a main cause of low efficiency), the plant has taken various steps, including control of the pulverized particle size during operation at two-hour intervals and improvement of the coarse particle separator. Although, with the existing facilities, it would be hard to attain a particle size smaller than the current 90 microns, the size of the particles is small enougt to fire.

It is thought that thermal conductivity is being lowered by the adherence of iron and copper scales to the inner walls of the boiler evaporator tubes due to long-term operation. Currently, the tubes are cleaned only by air-blow at the time of periodic inspection. Scale removal by means such as chemical washing could presumably bring the heat transfer performance back up.



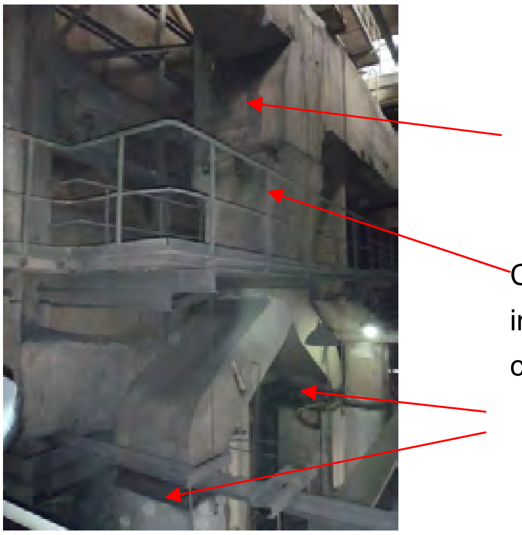
※ Each boiler of UNIT1 to 4 can send steam to all steam turbines.
The outlet of deaerator tanks is also a common header, hence, each BFP, 5 including stand-by, can feed water to all boilers UNIT 1 to 4.

Figure 2.2-1 Outline diagram of boilers at the Ninh Binh plant

- Air heaters

The Ninh Binh Thermal Power plant uses air heaters with heat transfer tubes. Deterioration caused by long-term operation was observed on the outer mounting plates of ducts, but the observation did not find any air suction due to a major rupture. While repairs are made every time a rupture occurs, there is a need for systematic maintenance in light of the difficulty of making repairs while the unit is in operation and the steep drop in efficiency if the operation is continued with air being suctioned. Details on this point are presented in Section 3.

As for the interior, it is thought that the transfer of heat is being impaired by grime inside heat transfer pipes and corrosion from the drain in the low-temperature part. Replacements and repairs are currently being made only when holes are opened in the pipes.



Mark of repair or inspection

Corrosion is little because of the indoors. Deterioration of outer casing are observed all over.

Deterioration of expansion joint

Figure 2.2-2 External appearance of air heaters

- Other matters

Examination revealed steam leaks in various parts and deterioration on fireproofing, insulation, and outer mounting plates, all of which are causes of heat loss. The major steam leaks are valve ground leaks and drain valve seat leaks. In some cases, it was unclear whether overhaul checks are made at the time of periodic inspections.

The valve on the sampling rack was close to being fully open and emitted a large amount of steam (see Figure 2.2-3). The purpose is apparently to assure the amount of flow at all times and heighten the precision of water quality readings in sampling, but the amount of flow ought to be adjusted with a view to preventing heat loss.

Boilers were for the most part fitted with fireproof material on the inside but did not have heat insulation and outer mounting plates on the outer surface of the skin casing (see Figure 2.2-4). Some part of the skin casing surface temperature tops 100 degrees, and the outside temperature drops below 10 degrees for a considerable duration in winter. As such, it is advisable to insulate the boilers in order to prevent radiation of the heat.

Examination of ducts in various parts revealed damage to outer mounting plates in several locations. This damage is thought to be due to expansion deterioration and the loss of interior fireproofing and insulation (see Figure 2.2-5). It is generally being repaired in lower spots where scaffolding is not required, but not in higher spots requiring elaborate scaffolding. There are apprehensions about a decline in efficiency because of the suction of air from the damaged spots. For this purpose, it is necessary to make a separate determination of the scope of inspection for each type of equipment and to control the interval.

Figure 2.2-3 Status of sampling rack

Figure 2.2-4 Status of boiler skin casing

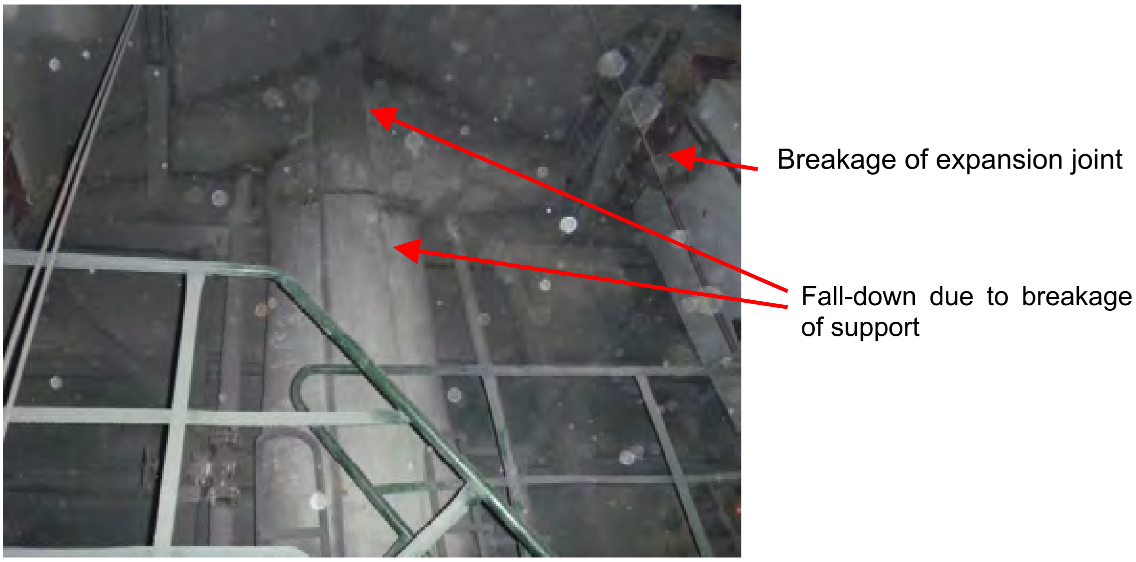


Figure 2.2-5 Duct damage

(2) Pha Lai Thermal Power plant

The unit interior is kept relatively clean, but damage was visible in certain parts. The cause is presumably the tight supply of power in Vietnam, which makes for very few opportunities to disconnect equipment and perform overhaul inspections on it.

- Boilers

The boilers at the Pha Lai I plant are Russian-made outdoor single-drum natural circulation types that were placed into operation in 1983. Those at the Pha Lai II plant are outdoor single-drum natural circulation types that were manufactured by the British firm Mitsui-Babcock and placed into operation in 2001.

As at the Ninh Binh plant, the inner walls of the evaporator pipes are thought to contain iron and copper scales built up over the many years of operation. Because the plant manages the quality of the makeup water and scales inside the pipes, a decline in heat transmission efficiency could presumably be prevented by chemical washing as necessary. At present, the plant cleans the pipe interiors by blowing air through them at the time of periodic inspection every four years, and performs chemical washing as may be necessary.

At both Pha Lai I and II, the boilers are fueled with domestically mined anthracite with a low slagging coefficient. As a result, there is comparatively little trouble with ash adherence to or sedimentation in boiler tubes. Personnel manually start up soot blowers at the relatively low frequencies of about once a day at Pha Lai I and twice a week at Pha Lai II. Because the start-up interval is fairly long, there is often trouble due to drain attack. This points to the need to prevent such trouble by sure performance of warming at the time of soot blower startup, as well as trend management for metal temperature inside the boiler and thinning of boiler tube walls in the vicinity of the soot blower, through monitoring in the central control room.

-Coal pulverizer

The pulverizer is of the ball type, but the pipe walls have become worn due to operation for long durations. In locations that are most worn, the drop location of the pulverizing iron balls is lower. This not only reduces the pulverizing efficiency but is also linked to a lower combustion efficiency and higher level of uncombusted matter, because of the resultant lowering in the degree of pulverization. Especially, at Pha Lai II, personnel are currently coping by operating one reserve pulverizer in addition to the three in the design plan, for a total of four.

- Air heater

Pha Lai I is equipped with heat transfer tubular air heaters, and Pha Lai II, with Jungstrom air heaters. At Pha Lai I, it is thought that the transfer of heat is being impeded by grime on the inner walls of the heat transfer tubes in heater and corrosion from the drain on the low-temperature side, due to long-term operation.

At Pha Lai II, air is leaking from the seal due to wear, and this can put the induced draft fan in an overload status. At present, the air leakage rate is 28 percent as compared to the design rate of 8 percent. There consequently appears to be room for improvement of performance through sure execution of maintenance.

- Induced draft fan

There is substantial erosion of the fan blades due to the combustion ash. This erosion is causing an increase in vibration due to imbalance and decline in performance, and urgently requires overhaul inspection and repair. During periodic inspection, personnel do not repair plating on blades or take other measures to combat erosion; they merely adjust the balance at the time.

- Other matters

At the Pha Lai plant as well, the Study Team noticed steam leaks from valves and pipes at several locations thought to have gone uninspected (see Figure 2.2-6 and Figure 2.2-7). Considering that it would be difficult to make repairs while the facilities are in operation and that it is hard to make time for repairs by shutting the units down, it is of critical importance to make advance repairs during periodic inspections of spots where damage is likely to occur. As such, personnel must make examinations with a view to revising the methodology for inspection management.

Figure 2.2-6 Status of valve

Figure 2.2-7 Status of duct

(3) Uong Bi Thermal Power Plant

As at the Pha Lai thermal power plant the Study Team observed damage in various locations at the Uong Bi thermal power plant owing to the difficulty of shutting down units, disconnecting equipment, and performing overhaul checks, because of the tight supply of power in Vietnam. The facilities for units 5 and 6 in particular exhibit marked dilapidation because they are still being operated for about 8,000 hours a year even though they have been in operation for more than 30 years.

- Boilers

The boilers for units 5, 6, and 7 are Russian-made outdoor single-drum natural circulation types. Those for units 5 and 6 were placed into operation in 1975, and those for unit 7, in 2009.

The boilers are fired with anthracite mined in the vicinity. The anthracite has a low calorific value and high ash content. It therefore produces a large quantity of clinker in absolute terms, and this is a cause of trouble that can lead to emergency shutdown.

A particularly large amount of clinker is derived in Unit 7. As a result of various measures in aspects such as combustion adjustment, the unit is operated at an output in the range of 280 - 290 MW as compared to the rated output of 300 MW. This allows operation of the boilers at a lower internal temperature to curtail the formation of clinker.

To remove scales on the inner walls of boiler pipes, the plant performs chemical (alkali) washing every two years.

There appears to be much trouble connected with soot blowers. The Study Team noticed erosion on pipe walls due to the jet steam and damage due to contact with the pipe.

- Pulverization-related facilities

The pulverizers are of the ball type, and the pipe walls are quite worn due to the long-term operation. The walls of the pulverized coal pipes also show serious wear, and leakages are frequent. When damage occurs, the personnel make spot repairs such as replacing the damaged parts or repairing them by welding. Reduction of leakage trouble during unit operation requires sure management of the pipe wall thickness at each part and assessment of remaining service life.

- Air heaters

It is thought that the transfer of heat is being impeded by grime on the inner walls of the heat transfer tubes in the heaters and corrosion from the drain on the low-temperature side, due to long-term operation. At present, the heat transfer tubes are replaced or repaired only when a hole opens up in them. A revision of the replacement standards based on measurement of tube wall thickness and assessment of remaining life (details noted in Section 3.2) would help to improve the heater efficiency and reduce the incidence of trouble compelling unit shutdown due to damage to heat transfer tubes.

- Other matters

At the Uong Bi plant, as at the other plants, the Study Team noticed steam leaks from valves and pipes at several locations. During periodic inspections, it is of critical importance to make advance repairs of spots where damage is likely to occur. As such, the Study Team recommends a revision of the methodology for inspection management.

2.2.4 Analysis of the current status in operation of environmental facilities

(1) Overall

For the main turbines, the plants make plans for periodic inspection once every four years, and prepare documents setting forth these plans. For auxiliary equipment, however, they do not prepare documents clearly presenting planning and actual data for the periodic inspections. This equipment ancillary to the main turbines, inclusive of valves, is apparently managed by the assigned personnel. As a result, it is hard for a third party to ascertain what units were inspected when, and the plans for future inspections. Similarly, although some of the plants kept gap records for the main turbines, this was not done for auxiliaries. This would make it difficult to ascertain the situation even if there occurred a decline in the efficiency of pumps due to gap increase, impeller erosion, or other factors.

The Pha Lai II has been in operation for about ten years, but has never undergone a full periodic inspection, due to the tightness of the supply of power in Vietnam. Its steam turbine facilities, too, have never had an overall inspection.

(2) Main turbines

At the Ninh Binh, Pha Lai, and Uong Bi power plants, have experienced replacement of rotor blades, reportedly for reasons such as serious blade erosion or breakage. At the Pha Lai and Uong Bi plants, the Study Team was told that turbines continued to be operated even with broken rotor blades. It appears that breakdown maintenance is the basic practice for steam turbines as well. At the Ninh Binh plant, there were control records indicating that permissible levels were not exceeded for the seal gap at the blade tip, the seal gap between the diaphragm and rotort, and the seal gap between the ground packing and rotort, but it was not possible to confirm these items in the case of the other plants. It is estimated that turbine efficiency is being lowered by rotor blade erosion, adherence of scales to stator blades, and expansion of seal gaps. In the absence of records, however, it is difficult to ascertain the situation.

(3) Feed water heaters

Personnel at all plants had experienced replacement of tubes on feed water heaters. The Study Team was told that they manage the number of tubes plugged and make replacements when the number exceeds the permissible level, but did not see any such actual records. At the Pha Lai plant, personnel said that the tube interiors were washed with water (10 kg per cm^2), but were not cleaned with high-pressure water jets or other equipment for the purpose of efficiency recovery. The heaters do not undergo preventive maintenance; personnel cope by means of breakdown maintenance.

(4) Condensers

For condenser tubes, the Pha Lai II uses SUS304, and Uong Bi Unit 7, titanium tubes. The other units utilize aluminum brass tubes. At the Ninh Binh plant, a switch was made from aluminum brass to cupronickle tubes along with the increase in the number of plugged tubes. At the Pha Lai II and Uong Bi 7, which use SUS304 and titanium tubes, respectively, ball-type condenser washing units have been installed to wash the tubes every day. Neither plant, however, is managing the washing balls, which are becoming smaller due to wear. The Study Team was told that if they became smaller than the interstices of the screens for trapping them, they would automatically be sent outside the system. At the Ninh Binh plant, the tubes are cleaned with rubber brushes at the time of periodic inspection and when units are shut down every three months for repair. At the Uong Bi plant, the Study Team was told that the tubes for units 5 and 6 receive a backwashing when the degree of vacuum worsens, but that the cleaning otherwise is done with the use of rubber brushes at the time of periodic inspections at two- or four-year intervals. Personnel at the Pha Lai I said that the tubes were washed by rubber brush once every two years. While it is difficult to ascertain the performance of individual condensers in terms of specific numerical data because they are not managed on this basis, it is estimated that efficiency has dropped in almost all units due to grime in the tubes of condensers.

At both the Pha Lai and Uong Bi plants, the Study Team was told that personnel measure the amount of air suction and take a serious view of high levels of air suction. It was not possible, however, to check the suction spots, amounts, and other related items in the control records.

2.2.5 Analysis of the current status of other facilities

(1) Water quality monitoring instruments

In Vietnam, management of water quality basically centers around manual testing and analysis.

Although there was some variation among power plants in respect of the measurement time interval, all plants had prepared manuals for water quality management with clearly defined items and values. For this reason, it is thought that water quality is being maintained on a problem-free level. Nevertheless, silica meters and other instruments for water quality measurement cannot be effectively kept in continuous use without periodic inspection and replacement of parts. In fact, at the Uong Bi plant, there was a remark to the effect that water meters were not being put to extensive use because the maintenance required sophisticated knowledge and expertise. Similarly, at the Pha Lai II, the silica meter on the water treatment system was out of order and not in use. The Study Team was also told that the indication on the pH meter was unstable and differed from the value obtained through manual testing.

(2) Plant automation

The Pha Lai II plant is being automated in line with a design enabling automatic startup and shutdown. Nevertheless, the bad condition of the equipment has made it impossible to maintain the conditions for sequence progression. The crews on the floor manually assist automatic valves and initiate some equipment, such that the unit is actually started up by hand. The Uong Bi 7 also is designed for automatic startup and shutdown, but the on-site personnel said that the automatic procedure was not being applied due to software problems. The Study Team was not able to determine the particulars of these problems.

(3) Belt conveyor

Of the facilities for coal handling and conveyance, it was found that the belt conveyor outside the plant is equipped with a cover, but is not completely sealed at at least one plant. The conveyor is not installed with a unit for draining water. If coal is sent in with rain water still on the belt, the water may be expected to infiltrate the bunker, and this could cause a decrease in the temperature inside the pulverizer due to excessive moisture. Repairs are urgently required in this area.

Trouble on both systems would immediately impede the sending of coal. It is consequently necessary to manage belt wear and perform periodic maintenance for the conveyor.

(4) Bunker

In Ninh Binh power plant, because water may be anticipated to infiltrate the bunker in wet weather, it would be effective to install a line for drainage at the bottom of the bunker. The removal of moisture before input into the pulverizer could prevent a decline in the temperature inside the pulverizer.

2.3 Coal property analysis

2.3.1 Coal properties and combustion characteristics

(1) Coal types used

Table 2.3-1 shows a list of the types of Vietnam's anthracite coal. The major types of coal supplied to the three power plants fall under 4b to 5, which are non-washed coal with calorific values of 5,500 to 6,000 kcal/kg and ash content of around 30 %(screening only).

Table 2.3-1 List of the types of Vietnam's anthracite coal

No.	Name		Size (mm)	Ash Content		Moisture	VM	TS	HHV	
				Average (%)	Range (%)	Average (%)	Average (%)	(%)	(kcal/kg)	
1	Lump	2a	50-100	7.00	6.00 ~ 8.00	3.0	6	0.6	7800	Hi Grade Coal
2		2a	25-60	7.00	6.00 ~ 8.00	3.0	6	0.6	7800	
3		2b	50-100	9.00	8.01 ~ 10.00	3.5	6	0.6	7650	
4		2b	25-200	9.00	8.01 ~ 10.00	3.5	6	0.6	7650	
5		3a	35-50	4.00	3.01 ~ 5.00	3.0	6	0.6	8100	
6		4a	15-35	5.00	4.01 ~ 6.00	3.5	6	0.6	8000	
7		4b	15-35	9.00	6.01 ~ 12.00	3.5	6	0.6	7450	
8		5a	6-18	6.00	5.00 ~ 7.00	3.5	6	0.6	7900	
9		5b	6-18	7.00	6.00 ~ 8.00	4.0	6	0.6	7450	
1	Fine	1	0-15	7.00	6.00 ~ 8.00	8.0	6.5	0.6	7800	
2		2	0-15	9.00	8.01 ~ 10.00	8.0	6.5	0.6	7600	
3		2	1-10	8.50	8.01 ~ 10.00	8.0	6.5	0.6	7600	
4		2	1-6	8.50	8.01 ~ 10.00	8.0	6.5	0.6	7600	
5		2	1-5	9.00	8.01 ~ 10.00	8.0	6.5	0.6	7600	
6		2	1-15	9.00	8.01 ~ 10.00	8.0	6.5	0.6	7600	
7		3a	1-15	11.50	10.01 ~ 13.00	8.0	6.5	0.6	7350	
8		3b	1-15	14.00	13.01 ~ 15.00	8.0	6.5	0.6	7050	
9		3c	1-15	16.50	15.01 ~ 18.00	8.0	6.5	0.6	6850	
10		4a	1-15	20.00	18.01 ~ 22.00	8.0	6.5	0.6	6500	Low Grade Coal
11		4b	1-15	24.00	22.01 ~ 26.00	8.0	6.5	0.6	6050	
12		5	1-15	30.00	26.01 ~ 33.00	8.0	6.5	0.6	5500	
13		6a	1-15	36.00	33.01 ~ 40.00	8.0	6.5	0.6	4850	
14		6b	1-15	42.00	40.01 ~ 45.00	8.0	6.5	0.6	4400	

(2) Analysis items and sampling sites

Table 2.3-2 shows analysis items and sampling sites. Coal was sampled at stockyards or mill entrances. The sampling was also conducted at mill exits in order to measure the grain size distribution after pulverization in the mill. Furthermore, in order to understand coal ash properties, fly ash was sampled.

Table 2.3-2 Analysis items and sampling sites

	Coal Sample					Fly Ash Sample			
	Proximate Analysis	Ultimate Analysis	Total Sulfur	Calorific Value	Size Distribution	Ash Content	Ignition Loss	Fusion Temp	Major Element
Ninh Binh	Stock Yard				Mill Outlet	FA Pond			
Pha Lai	Mill Inlet (No.1)				(Using FA Sample)	FA Silo (No.1)			
Uong Bi	Mill Inlet (300MW)				Mill Outlet (300MW+110MW)	FA Silo (300MW+110MW)			

(3) Analysis results

Table 2.3-3 shows results of the coal analysis (excluding the grain size distribution), and Table 2.3-4 shows results of the fly ash analysis.

Table 2.3-3 Results of coal analysis

			Ninh Binh	Pha Lai-1	Uong Bi-300MW
Proximate Analysisi	Inherent Moisture	a.d. %	1.75	2.02	1.64
	Ash Content	a.d. %	27.12	30.48	29.86
	Volatile Matter	a.d. %	6.63	5.77	3.88
	Fixed Carbon	a.d. %	66.25	63.75	66.26
Fuel Ratio			10.0	11.0	17.1
Ultimate Analysisi	Ash Content	d.b.%	27.60	31.11	30.35
	C	d.b.%	66.91	64.62	66.25
		d.a.f.%	92.42	93.80	95.12
	H	d.b.%	2.28	1.92	1.28
	N	d.b.%	0.89	0.79	0.61
	O	d.b.%	2.50	2.25	1.25
	S	d.b.%	0.60	0.52	0.78
Total Sulfur	S	a.d. %	0.63	0.56	1.26
Calorific Value	HHV	a.d. %	6020	5570	5390

Table 2.3-4 Results of fly ash analysis

			Ninh Binh	Pha Lai-1	Uong Bi	
					300MW	110MW
Proximate Analysis	IM	a.d. %	15.5	0.3	0.2	0.2
	Ash	a.d. %	74.0	84.6	94.5	61.3
Loss on Ignition		d.b. %	12.43	15.16	5.27	38.58
Ash Fusion Temp(Oxidization)	Deformation		1470	1410	1420	
	Hemisphere		>1500	>1500	1490	
	Flow		>1500	>1500	1500	
Major Element	SiO2		60.05	57.85	55.35	
	Al2O3		22.37	24.52	24.67	
	TiO2		0.79	0.79	0.71	
	Fe2O3		5.91	6.30	10.84	
	CaO		0.60	0.90	0.80	
	MgO		1.18	1.03	1.03	
	Na2O		0.18	0.32	0.11	
	K2O		4.60	3.92	3.52	
	P2O5		0.14	0.19	0.18	
	MnO		0.05	0.05	0.10	
	V2O5		0.03	0.03	0.03	
	SO3		0.05	0.05	1.04	

(4) General physical and chemical relationships between the coal rank and coal properties

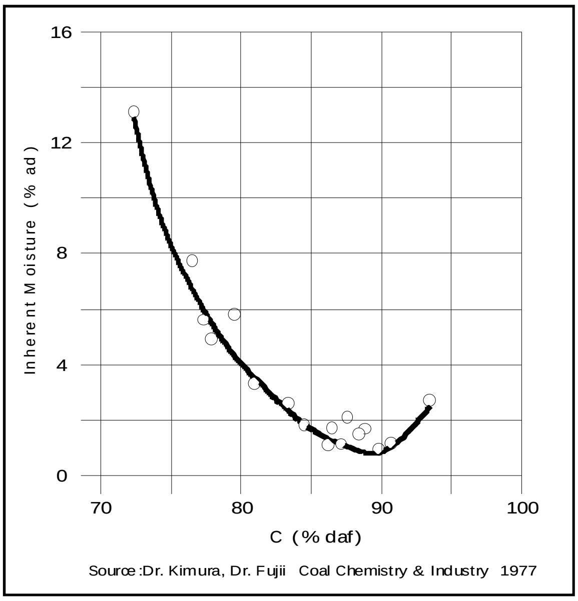
The ignitability of the coal consumed at the three power plants reaches 10.0 to 17.1%, indicating the coal being anthracite with a higher coal rank. When using the organic carbon percentage (% C) (d.a.f. – dry ash-free basis) as an indicator showing the coal rank, successive changes are observed in the general physical and chemical characteristics of coal according to the increase and decrease in % C.

1) Moisture

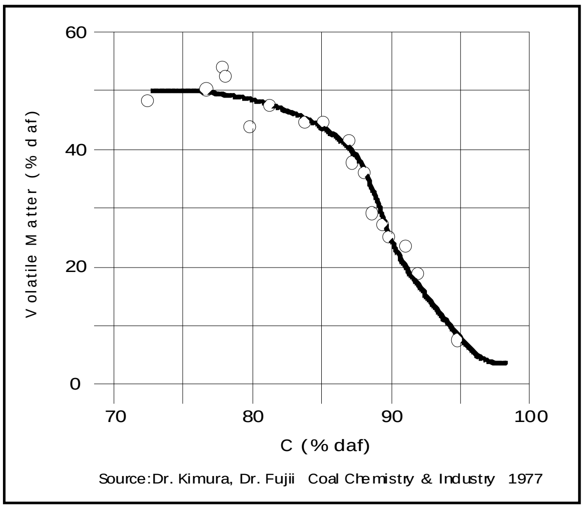
Figure 2.3-1 shows the general relationship between % C and moisture. As % C drops (as the coal rank lowers), moisture rises steeply. After showing the minimum value of approximately 1%at 90%C, moisture increases again.

2) Volatile matter

Figure 2.3-2 shows the general relationship between % C and volatile matter. Volatile matter decreases according to the increase in % C.



Source :Dr. Kimura, Dr. Fujii Coal Chemistry & Industry 1977



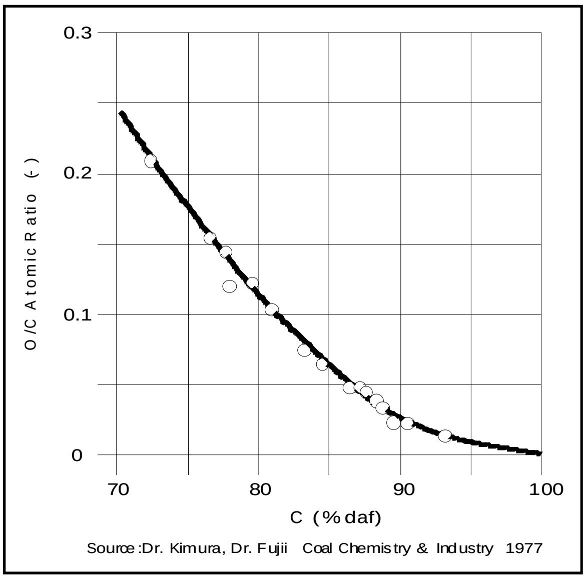
Source:Dr. Kimura, Dr. Fujii Coal Chemistry & Industry 1977

Figure 2.3-1 C% vs IM

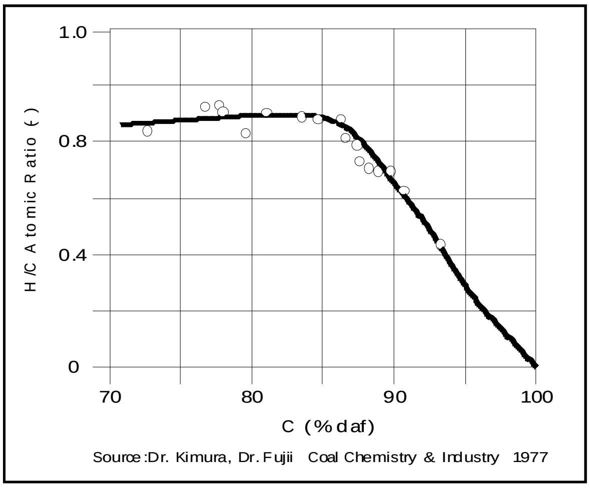
Figure 2.3-2 C% vs VM

3) O/C atomic number ratio, H/C atomic number ratio

Figure 2.3-3 shows the general relationship between % C and the O/C atomic number ratio, and Figure 2.3-4 shows the general relationship between % C and the H/C atomic number ratio.



Source :Dr. Kimura, Dr. Fujii Coal Chemistry & Industry 1977



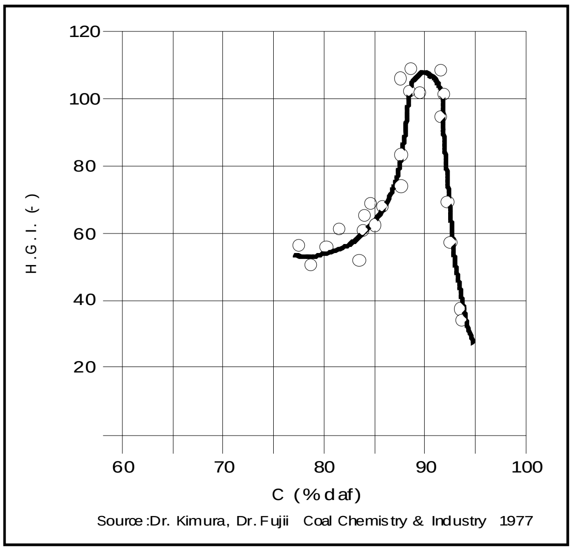
Source :Dr. Kimura, Dr. Fujii Coal Chemistry & Industry 1977

Figure 2.3-3 C% vs IM

Figure 2.3-4 C% vs VM

4) HGI

Figure 2.3-5 shows the general relationship between % C and HGI. There is a local maximum value of HGI at 90 % C, and HGI steeply decreases when % C increases further.



Source :Dr. Kimura, Dr. Fujii Coal Chemistry & Industry 1977

Figure 2.3-5 C% vs HGI

(5) Combustion characteristics

1) Comparison with steam coal in Japan

We would like to evaluate the combustion characteristics of Vietnam's anthracite by comparing the obtained analysis values of the coal in the three power plants in Vietnam with the analysis values of the imported coal used at power plants in Japan. The analysis values used for the comparison are the values of imported coal used in Japanese power plants, based on the survey conducted by NEDO in the fiscal year 2005 (a total of 56 coal types: one from Vietnam, 29 from Australia, 19 from Indonesia and 7 from Russia). Table 2.3-5 shows analysis values of the imported coal.

Table 2.3-5 Analysis values of imported coal

	Proximate anal.				HHV	Ultimate anal.						Total Sulphur	HGI
	IM	Ash	VM	FC		Ash	C	H	N	S	O		
	wt%	wt%	wt%	wt%	kcal/kg	wt%	wt%	wt%	wt%	wt%	wt%	wt%	-
	a.d.	a.d.	a.d.	a.d.	a.d.	d.b.	d.b.	d.b.	d.b.	d.b.	d.b.	a.d	
Nhin Binh	1.75	27.12	6.63	66.25	6020	27.60	66.91	2.28	0.89	0.60	2.50	0.63	
Pha Lai-1	2.02	30.48	5.77	63.75	5570	31.11	64.62	1.92	0.79	0.52	2.25	0.56	
Uong Bi-300	1.64	29.86	3.88	66.26	5390	30.35	66.25	1.28	0.61	0.78	1.25	1.26	
Other Vietnam	1.41	4.55	6.41	87.60	8050	4.61	89.15	3.21	1.04	0.53	1.46	0.58	32
Vietnam Average	1.71	23.00	5.67	70.97	6258	23.42	71.73	2.17	0.83	0.61	1.87	0.76	32
Australia Average	2.72	12.15	29.93	55.07	6948	11.95	72.86	4.62	1.60	0.41	7.85	0.46	53
Indonesia Average	8.13	5.35	41.49	45.02	6632	5.77	71.94	5.30	1.39	0.48	15.12	0.58	43
Russia Average	3.52	11.01	33.01	52.46	6964	11.40	71.79	4.66	1.97	0.31	9.87	0.37	48
Whole Average	4.64	9.57	33.82	51.92	6862	9.66	72.71	4.83	1.56	0.43	10.46	0.49	49

2) Combustion process of coal

Coal particles burn with the following process:

- Temperature rise of coal particles: The rate of temperature rise is very fast. A 60 µm particle reaches the furnace temperature (over 1700 degrees C) within 0.05 to 0.1 seconds.
- Emission of volatile matter: Emitted at a rate almost the same as the abovementioned.
- Combustion of volatile matter: Oxygen around a particle is instantaneously consumed the moment the emitted gas ignites. At this point, the volatile matter burns independently of char.
- Combustion of char: The rate of combustion is 0.3 to 1 second or longer and the combustion accounts for the majority of time required for the overall combustion process.

For proper combustion to take place, the temperature of the whole gas needs to be high enough so that it can ignite char using the amount of heat produced by the combustion of volatile matter. In the case of coal that has a small amount of volatile matter such as Vietnamese coal, the amount of heat emitted from the combustion of volatile matter may not be sufficient for the char temperature to rise to its ignition temperature. In this case, measures such as supply of supporting fuel, micronization of coal grain, and a higher residual heat temperature of burning air are required.
The following properties can be listed as parameters that characterize the combustion of coal.

- Content and composition of volatile matter
- Char reactivity

The amount of char produced is linked to the amount of fixed carbon, etc. Indicators that relate to the above-mentioned two parameters include ignitability (fixed carbon/volatile matter). Ignitability shows the relative percentage of char to volatile matter.

3) Inherent moisture

Figure 2.3-6 shows the relationship between % C and inherent moisture. Most of Vietnamese coal has low inherent moisture of around 2 %. In the case of the total moisture content including adherent moisture, proper criteria in power plants in Japan is 10 % or lower.

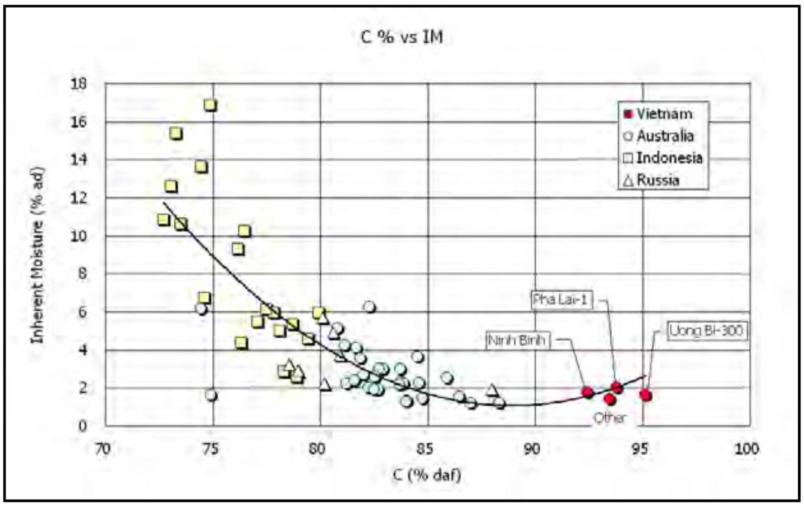


Figure 2.3-6 C% vs moisture

4) Ash and calorific value

Ash impacts ignition stability. Mineral matter contained in coals transforms into ash as a result of heat absorption reaction, which removes heat generated by organic coal matter. This lowers the ignition quality of coal particles that contain a large amount of mineral matter. Coupled with the decreased calorific value resulting from the increase in mineral matter, the amount of unburnt carbon in ash could increase.

Figure 2.3-7 shows ash content and calorific value. Values set as appropriate criteria in Japanese power plants are; ash shall be less than or equal to 20 %and calorific value shall be greater or equal to 6,000 kcal/kg. On the other hand, Vietnamese coal has a higher ash content of approximately 30 and generates lower heat of 5,500 to 6,000 kcal/kg (ad – air dried)

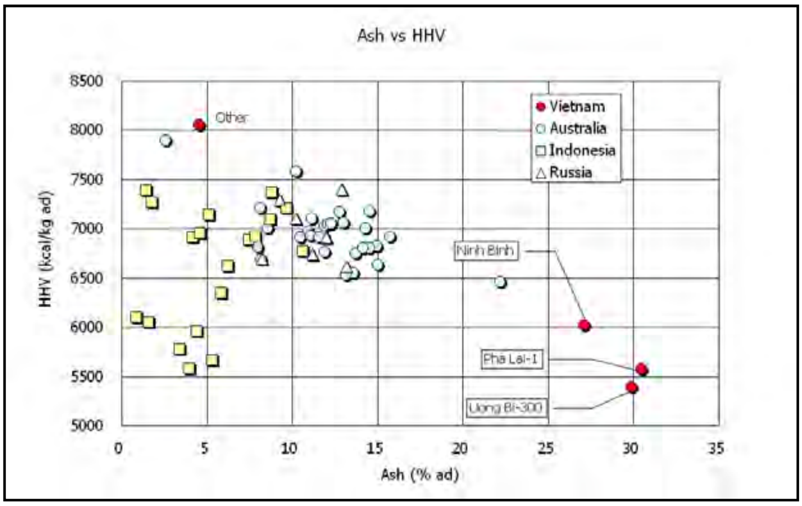


Figure 2.3-7 Ash vs calorific value

5) Volatile matter

Figure 2.3-8 shows the volatile matter content. Volatile matter in Vietnamese coal (d.a.f) is less than 10 %, with 5.66 % in the Uong Bi 300 MW power plant and 9.32 % in Ninh Binh. Volatile matter content characterizes the ignition characteristics and the post-ignition flame stability of coal particles. Ignition stability is the most important characteristic at the time of the combustion of pulverized coal. Coal with higher volatile matter content provides stable ignition and higher flame density, resulting in less unburnt carbon in ash.

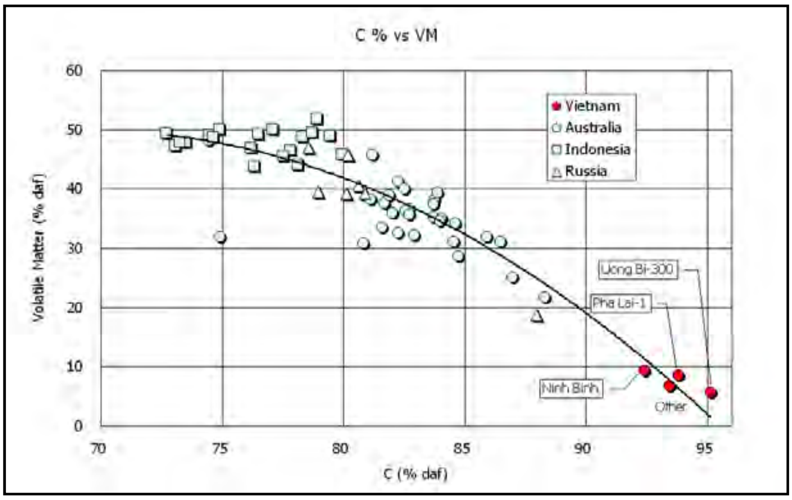


Figure 2.3-8 C% vs volatile matter content

6) Fuel ratio

Figure 2.3-9 shows ignitability. The ignitability of Vietnamese coal is remarkably high, with 10.0 in Ninh Binh and 17.1 in the 300 MW Uong Bi power plant. Higher ignitability raises ignition temperature and slows combustion speed. In order to completely burn this type of coal, the coal needs to stay longer in the boiler, requiring larger furnace capacity. Compared to the appropriate ignitability criteria for Japanese power plants which is less than or equal to 2.5, the ignitability of Vietnamese coal largely deviates from this criteria.

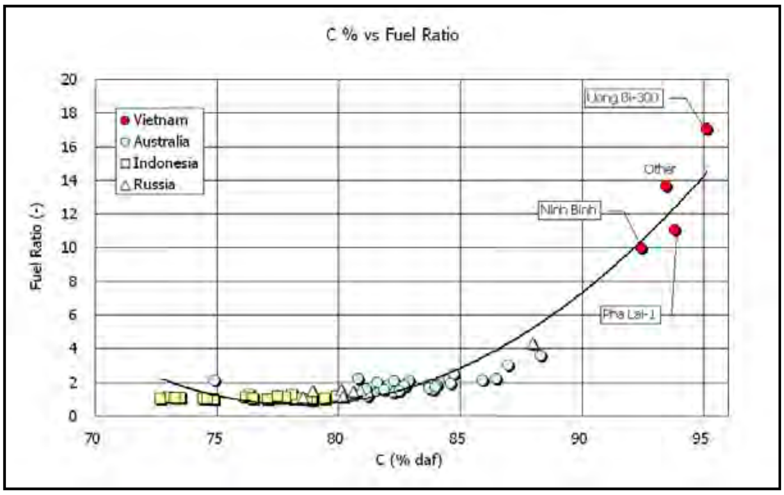


Figure 2.3-9 C% vs ignitability

7) Unburnt carbon in ash

Figure 2.3-10 shows unburnt carbon content in ash. Unburnt carbon content in ash in Vietnamese coal with low volatile matter content and high ignitability reaches as high as 38.58 % in the 110 MW Uong Bi plant, with the 300 MW Uong Bi plant at the lowest rate of 5.27 %, followed by 12.43 % in Ninh Binh and 15.16 % in Pha Lai-1.

Unburnt carbon content in coal that is commonly and effectively used in Japan is 5 % or lower. Ash containing a higher amount of unburnt carbon affects effective utilization of energy spent within facilities for power of coal transport, pulverization, etc. It not only increases the amount of ash that needs to be handled due to the portion of unburnt carbon, but also impedes the way to the effective utilization of ash.

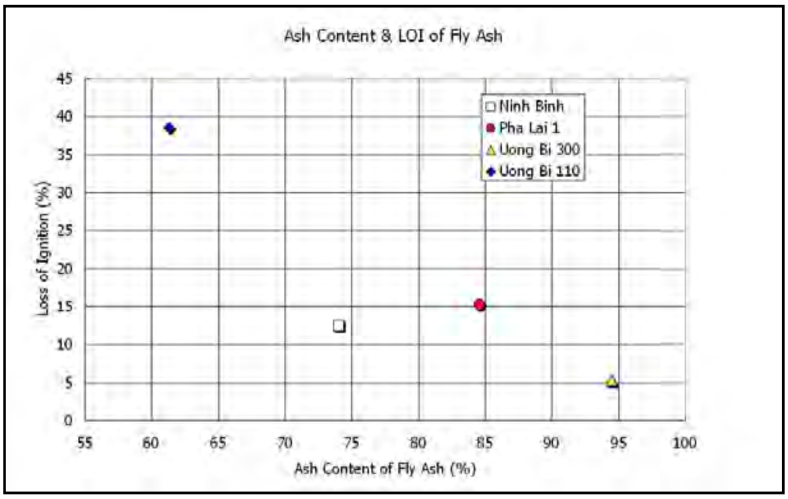


Figure 2.3-10 Unburnt carbon in ash

8) Grain size of mill pulverization

One way to increase the combustion speed of coal particles and reduce unburnt carbon content is the micronization of fuels. Therefore, the grain size distribution of the pulverized coal that exited mills was measured immediately before it is blown into a burner, the results of which are shown in Figure 2.3-11. For the Pha Lai-1 plant, due to the difficulty in conducting sampling, the grain size distribution of the fly ash after combustion was measured.

Table 2.3-6 shows the appropriate values of volatile matter content and pulverized grain size. The amount of particles passed through a 75 µm sieve was 82 % for the volatile matter content (d.a.f) of 9.32 % in Ninh Binh, and 96 % for the volatile matter content (d.a.f) of 5.66 % in the Uong Bi 300 MW plant. Since the results in both plants meet the appropriate values, EVN is considered to have established a technology to control the grain size of pulverized coal. Apart from the importance of the amount of the passage of the grain sized 75µm, the existence of coarse particles with the size of 0.1 mm and 0.2 mm also has significant impacts on unburnt carbon content. The presence of these coarse particles also contributes to the occurrence of slugging.

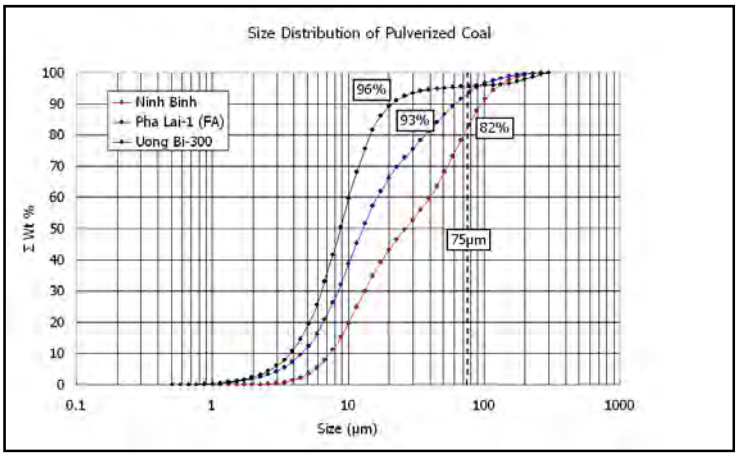


Figure 2.3-11 Grain size structure of pulverized coal

Table 2.3-6 Appropriate values of volatile matter and amount of particles passed through a 75 μm sieve

Volatile Matter (daf)	< 10	10 - 20	20 - 25	> 25
Below 75 μm	85%	80%	75%	70%

9) Clinker trouble

From the standpoint of efficient use of coal, deposition of coal ash is the most important issue in terms of operation of boilers. A high amount of ash deposition causes the following problem with boilers.

- Poor heat transmission: Ash adheres to and accumulates on heat transmission tubes or side walls of boilers, lowering boiler efficiency.
- Impeded gas flow: Gas passage is partially clogged with adhered and accumulated ash.
- Damage to pressure components: Adhered and accumulated ash come off and fall into a furnace, damaging transmission tubes, etc.
- Abrasion of pressure components: Abrasion caused by abrasive substance in ash.

As an indicator to assess the possibility of the occurrence of clinker trouble, a slugging index and fouling index are shown in Figure 2.3-12, and ash fusion temperature is shown in Figure 2.3-13. Samples whose ash fusion temperature is 1,500 degrees C or above are also plotted on the 1,500 degrees C scale. These values for Vietnamese coal are as follows:

- Slugging: Around 0.1- 0.3
- Fouling: Around 0.1
- Ash fusion temperature: 1,500 degrees C or above

Compared to the indicators shown above, the evaluation criteria set for Japanese power plants is shown in Table 2.3-7. The table indicates that the possibility of clinker trouble in Vietnamese coal is low. However, there was a report from the site of the Uong Bi-300 MW plant that it is suffering from clinker trouble.

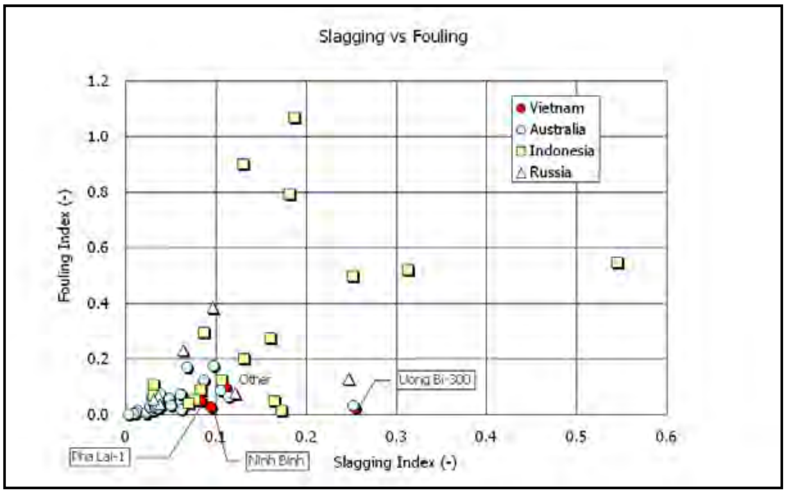


Figure 2.3-12 Slagging vs fouling

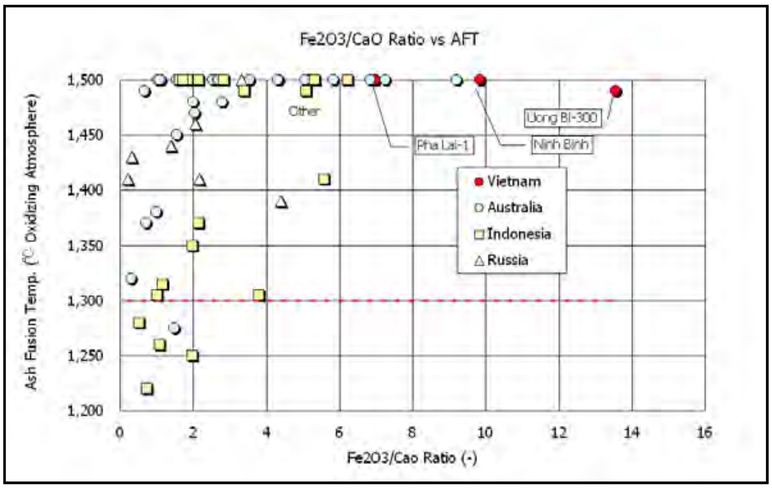


Figure 2.3-13 Ash fusion temperature

Table 2.3-7 Clinker trouble evaluation criteria in Japan

	Slagging			Fouling			Ash Fusion Temp (℃)		
Small		Slagging Index	≦ 0.6		Fouling Index	≦ 0.2	1280 ≦	Flow Point	
Medium	0.6 <		≦ 2.0	0.2 <		≦ 0.5			
Big	2.0 <			0.5 <		≦ 1.0			< 1280
No-acceptable				1.0 <					

10) Conclusion

Coal of these three power plants is characterized by its high ignitability of 10.0 to 17.1 % (d.a.f.) which is often seen in anthracite. As a result, its combustion speed is low and a large amount of unburnt carbon is produced in ash. In the Uong Bi-110 MW plant, in particular, the unburnt carbon of nearly 40 % is contained in fly ash.

A plant that collects the unburnt carbon in ash is located adjacent to the Pha Lai power plant and is currently in operation. The plant collects unburnt carbon by using a flotation (a technology widely used for concentration and coal preparation, through which coal and ash are separated by using the characteristics of their particle surface—coal is lipophilic and ash is lipophobic).

Ash content in coal is high at around 30 %. There is also a report from the site that the percentage was lower in the past. Because the transformation of mineral matter into ash is due to a heat absorption reaction, the thermal energy from organic coal matter is not effectively used. The transformation could also cause lower ignitability of coal particles and an increase in unburnt carbon in ash. It is basically a waste of energy to carry unnecessary mineral matter from coal mines to power plants, incinerate it into ash by consuming power in facilities and transport and dispose of a large amount of ash that contains unburnt carbon. It is certain that underground mining will increase in the future and therefore the deterioration in the quality of coal in terms of coal ash content is inevitable. Reduction of coal ash is proposed in Section 3.3.

2.3.2 Flow of coal and its impacts on coal quality (coal mines – screening process, etc. - shipment – coal feeding bunker at power plants)

The presence of the impacts of coal flow (mixing of rain water, etc.) on coal quality was investigated throughout the process in which coal is mined from coal mines, screened, shipped and arrives at coal feeding bunkers.

(1) Coalfield

Figure 2.3-14 shows locations of coal fields. Anthracite consumed in the three power plants is mined at the Quang Ninh coal field. This coalfield is divided into three main districts of Uong Bi district, Hon Gai district and Cam Pha district.

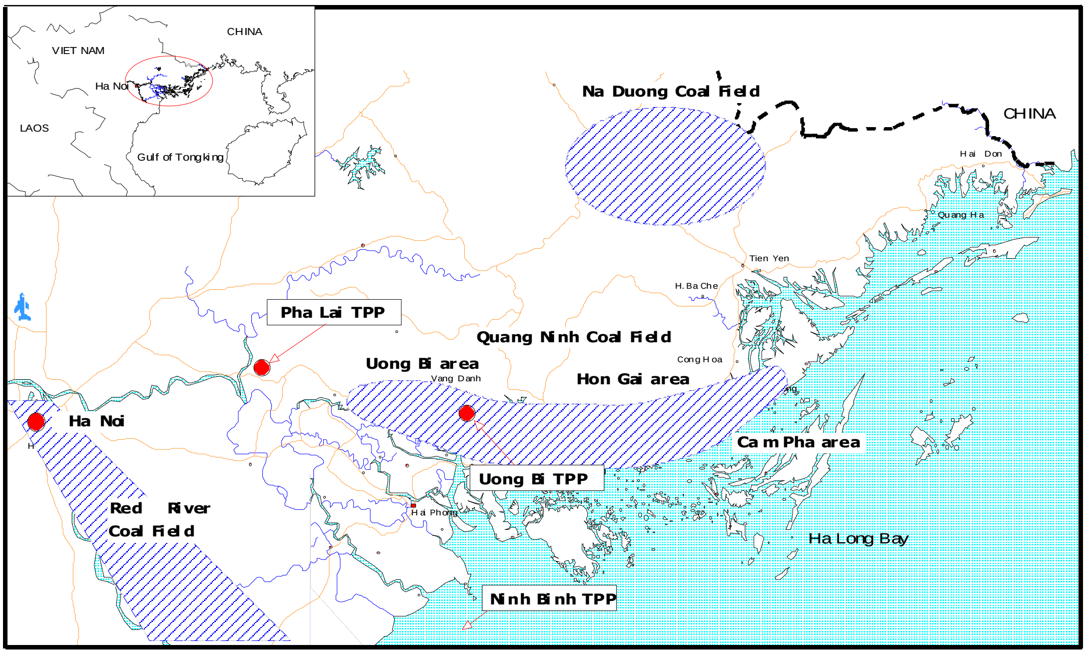


Figure 2.3-14 Locations of coalfields

(2) Coal mine

At present, about 20 coal companies under Vietnam National Coal-Mineral Industry Group (VINACOMIN) produce about 45 million tons of coal (raw coal) annually, about 40% of which is produced by underground mining and about 60% of which is produced by open cut mining. In the future, as mining sites become deeper and as environmental restrictions become more rigid, open cut mining will decrease and underground mining will increase instead. This indicates further deterioration in the quality of mined coal in terms of ash content and calorific value.

Figure 2.3-15 Uong Bi district underground coal mine

Figure 2.3-16 Cam Pha district open cut coal mine

(3) Screening processing

Mined coal is transported to screening facilities by rail, belt conveyor and truck for screening processing. There are two types of screening facilities, one is a simple facility (Figure 2.3-17) adjacent to a coal mine, and the other is a large-scale facility installed at a coal preparation plant (Figure 2.3-18). Coal with the size of 15 mm or smaller that were screened at the facility is shipped to power plants.

Figure 2.3-17 Simple facility

Figure 2.3-18 Coal preparation plant with a screening facility

(4) Shipment

Coal is shipped to the Ninh Binh power plant by ship, to the Pha Lai power plant by ship and rail, and to the Uong Bi power plant by rail (an exclusive guideway). In order to increase transport capacity, double tracking of this exclusive guideway is currently underway. Figure 2.3-19 and Figure 2.3-20 show the loading of coal.

Figure 2.3-19 Loading the ship

Figure 2.3-20 Loading the freight car

(5) Unloading

Figure 2.3-21 and Figure 2.3-22 show unloading, Figure 2.3-23 shows a new unloading facility at the Pha Lai plant and Figure 2.3-24 shows the barge waiting for unloading at the Pha Lai power plant. The barge's load capacity is 800 tons. The coal is cured with vinyl sheets until the start of unloading in order to prevent the increase of coal moisture.

Figure 2.3-21 Unloading (Ninh Binh)

Figure 2.3-22 Unloading (Pha Lai)

Figure 2.3-23 New unloading facility (Pha Lai)

Figure 2.3-24 Barge waiting for unloading (Pha Lai)

(6) Storage and loading of coal

All of the three power plants have indoor coal storage. In particular, both the Pha Lai and Uong Bi power plants have excellent coal storage facilities. When storing coal, coal is loaded in the longitudinal direction of the storage facility, and at the time of loading, coal is loaded perpendicular to the loaded direction so that coal quality is homogenized. Also, the belt conveyor from the coal storage to the coal feeding bunker is covered, providing full protection against rain fall. Photos 2.5-11 to 2.5-13 show the stockyards, and Photo 2.5-14 shows the belt conveyor.

Figure 2.3-25 Stockyard (Pha Lai)

Figure 2.3-26 Stockyard (Uong Bi)

Figure 2.3-27 Stockyard (Uong Bi)

Figure 2.3-28 Stocked coal loading BC (Uong Bi)

(7) Conclusion

Coal which merely completed the screening process with a 15-mm sieve is supplied to the three power plants. Although the grain size is controlled, the quality such as ash content and the calorific value are not controlled. (The coal with the size of 15 mm or larger is separated by gravity separation and shipped for export, domestic cement production, etc. as high-quality coal with low ash content).

As mining areas become deeper and as environmental restrictions become more rigid, the percentage of underground mining will increase in the future, which inevitably deteriorates and fluctuates the quality of mined coal. The control of coal grade, or achieving low ash content and reducing fluctuations are considered to become necessary in the medium and long term perspectives.

During the monsoon season, there are heavy squalls in Vietnam. To protect coal against heavy rains, all possible measures are taken for the coal loaded on barges, stockyards at power plants and for belt conveyors reaching to coal feeding bunkers.

2.4 Power development plans

2.4.1 Outlook for the domestic energy demand

In Vietnam, domestic consumption of energy is expanding along with the country's economic growth in recent years. Although there was a temporary drop due to the influence of the Asian currency and financial crisis in 1997, energy consumption continues to increase as industrialization and motorization progress.

This expansion trend is expected to continue toward the future. In its sector-specific outlook for energy demand (Table 2.4-1 and Figure 2.4-1), the Institute of Energy (IE) is predicting that, relative to the 2005 level, energy consumption will be 3.4 times as large in 2030 and 7.4 times as large in 2050

The average annual rate of increase in energy consumption from 2010 to 2030 is predicted to be 5.0 % overall. By sector, the rate will be 2.5 % in the agricultural sector, 6.0 % in the industrial sector, 5.0 % in the transport sector, 7.0 % in the commercial and service sector, and 3.9 % in the residential sector.

Table 2.4-1 Energy Demand by sector upto 2050 (unit: million TOE)

Year	**2005**	**2010**	**2020**	**2030**	**2040**	**2050**
(1) Agriculture	579	692	898	1,142	1,308	1,476
(2) Industry	11,834	15,323	31,307	49,154	82,958	123,032
Light industry	6,435	6,172	14,350	27,606	48,640	72,496
Heavy industry	5,399	9,151	16,957	21,549	34,318	50,536
(3) Transport	6,970	10,673	20,200	28,058	43,266	62,694
(4) Commerce & service	1,568	2,681	6,119	10,454	16,464	25,277
(5) Resident	15,585	18,214	26,453	38,893	48,023	64,670
Urban	1,146	2,009	6,015	12,989	18,773	29,241
Rural	14,439	16,205	20,438	25,904	29,250	35,429
(6) Non-commerce	1,025	1,433	1,507	1,584	1,665	1,750
Total	**37,561**	**49,015**	**86,485**	**129,286**	**193,683**	**278,899**

Source: CO_2 emissions reduction potential in Vietnam, IE - January 2011

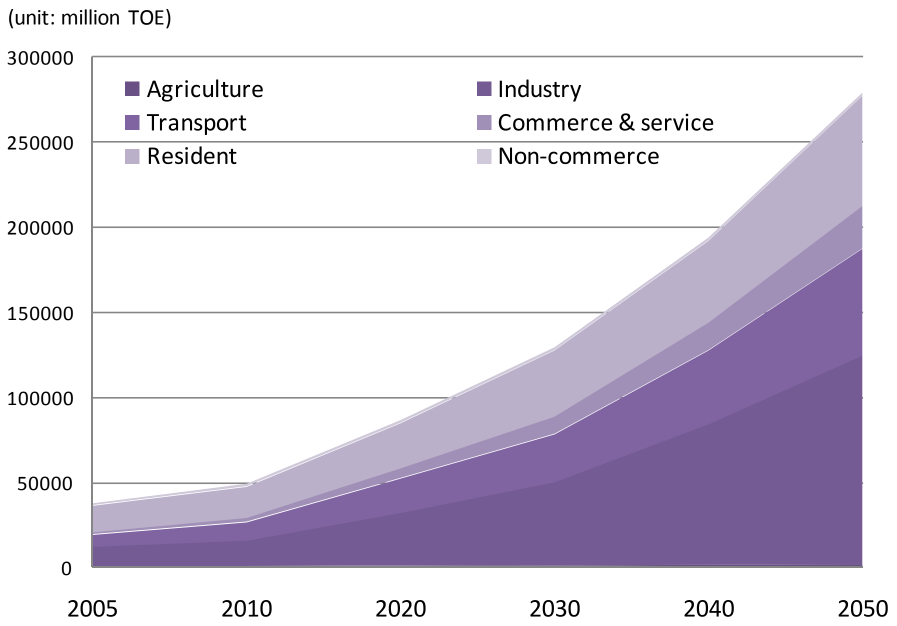


Figure 2.4-1 Energy demand by sector upto 2050 (unit:million TOE)

Figure 2.4-2 shows the breakdown of energy consumption by sector. The residential sector had the highest share (42 %) of the total in 2005. The share of the industrial sector is expected to rapidly expand and account for 38 % of the total in 2030.

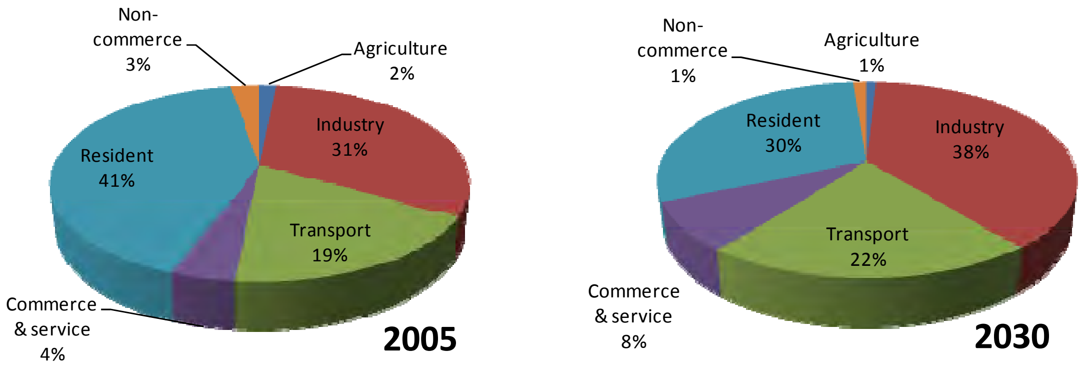


Figure 2.4-2 Composition of energy demand by sector in 2005 and 2030

2.4.2 Outlook for CO_2 emissions in Vietnam

According to the estimates made by the IE, CO_2 emissions in Vietnam as a whole came to about 76 million tons in 2005, and will reach 388.8 million tons or about five times as much in 2030. The industrial, transport, and power sectors account for the majority of these emissions.

Table 2.4-2 Estimate of CO_2 emissions from sectors in Vietnam (unit: 1000 tons)

Year	2005	2010	2015	2020	2025	2030
Industry	24,755	35,598	48,127	64,336	70,631	91,524
Agriculture	1,386	1,479	1,758	2,084	2,437	2,914
Transport	18,969	30,884	43,839	62,594	86,311	124,370
Commerce and service	4,354	6,002	8,067	9,832	12,141	14,597
Residential	4,861	5,767	6,414	7,823	9,285	9,943
Power sector	21,527	39,792	63,107	73,449	94,760	145,484
Total	**75,852**	**119,522**	**171,312**	**220,118**	**275,565**	**388,832**

Source: The study on CO_2 reduction potential in energy activities in Vietnam, Institute of Energy in 2005

2.4.3 Outlook for power supply and demand

Vietnam’s Ministry of Industry and Trade (MOIT) and the IE are formulating the seventh master plan for power source development to meet the rapidly growing demand. As of May 2011, the plan was being examined by the government. The IE draft envisions a sharp increase in the power demand. Relative to 2010, the 2030 demand is forecast to increase by seven times, and the generated output and peak power will also increase by 6.9 times (Table 2.4-3 and Figure 2.4-3).

The average annual rates of increase in various forecast items over the targeted period (2010 to 2030) are all around 10 % (Table 2.4-4). The increase rates at five-year intervals are particularly higher (over 10 %) in the first ten years. This outlook points to the need for fast-paced development of power sources.

Table 2.4-3 Electrical demand forecast for the whole country to 2030

	2010	2015	2020	2025	2030
Demand(GWh)	87,665	169,821	289,882	430,867	615,205
Generation(GWh)	100,880	194,304	329,412	489,621	695,147
Pmax(MW)	16,048	30,803	52,040	77,084	110,215

Source: First Draft of PDP VII (IE)

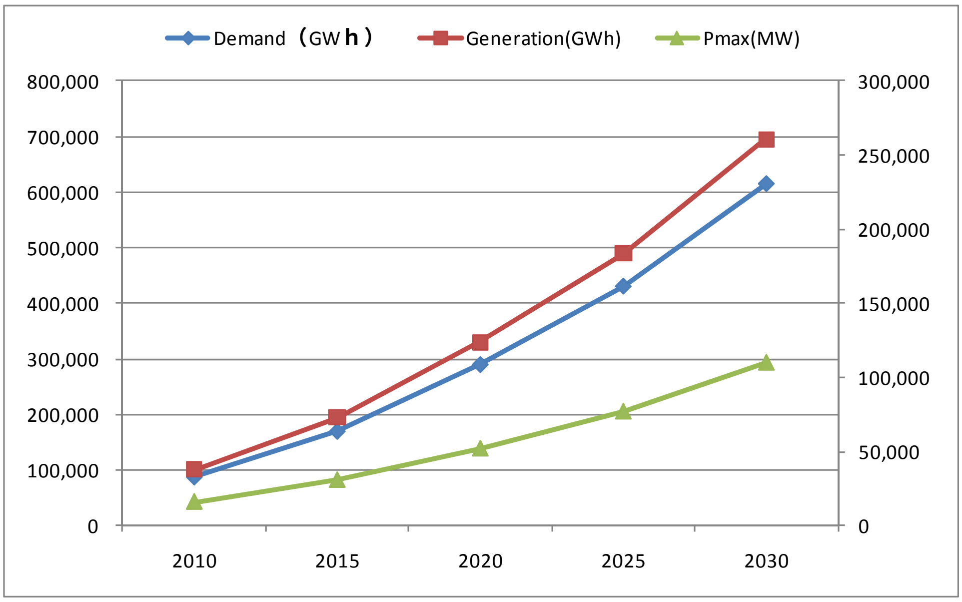


Figure 2.4-3 Electrical demand forecast for the whole country to 2030

Table 2.4-4 Annual average growth rate of demand forecast

	2010–2015	2015–2020	2020–2025	2025–2030	2010–2030
Demand(GWh)	14.1%	11.3%	8.2%	7.4%	10.2%
Generation(GWh)	14.0%	11.1%	8.2%	7.3%	10.1%
Pmax(MW)	13.9%	11.1%	8.2%	7.4%	10.1%

Source: First Draft of PDP VII (IE)

2.4.4 Generation plans

(1) Results of the sixth national power source development plan (PDP6)

Table 2.4-5 and Figure 2.4-4 show the actual installed capacity and peak demand for the period from 2006 to 2010. The reserve rate (Installed capacity/Peak Demand-1) is predicted to reach 31.9 % in 2010, but the output sometimes declines by about 200 MW during the drought season at the Hoa Binh hydroelectric power plant (1,920 MW) located in the northern part of the country (according to the JICA report published in 2006). The actual reserve rate is therefore below 20 %, leading to a tight electricity situation.

Table 2.4-5 Actual Installed capacity and Peak Demand (2006-2010)

Year	2006	2007	2008	2009	2010 (estimate)
Capacity	12,270	13,513	15,697	18,201	21,163
Peak Demand	10,187	11,286	12,636	13,867	16,048
Reserve	20.4%	19.7%	24.2%	31.3%	31.9%

Source: IE

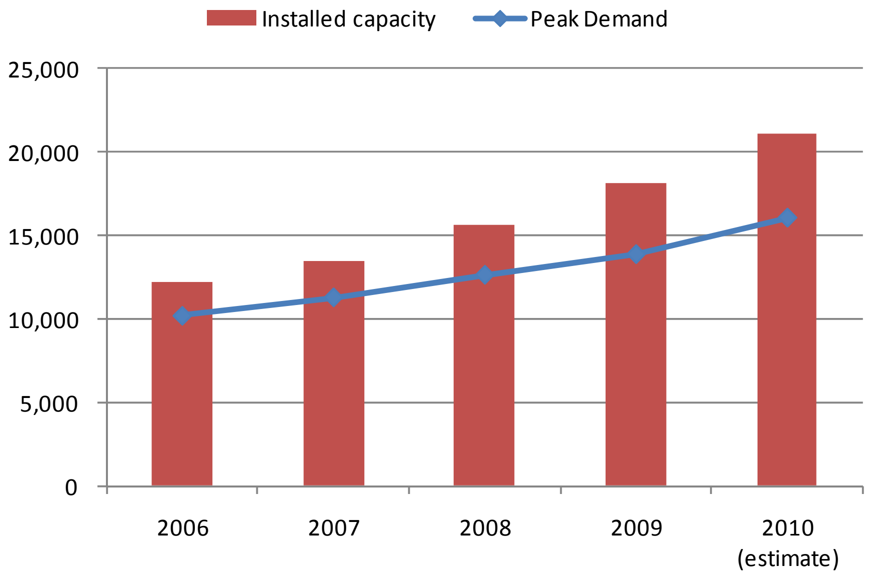


Figure 2.4-4 Actual Installed capacity and Peak Demand (2006-2010)

The PDP6 is formulated in consideration of the actual output from hydroelectric power generation during the drought season, but the construction of power generation plants has been obviously delayed. It was planned to develop 14,581 MW power generation facilities during the period from 2006 to 2010, but actually only about 60 % of the capacity, namely 9,055 MW will be developed (Table 2.4-6).

The delay in the power source development is a major factor that contributes to the tight electricity situation, and it is urgently required to develop coal-fired power generation facilities as a base power source with stable output.

Table 2.4-6 The Comparison of the Power Outputs between the Power Generation Plan in 2006 to 2010 on PDP6 and the Actual Implementation

Year	2006	2007	2008	2009	2010	Total
Approval on PDP6 (MW)	861	2,096	3,271	3,393	4,960	14,581
Actual implementation (MW)	756	1,297	2,251	1,789	2,962	9,055
Ratio of actual implementation	88%	62%	69%	53%	60%	62%

Source: Review of Implementation of Power Development Plan VI (IE)

(2) Seventh national power source development plan (PDP7)

Table 2.4-7 presents forecast figures for generated output and generation facility capacity described in the draft PDP7. The availability rates in this table are based on these forecast figures. Overall, the rates are in the range of 50 to 60 %. By type of fuel, coal-fired power generation, which is expected to act as a base source, is anticipated to have the second highest availability rate following the nuclear power generation (in 2030).

The reserve rate in 2030 is predicted to be 24.3 % and is lower than the present rate of about 30 %. The development of coal-fired power, however, will cause the rate of hydroelectric power to decrease, and the reserve rate is expected to be over 20 % even during the dry season.

Table 2.4-7 Power development plan in PDP-VII (Draft July 2010)

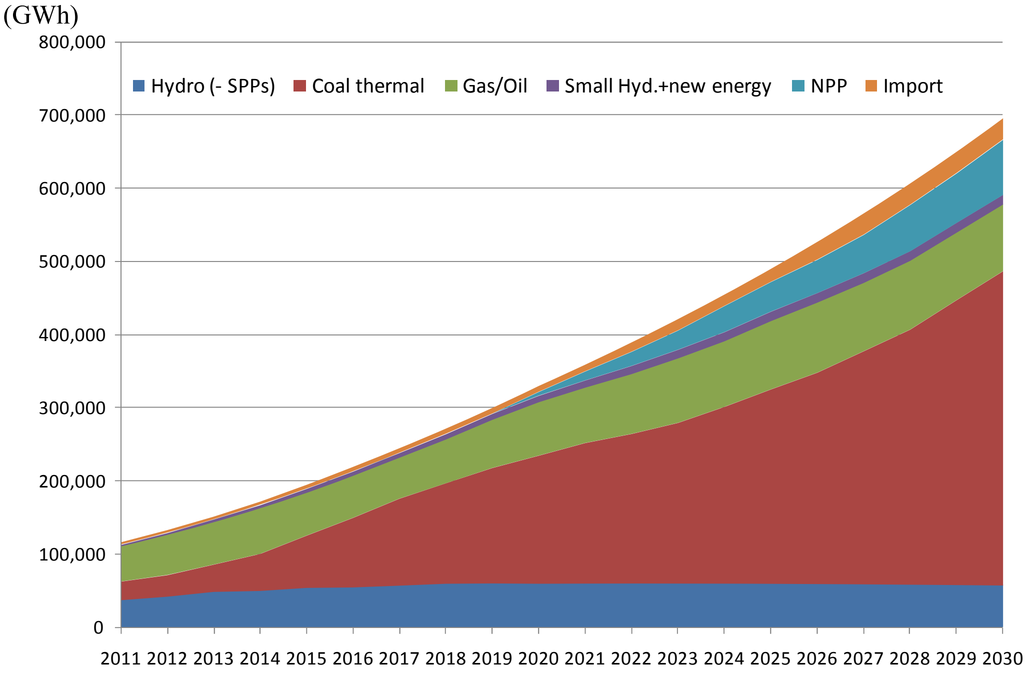
Year		2011	2015	2020	2025	2030
Generation (GWh)	**Total**	**115,777**	**194,303**	**329,412**	**489,621**	**695,147**
	Hydro (- SPPs)	37,553	54,381	59,989	59,833	57,572
	Coal thermal	25,172	71,055	174,615	265,248	428,695
	Gas/Oil	48,420	58,683	73,177	93,512	91,528
	Small Hyd.+new energy	1,970	5,325	8,894	12,976	13,343
	NPP	0	0	4,879	40,197	75,235
	Import	2,662	4,860	7,858	17,856	28,775
Peak Load (MW)		**18,406**	**30,803**	**52,040**	**77,084**	**110,215**
Capacity (MW)		**24,607**	**43,132**	**70,115**	**98,010**	**137,780**
Reserve (Dry season)		**33.7%**	**40.0%**	**34.7%** **(22.1%)**	**27.1%** **(20.1%)**	**25.0%** **(20.0%)**
Capacity (MW)	Hydro (- SPPs)	10,631	14,283	17,987	19,857	21,057
	Coal thermal	4,185	15,515	32,535	45,190	77,310
	Gas/Oil	8,362	10,582	13,625	17,525	17,525
	Small Hyd.+new energy	511	1,679	3,129	4,829	4,829
	NPP			1,000	6,000	10,700
	Import	918	1,073	1,839	4,609	6,359
Availability	**Total**	**53.7%**	**51.4%**	**53.6%**	**57.0%**	**57.6%**
	Hydro (- SPPs)	40.3%	43.5%	38.1%	34.4%	31.2%
	Coal thermal	68.7%	52.3%	61.3%	67.0%	63.3%
	Gas/Oil	66.1%	63.3%	61.3%	60.9%	59.6%
	Small Hyd.+new energy	44.0%	36.2%	32.4%	30.7%	31.5%
	NPP	-	-	55.7%	76.5%	80.3%
	Import	33.1%	51.7%	48.8%	44.2%	51.7%

Source: IE (2011.2)

(3) Generated output

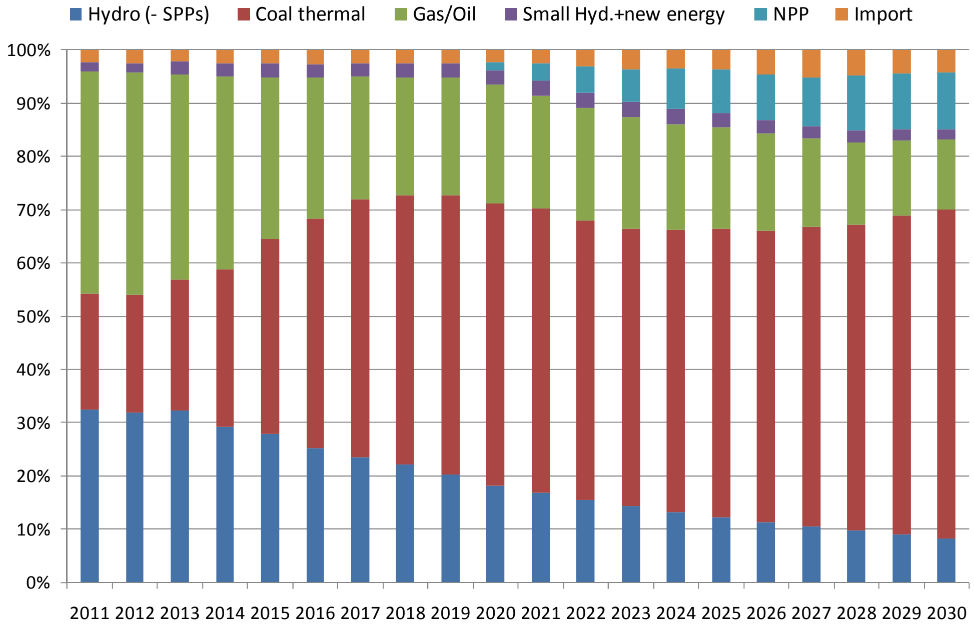
Viewing the forecast figures for generated output by type of fuel that are set based on the IE's draft power source development plan (July 2010), it can be seen that the draft foresees a big increase in output generated by coal-fired power (Figure 2.4-5). The increase in output from coal-fired power is forecast to slow down in 2020, when nuclear power, which are also to serve as base sources, are slated to commence operation. Nevertheless, the share occupied by coal-fired power is expected to soar from

22 % in 2011 to 62 % in 2030 (Figure 2.4-6). Although the draft anticipates the development of nuclear power, the combined fossil fuel share of the total generated output is projected to expand to 75 % in 2030. The need to curtail emissions of greenhouse gases requires the input of high-efficiency facilities and maintenance of highly efficient operations at coal-fired power generation.



Source: IE (2010.7), JICA report 2010

Figure 2.4-5 Power generation forecast by fuel (2011-2030)



Source: IE (2010.7), JICA report 2010

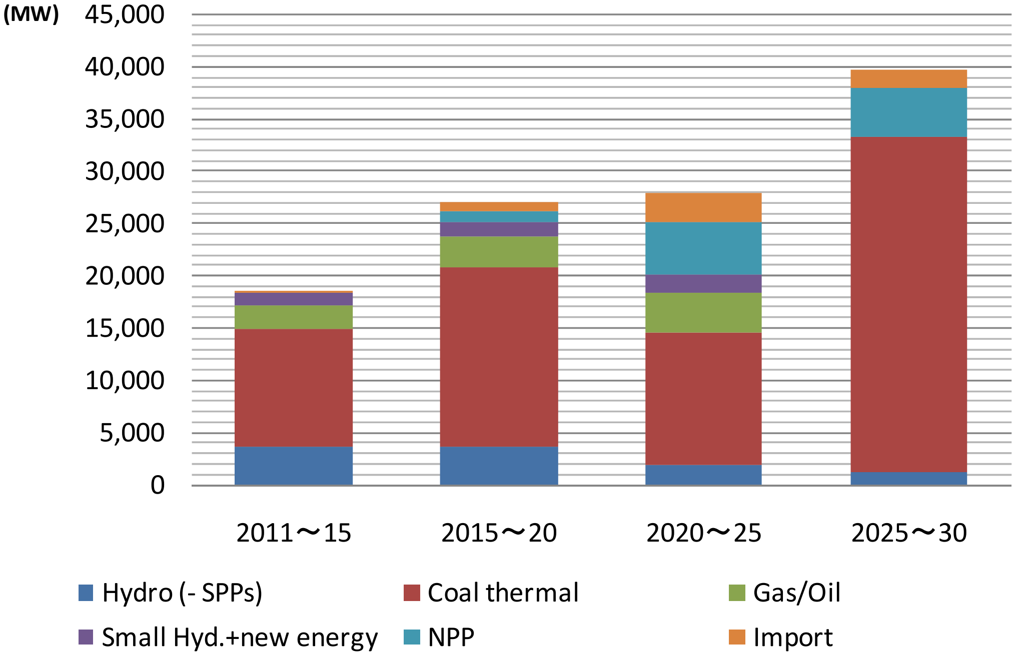
Figure 2.4-6 Composition of power generation by fuel (2011-2030)

(4) Generation facilities

Figure 2.4-7 shows the trend of generation facility development (amount of increase) by type of fuel. Domestic hydroelectric power development (capacity) is anticipated to peak in 2020, and there are no plans for development of additional gas-fired power in and after 2025. As such, coal-fired power will be the main subject of power source development into the future.

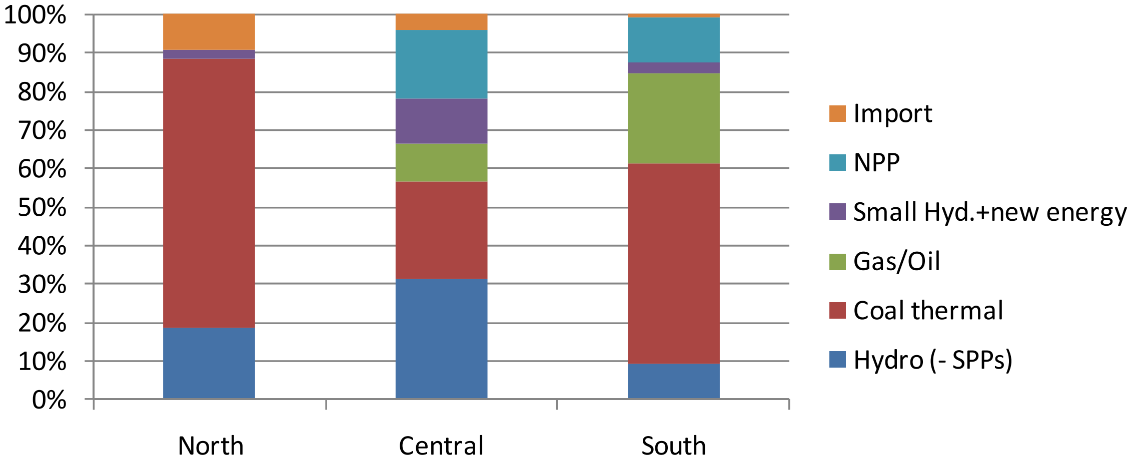
Coal resources are located mainly in the northern part of the country, and the development of coal-fired power will be fostered by the use of domestic coal in the northern region.

In the central and southern regions, which currently lack coal-fired power, introduction of power generation facilities using imported coal will begin to be accelerated in around 2015. In 2030, coal-fired power could come to account for about 70 % of the installed generation capacity in the northern region and 30 to 50 % of that in the central and southern regions (Figure 2.4-8). The EVN wants to introduce high-efficiency facilities applying supercritical (SC) pressure and ultra supercritical (USC) pressure to heighten the economic feasibility of the facilities burning imported coal, which is more expensive than the domestic variety.



Source: IE (2011.2)

Figure 2.4-7 Forecast of installed capacity by fuel



Source: IE (2010.7) , JICA report 2010

Figure 2.4-8 Composition of capacity by fuel in 2030

2.4.5 CO_2 emissions in the power sector

Table 2.4-8 and Figure 2.4-9 show the IE forecast for CO_2 emissions from Vietnam's power sector. The emission level is largely depends on the amount of power generated with coal-fired and other fossil fuels. CO_2 emissions in 2030 are projected to reach about 443.8 million tons, increased by 7.5 times from the 2011 level.

Table 2.4-8 Predicted CO_2 emissions from power sector

Year	2011	2015	2020	2025	2030
CO_2 (1,000tons)	59,463	107,162	201,491	297,237	443,802
Generation by fossil fuel (GWh)	73,592	129,738	247,792	358,760	520,223

Note: The calculation of CO_2 emission is based on the formula:

CO_2= FC * NCV * $EFCO_2$

FC: Amount of fossil fuel consumed by power plant (mass or volume unit)

NCV: Net calorific value (energy content) of fossil fuel (GJ/mass or volume unit)

$EFCO_2$: CO_2 emission factor of fossil fuel (tCO2/GJ)(IPCC)

Source: SEA of PDP VII, IE (2010.7)

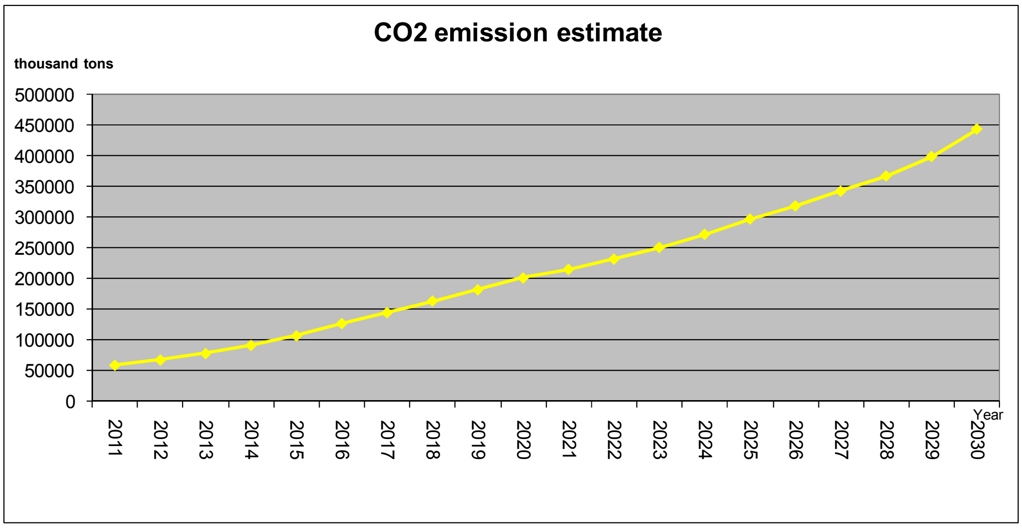


Figure 2.4-9 Predicted CO_2 emissions from power sector

2.4.6 Trial calculation of CO_2 emissions from coal-fired power plants

(1) Plans for construction of coal-fired power plants

Table 2.4-9 and Table 2.4-10 show the planning list of coal-fired thermal power plants based on the IE's draft power source development plan (prepared in July 2010).

Table 2.4-11 shows the list of plants slated for development over the next few years. Development in the northern region accounts for the majority, while projects in the southern region will begin to be implemented in and after 2014.

Table 2.4-9 Coal-fired thermal power plant development plan (North & Central)

	COD	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total (Whole country)		4,035	4,855	5,975	9,325	15,185	20,945	24,405	27,565	30,820	32,205	33,560	34,760	37,160	39,860	44,860	49,720	55,380	60,680	68,980	76,980
North		4,035	4,855	5,975	7,525	10,325	13,025	14,625	15,925	17,260	18,045	18,440	18,440	19,640	20,840	22,640	25,040	27,440	30,140	33,440	37,440
Pha Lai 1	1983	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Pha Lai 2	2001	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Uong Bi	1975	105	105	105	105	105	105	105	105	105	105	0	0	0	0	0	0	0	0	0	0
Uong Bi MR1&2	2008	300	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Ninh Binh	1974	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0
Na Duong	2004	110	110	110	110	110	110	160	210	210	210	210	210	210	210	210	210	210	210	210	210
Cao Ngan	2007	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Hai Phong	2010	600	600	900	1,200	1,200	1,200	1,200	1,800	2,400	2,400	2,400	2,400	2,400	2,400	3,000	3,600	3,600	3,600	3,600	3,600
Cam Pha	2010	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
An Khanh	2017	0	0	0	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	100	100
Quang Ninh	2010	900	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Song Don	2010	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220
Mao Khe	2012	0	220	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440
Luc Nam	2014	0	0	0	50	50	50	50	50	50	100	100	100	100	100	100	100	100	100	100	100
Nghi Son	2014	0	0	0	600	600	600	600	600	600	600	600	600	600	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Mong Duong	2015	0	0	0	0	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
Vung Ang	2013	0	0	600	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	2,400	2,400	2,400	3,000	3,600	3,600	3,600	3,600
Thang Long I	2016	0	0	0	0	0	300	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Cam thinh	2019	0	0	0	0	0	0	0	0	135	270	270	270	270	270	270	270	270	270	270	270
Thai Binh	2015	0	0	0	0	600	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Hai Duong	2016	0	0	0	0	0	600	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Quang Trach	2018	0	0	0	0	0	0	0	600	1,200	1,200	1,200	1,200	1,200	1,200	2,400	2,400	2,400	2,400	2,400	2,400
Nam Dinh	2016	0	0	0	0	0	600	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	2,400	2,400	2,400	2,400	2,400
Quynh Luu	2020	0	0	0	0	0	0	0	0	0	600	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Bac Giang	2028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	300	300
Cong Thanh	2029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	300
Dam Ha	2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,800	2,400	2,400	2,400
New Coal	2028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,800	4,800	8,800
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Central		0	0	0	0	0	0	660	1,320	1,320	1,320	1,620	1,620	1,620	1,920	2,520	3,180	3,840	3,840	3,840	3,840
Van Phong #3	2017	0	0	0	0	0	0	660	660	660	660	660	660	660	660	660	660	660	660	660	660
Van Phong #4	2018	0	0	0	0	0	0	0	660	660	660	660	660	660	660	660	660	660	660	660	660
Coal 300 #1	2021	0	0	0	0	0	0	0	0	0	0	300	300	300	300	300	300	300	300	300	300
Coal 300 #2	2024	0	0	0	0	0	0	0	0	0	0	0	0	0	300	300	300	300	300	300	300
Coal 300 #3	2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	300	300	300	300	300
Coal 300 #4	2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	300	300	300	300	300
Coal 600 #1	2026	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	660	660	660	660
Coal 600 #2	2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	660	660	660

Source: IE (2010.7), JICA report 2010

Table 2.4-10 Coal-fired thermal power plant development plan (South)

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
South		0	0	0	1,800	4,860	7,920	9,120	10,320	12,240	12,840	13,500	14,700	15,900	17,100	19,700	21,500	24,100	26,700	31,700	35,700
Vinh Tan II #1	2014	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Vinh Tan II #2	2014	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Vinh Tan I #1	2015	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Vinh Tan I #2	2015	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Vinh Tan #1	2019	0	0	0	0	0	0	0	0	660	660	660	660	660	660	660	660	660	660	660	660
Vinh Tan #2	2019	0	0	0	0	0	0	0	0	660	660	660	660	660	660	660	660	660	660	660	660
Vinh Tan #3	2021	0	0	0	0	0	0	0	0	0	0	660	660	660	660	660	660	660	660	660	660
Duyen Hai I #1	2014	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Duyen Hai I #2	2015	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Duyen Hai II #1	2018	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600
Duyen Hai II #2	2018	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600
D.Hai III,1	2016	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
D.Hai III,2	2016	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
D.Hai III,3	2017	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Van Phong #1	2015	0	0	0	0	660	660	660	660	660	660	660	660	660	660	660	660	660	660	660	660
Van Phong #2	2016	0	0	0	0	0	660	660	660	660	660	660	660	660	660	660	660	660	660	660	660
Long Phu I #1	2015	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Long Phu I #2	2016	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Long Phu II #1	2022	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600
Long Phu II #2	2022	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600
Long Phu III,1	2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000
Long Phu III,2	2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000	1,000	1,000	1,000
Song Hau I #1	2019	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600
Song Hau I #2	2020	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600
Long an #1	2024	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600
Long an #2	2024	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600
Kien Giang I #1	2016	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Kien Giang I #2	2017	0	0	0	0	0	0	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Kien Giang II #1	2023	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600
Kien Giang II #2	2023	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600	600	600
Kien Giang III #1	2025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600	600
Kien Giang III #2	2026	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600
Son My I #1	2026	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600
Son My I #2	2026	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600	600
Son My II #1	2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600	600
Son My II #2	2028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	600	600
Tra Cu I,1	2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000	1,000
Tra Cu I,2	2027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000	1,000
Tra Cu II,1	2028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000
Tra Cu II,2	2028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	1,000	1,000
New Coal	2029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,000	9,000

Source: IE (2010.7) , JICA report 2010

Table 2.4-11 Schedule of the Operating Project (2010-2015)

Year	Power plant	Area	Capacity (MW)	Developer
2010	TPP than Son Dong	North	220	TKV
	TPP Hai Phong I #1	North	300	Hai Phong Thermal Power JSC
	TPP Cam Pha I	North	300	TKV
	TPP Quang Ninh I	North	600	Quang Ninh Thermal Power JSC
2011	TPP Hai Phong I #2	North	300	Hai Phong Thermal Power JSC
	TPP Cam Pha II	North	300	TKV
	TPP Quang Ninh II #1	North	300	EVN
2012	TPP Nong Son	North	30	TKV
	TPPMao Khe #1	North	220	TKV
	TPP Uong Bi MR #2	North	300	EVN
	TPP Quang Ninh II #2	North	300	Quang Ninh Thermal Power JSC
2013	Hai Phong 2 #1	North	300	EVN
	TPP Mạo Khe #2	North	220	TKV
	TPP Vung Ang I	North	1,200	PVN
2014	TPP Hai Phong 2 #2	North	300	EVN
	TPP Nghi Son 1	North	600	EVN
	TPP Luc Nam #1	North	50	IPP
	TPP Vinh Tan 2	South	1,200	EVN
	Duyen Hai (Tra Vinh) 1 #1	South	600	EVN
2015	Mong Duong 1	North	1,000	EVN
	Mong Duong 2	North	1,200	AES (BOT)
	Hai Duong #1	North	600	Jak Behad (BOT)
	Thai Binh II #1	North	600	PVN
	Vih Tan 1	South	1,200	CSG (BOT)
	Duyen Hai (Tra Vinh) 1 #2	South	600	EVN
	TPP Long Phu 1 #1	South	600	PVN
	TPP Van Phong #1	South	660	Sumitomo(BOT)

Source: IE

(2) Procedure for trial calculation of CO_2 emissions from coal-fired thermal power plants

The trial calculation of future CO_2 emissions from coal-fired thermal power plants is made on the basis of the data already obtained for generated output and power plant plans. The procedure is as follows.

i. Estimate the amount of power generated by each plant in the future
   Distribute the total generated output in each year among the plants based on the power plant plans (proportional distribution in accordance with capacity).

ii. Estimate the coal consumption at each plant
   Calculate this amount from the amount of power generated at each plant, using the following equation.
   Coal consumption = Generated output × 3,600 / (Thermal efficiency × Coal calorific value)

iii. Estimate CO$_2$ emissions from each plant

Calculate CO$_2$ emissions from each plant based on the amount of fuel consumed at the plant, using the following equation.

CO$_2$ emissions = Amount of coal consumption × Coal calorific value × Emission amount factors

For the thermal efficiency of the power plants targeted for the study (Ninh Binh, Pha Lai and Uong Bi thermal power plants), actual data obtained in the study were used. For other plants, thermal efficiency was assumed to be 35 %, the same as for the Uong Bi Ext (which commenced operation in 2009), the newest of the plants targeted for the study. Because there are no significant differences in the caloric value of the coal used at the targeted plants, it was assumed that all of the plants burned coal with the same calorific value (5,000 kcal/kg).

The emission factor was assumed to be equivalent to the maximum for "Anthracite" coal in Table 2.4-12 (i.e., 98,535 kg-CO$_2$/TJ).

Table 2.4-12 Coal properties

			Anthracite	Coking coal	Other Bitminous	Sub-Bitminous	Lignite/ Brown coal
Calorific value as used (MJ/kg)	GCV*	MAX	30.35	30.8	26.75		
		MIN	29.65	27.8	23.85		
	NCV*	MAX	30.35	29.8	25.50	(23.87)	(14.66)
		MIN	28.95	26.6	22.60		
Carbon content -as used- (kg/kg)	MAX		0.782	0.771	0.657		
	MIN		0.778	0.674	0.590		
Carbon content -daf- (kg/kg)	MAX		0.980	0.920	0.845		
	MIN		0.920	0.845	0.810		
Moisture -as used- (kg/kg)	MAX		12	9	18		
	MIN		10	7	13		
CO$_2$ emission factor** (kg-CO$_2$/TJ)	MAX		98,538	92,909	95,723		
	MIN		94,476	94,866	94,471		

* GCV: Gross Calorific Value, NCV: Net Calorific Value

** Calculated value based on Calorific value and Carbon content

Source: World Coal Report, JCOAL

(3) Results of the trial calculation of the amount of CO$_2$ emissions

Table 2.4-13, Figure 2.4-10, and Figure 2.4-11 show the results of the trial calculation of the amount of CO2 emissions and coal consumption made based on IE's draft plans (JICA report 2010) for coal-fired thermal power plant development.

As a result of trial calculation, the total CO2 emissions and coal consumption in the country are projected to be 3855.25 million tons and 1870.2 million tons, respectively during the period from 2011 to 2030. Total CO2 emissions from and coal consumption by EVN's power plants are projected to be 1713.02 million tons and 830.99 million tons, respectively.

As for the power plants owned by EVN, because there are no data about the owners of power plants to be constructed in and after 2025 available, assumptions were made based on the trends before 2025.

Table 2.4-13 Result of annual CO2 emission of coal-fired thermal power plants

Year		2011	2015	2020	2025	2030
CO_2 (1,000tons)	Total	26,802	72,938	178,098	269,334	434,964
	EVN	20,290	38,457	81,820	109,206	183,003
Coal fuel consumption (1000tons)	Total	13,002	35,404	86,396	130,655	211,003
	EVN	9,843	18,656	39,691	52,976	88,776
Generation by fossil fuel (GWh)	Total	25,172	71,055	174,615	265,248	428,695
	EVN	18,747	36,990	79,622	107,258	180,099

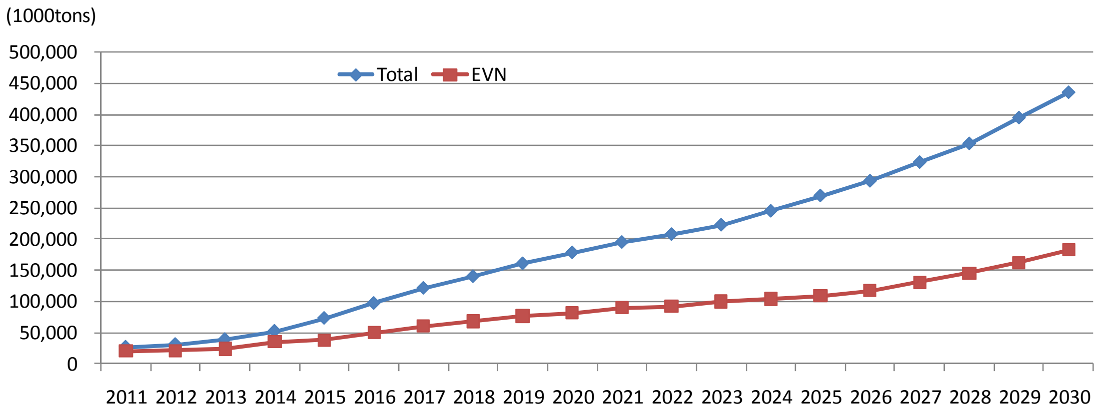


Figure 2.4-10 Result of CO2 emission of coal-fired thermal power plants

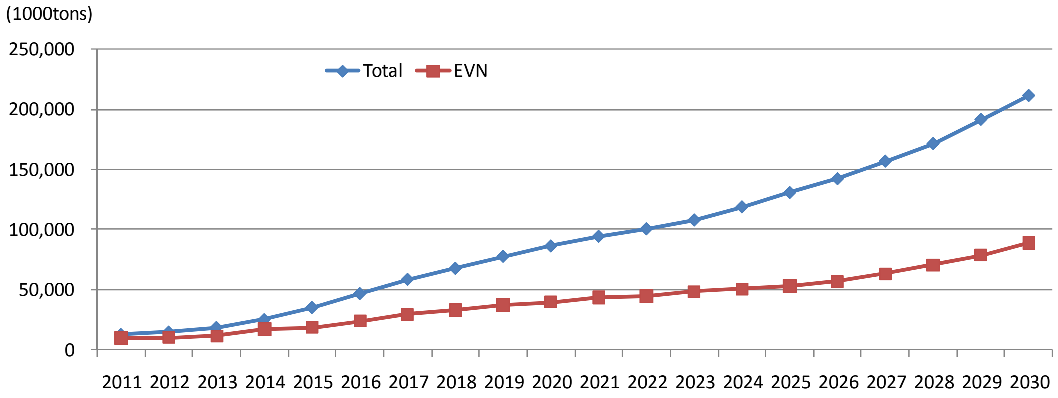


Figure 2.4-11 Result of coal fuel consumption

2.5 Trends on greenhouse gas emission limitation, and research and analyses of legal frameworks

2.5.1 International trends on greenhouse gas emission limitation

(1) Current situations of international framework and negotiations

The United Nations Framework Convention on Climate Change (UNFCCC) is a treaty that has established an international framework for limiting greenhouse gas (GHG) emissions from a standpoint of global warming prevention. The Conference of the Parties (COP) is an occasion for conducting negotiations on UNFCCC. Under the Kyoto Protocol adopted at COP 3 in Kyoto, Japan, GHG emission reduction targets are nationally set. For international emissions trading, the Kyoto mechanisms (Joint Implementation [JI], the Clean Development Mechanism [CDM], and Emissions Trading [ET]) are in operation.

As defined in Article 6 of the Kyoto Protocol, JI is a mechanism that allows an Annex I Party (developed country) assigned the amount of GHG emission limitation to earn carbon credits based on GHG emissions reduced or GHG removals enhanced by assisting another Annex I Party in implementing a project to reduce emissions or enhance removals. Credits given in JI are called emission reduction units (ERUs). Since ERUs are transferred between developed countries that are assigned their quantified targets, the total amounts of emissions assigned to all developed countries remain unchanged.

The CDM is a mechanism that allows an Annex I Party to earn certified emission reductions (CERs) that are the amounts reduced by implementing, as an investing country, an emission-reduction project in a non-Annex I Party (developing country). It is defined in Article 12 of the Kyoto Protocol. Since a non-Annex I Party has no obligation to reduce emissions, the total emissions assigned to an Annex I Party are increased through the transfer of CERs. A country hosting a CDM project benefits from investments in the project, technology transfer, and others.

As defined in Article 17 of the Kyoto Protocol, ET is a mechanism that allows an Annex I Party to acquire form or transfer to another Annex I Party assigned amounts of emissions or credits in order to achieve targeted emission reductions. If actual GHG emissions from an Annex I Party (Country A) stay below assigned amounts, spared assigned amount units (AAUs) can be transferred to another Annex I Party (Country B) that prefers to increase its assigned amounts of emissions. Like JI, ET is a mechanism working between Annex I Parties. The total amounts of emissions assigned to Annex I Parties, therefore, remain unchanged.

Since the first commitment period under the Kyoto Protocol begins in 2008 and ends in 2012, activities to be done in and after 2013 are under discussion. The Kyoto Protocol has serious flaws. First, countries that assume obligations to reduce emissions account for only 27.4% of the actual worldwide emissions in 2008; China accounts for 22.3% of the worldwide emissions, having no obligation; and the United States of America accounts for 19.0%, having yet to ratify the Protocol. Their efforts to limit emissions in the obliged countries, therefore, will not result in fully effective prevention of global warming. Then, economic burdens are imposed only on the particular countries that assume obligations to make reductions, which will have a profound influence on industries and livelihood of peoples in the countries.

From the above standpoint, intense discussions on post-Kyoto issues have been taking place. At COP 15 held in Copenhagen, Denmark in December 2009, developed and developing countries directly confronted each other. As a matter of course, developing countries that are non-Annex I Parties having no obligation to reduce GHG emissions under the Kyoto Protocol, requested the extension of the Protocol, and demanded that developed countries, having emitted GHG until now, achieve further significant reductions and provide the transfer of financial resources and technologies. On the other hand, developed countries required emission reductions of the United States, a worst emitter, and major developing countries including China. A day before the conference ended, the Copenhagen Accord was drafted, but was not reached unanimously. COP 15 agreed to "take note of" the Copenhagen Accord and closed.

At COP 16 held in Cancun, Mexico from November 29 to December 10, 2010, the gap was not yet easily narrowed between developed countries calling for practical mitigation actions by the United States and developing countries, and developing countries insisting on emission reductions by and technology cooperation from developed countries in accordance with the Kyoto Protocol; however, progress was made toward decisions including "agreement" on the content of the Copenhagen Accord, which had been merely "taken note of" at COP 15. The summary of the Cancun Agreements adopted at COP 16 is as follows:

- Decides to hold the increase in global average temperature below 2 degrees Celsius on pre-industrial levels.
- Decides to reach a conclusion as soon as possible so that no blank moment will be given between the first commitment period (2008-2012) and the second commitment period, which is supposed to begin in 2013, under the Kyoto Protocol.
- Ensures that the parties to the Protocol reserve the right not to agree to reduction targets for 2013 and subsequent years.
- Recognizes that developed countries shall reduce their GHG emissions by 25-40% on 1990 levels by 2020.
- Decides to discuss, at COP 17, the worldwide reduction target to be reached by 2050.
- Takes note of country-by-country emission reduction targets and mitigation actions communicated by developed and developing countries in accordance with the Copenhagen Accord.
- Decides to continue dialogue on a single reduction framework targeting all countries, and make decisions including whether such a framework will be legally binding.
- Agrees that developed countries will set emission reduction targets, and submit annual reports of their emissions to be reviewed internationally.
- Agrees that developing countries will voluntarily set reduction targets relative to 'business as usual' emissions by 2020, and submit biennial reports of their achievements to be reviewed internationally.
- Decides to establish a Green Climate Fund to assist developing countries in reducing emissions.
- Decides to newly establish a Cancun Adaptation Framework for international cooperation in

reducing vulnerability to global warming.

While details about and a new framework for the second commitment period under the Kyoto Protocol will probably be discussed at COP 17, it seems that, at COP 16 , agreement was reached for the whole world (including countries that are not parties to the Kyoto Protocol) to commit itself to limit GHG emissions. It was clarified that developing countries would implement emission mitigation measures to meet voluntarily-set targets although they were not yet in the phase in which they were willing to assume obligations to reduce emissions within a binding framework.
Quantified emission reduction targets for major countries are shown in Table 2.5-1.

Table 2.5-1 Quantified GHGs emission reduction targets for major countries

	Base year	Midterm targets	Notes
Japan	1990	▲25%	
EU	1990	▲20-30%	
United States of America	2005	▲17%	
Canada	2005	▲17%	
Australia	2000	▲5-25%	
New Zealand	1990	▲10-20%	
Russia	1990	▲15-25%	
Brazil		▲36.1-38.9% (Relative to BAU in 2020)	BAU: Business as Usual
South Korea		▲30% (Relative to BAU in 2020)	
China	2005	▲40-45% (Per unit of GDP)	With an 8% growth by 2020, the emissions will be 1.9 times more than those in 2005. With a 6% growth in and after 2015, the emissions will be 1.7 times more than those in 2005.
India	2005	▲20-25% (Per unit of GDP)	With a 7% growth by 2015 and a 6% growth thereafter, the emissions will be 2.1 times more than those in 2005.

Before the implementation of a CDM project, its methodology needs to be approved by the CDM Executive Board so that a project activity is validated to reduce GHG emissions. Methodologies that have been approved for coal-based thermal power generation are as follows:

- ACM0013: A Consolidated methodology for a new grid connected fossil fuel-fired thermal power plant using a less GHG intensive technology
  - The project activity shall be the construction and operation of a new grid-connected fossil fuel-fired thermal power plant that uses a more efficient power generation technology (i.e., supercritical coal-based thermal power generation) than what the fossil fuel-fired plant would use otherwise.
  - A baseline fuel shall be used by facilities to provide 50% or more of the total generating capacity in the host country.
  - The methodology is applicable only to a new power generation facility. A proposal for a new methodology is likely to be required for retrofitting an existing facility.
- AM0056: Energy efficiency improvement by boiler replacement or rehabilitation (and an optional fuel switch) in a fossil fuel-fired steam boiler system
  - The methodology is used to replace or retrofit exsisting boilers, and make an optional switch in fossil fuel when national regulations require no replacement or retrofit of the exsiting equipment.
- AM0062: Energy efficiency improvement in a power generation facility by retrofitting turbines
  - The methodology is applicable to a project activity concerning the retrofit of steam or gas turbines with components using improved designs for energy efficiency improvement in an existing fossil fuel-fired power plant.
  - No biomass or waste heat can be used. All power generated at the facility shall be supplied through the grid.

Since projects targeting coal-based thermal power generation are subject to very stringent reviews, few CDM projects based on the above methodologies have been approved. In March 2010, there were four approved projects based on ACM0013 (Table 2.5-2), but there was no approved project based on AM0056 or AM0062. As described above, ACM0013 is applicable only to a country in which 50% or more of the total generating capacity is provided by using coal-based thermal power generation, which virtually limits ACM 0013 application to China and India.

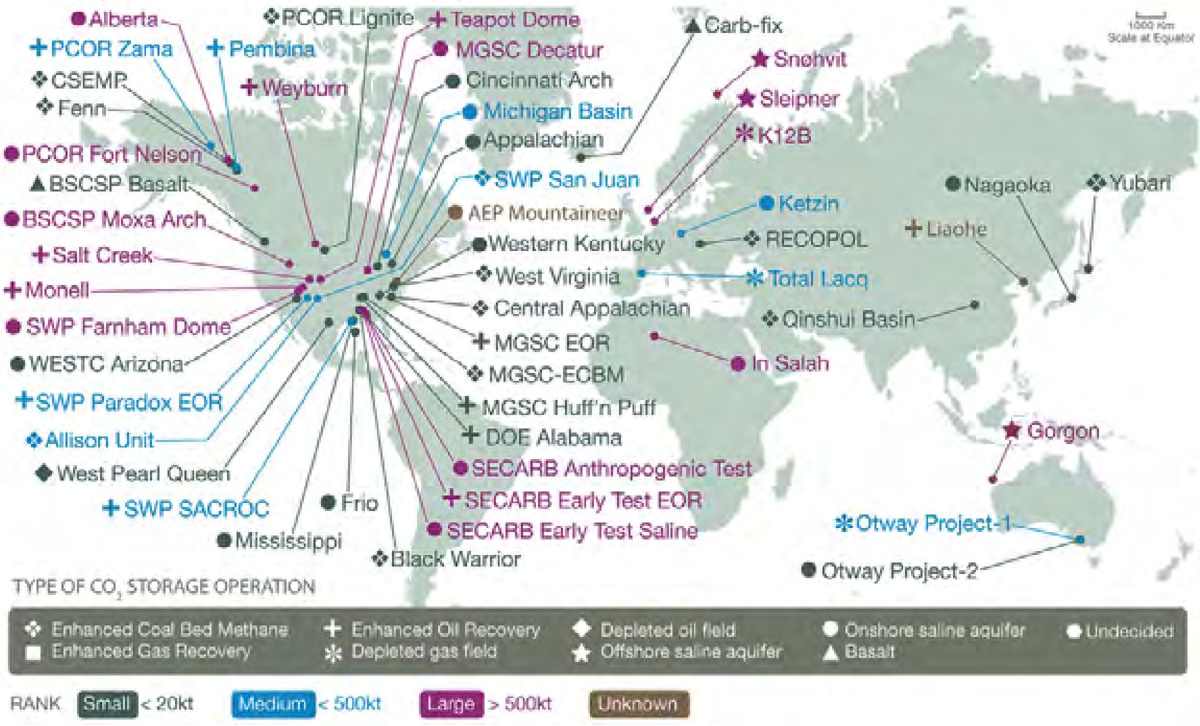
Table 2.5-2 ACM0013 projects registered with CDM Executive Board

Project Title	Registered	Host Parties	Other Parties	Estimated Emission Reductions(tCO2/year)
Shanghai Waigaoqiao coal-fired power project using a less GHG intensive technology	Dec 24, 2010	China	United Kingdom	305,783
Energy efficient power generation in Tirora, India	Nov 30, 2010	India		1,193,017
Greenhouse Gas Emission Reductions Through Super-Critical Technology - Sasan Power Ltd.	Oct 21, 2010	India		2,245,875
Grid connected energy efficient power generation	Dec 16, 2009	India		1,839,516

Source: the website of the Kyoto Mechanisms Information Platform

At COP 16, the Parties decided that CO_2 capture and storage (CCS) was eligible as an effective means of limiting CO_2 emissions to the atmosphere under the CDM. While methodologies using CCS need to be developed and approved, quite a few applications for projects combining coal-fired thermal power generation and CCS are expected.

CCS involves three processes—capturing, transporting and storing CO_2—each of which is subject to research and development. Figure 2.5-1 shows CCS projects all over the world.



Source: the website of the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Figure 2.5-1 CCS projects in the world

Major CCS projects are described as follows:

- Sleipner Project
  Sleipner is a large-scale natural gas field in the North Sea, 240 km off Stavanger, Norway. The production of crude oil and natural gas started in 1993. Gas produced from the gas field contains 9% CO_2, which is separated and captured. One million tons of CO_2 are stored in an aquifer each year. This is the world's first project for commercial-scale CO_2 storage to mitigate climate change.

- Weyburn Project
  Discovered in Saskatchewan, Canada in 1954, Weyburn has been known as an oilfield for decades. In October 2000, EnCana started to inject CO_2 in Weyburn for oil production boost or enhanced oil recovery (EOR). CO_2 is transported through a pipeline from North Dakota, U.S.A. Approximately 2.5 million tons of CO_2 are stored each year. This is the first project in which CO_2 has been internationally traded for a purpose of reducing GHG emissions.

- In-Saleh Project
  In Algeria, Africa, a gas field has been developed on a large scale. CO_2 in produced gas is separated, captured, and stored underground, which is part of the development. Approximately 1.2 million tons of CO_2 are stored each year.

Japan has run a project for storing CO_2 in an aquifer in Nagaoka, Niigata, and completed an enhanced coal bed methane (ECBM) recovery project for producing methane by injecting compressed CO_2 into a coal bed in Yubari, Hokkaido. The Yubari project achieved the recovery of methane gas existing in the coal bed by injecting and absorbing CO_2 into the coal bed that was 890 meters underground and 5–6 meters in thickness. CCS/ECBM production allows methane gas to be recovered as an energy resource, which can lower the costs of CCS.

One of the current issues with CCS lies in its economic aspect. CCS has yet to reach a stage in which a private business can carry its economic burden independently. While the above Weyburn project has taken advantage of EOR to lower the costs of CCS, storage in an aquifer has no means of reducing the costs, and requires tax incentives and subsidies. Another issue is that local residents may be concerned about the potential leakage of CO_2 and opposed to a CCS project, which can make its implementation unachievable. There is also a view that stored CO_2 may have an impact on the surrounding environment. These issues need to be addressed.

(2) Trends in each country

<United States of America>

Compared to 2005 levels, the emissions target for 2020 is in the range of ▲17%, which is a quantified target registered in accordance with the Copenhagen Accord. The target is in conformity with anticipated U.S. energy and climate legislation. The final target will be reported to the Secretariat in light of enacted legislation.

On May 12, 2010, Senators Kerry (Democrat) and Lieberman (Independent) introduced the Kerry-Lieberman American Power Act bill to the Senate. Currently, Democrat-held seats in the Senate, however, have been reduced from 60 that is the supermajority. Further, Senator Graham (Republican) had co-authored the bill, but dropped his backing for the joint proposal, which makes it less likely to gain support from Republicans. Therefore, the bill has a very slim chance to pass the Senate.

<EU>

Compared to 1990 levels, the quantified reduction target is ▲20% or ▲30% (provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities, forming part of a global and comprehensive agreement for the period beyond 2012).

In March 2010, the EU Council of Environment Ministers and the European Council reached conclusions that generally maintained their previous stance toward the negotiations. While some countries propose simply extending the Kyoto Protocol, others seek different directions outside the framework established under the Kyoto Protocol. For example, the United Kingdom has launched a demonstration project on offset credits with India.

In its territory, the EU is operating a European Union Emissions Trading Scheme (EU ETS). Aimed at the energy and industry sectors, the scheme is in phase 2 (2008-2012), in which non-EU countries—Norway, Iceland, Liechtenstein and Switzerland are also participating.

<Australia>

The quantified reduction target is at least ▲5% below 2000 levels (unconditionally). It will be ▲15% if major developing countries agree to make substantial reductions, and developed countries agree to make reductions comparable to Australia's. It will be ▲25% if agreement to the IAE 450 scenario is reached. Australia has announced that more than ▲5% reductions will be premised to verifiable reduction actions by China, India and other countries.

In Australia, a Carbon Pollution Reduction Scheme (CPRS) bill was introduced to the parliament, but the industrial circle expressed determined opposition. Although the House of Representatives passed it, the Senate voted against it twice. The Senate also refused to debate the amended bill, which is highly unlikely to be approved under the current situation.

<Canada>

The quantified reduction target is ▲17% below 2005 levels, and will be aligned with the final economy-wide target of the United States in its enacted legislation. Canada has announced no participation in an international framework excluding the United States.

<Developing countries>

China has announced that it will make efforts to reduce its CO2 emissions per unit of GDP by ▲40-45% from 2005 levels, increase the share of non-fossil fuels in primary energy consumption in the range of 15% by 2020, and increase the forest area by 40 million hectares and the forest carbon stocks by 1.3 billion square meters from 2005 levels by 2020.

India aims to reduce its emissions per unit of GDP by ▲20-25% from 2005 levels by 2020.

Brazil aims to make ▲36.1-38.9% reductions from BAU levels by conserving forests, improving energy efficiency, and taking other reduction actions by 2020.

South Africa will implement mitigation measures to make ▲34% reductions by 2020, and ▲42% reductions by 2025 from the current emission baseline. If these reduction targets have been achieved, the emissions from South Africa will peak between 2020 and 2025, and will decrease after approximately 10 years of equilibrium.

Called a BASIC group, which includes the initials of the countries' names, the above four countries have been more influential at COP.

2.5.2 Current situations of greenhouse gas emission limitation in Vietnam

(1) Greenhouse gas emissions from Vietnam

Currently, Vietnam does not calculate emissions of CO_2 and other GHGs on a regular basis, and therefore collects no statistics on emissions. However, it collected data twice in the past, and recently presented a report to COP 16 (Vietnam's Second National Communication to the United Nations Framework Convention on Climate Change). The latest reported data are for the year of 2000. Emissions from respective sectors are shown in Table 2.5-3.

Table 2.5-3 GHGs emissions from respective sectors in Vietnam (in 1994 and 2000)

	1994		2000	
	Emissions ($ktCO_2e$)	Percentage (%)	Emissions ($ktCO_2e$)	Percentage (%)
Energy	25,637.09	24.7	52,773.46	35.0
Industry	3,807.19	3.7	10,005.72	6.6
Agriculture	52,450.00	50.5	65,090.65	43.1
LULUCF	19,380.00	18.6	15,104.72	10.0
Waste	2,565.02	2.5	7,925.18	5.3
Total	103,839.30	100.0	150,899.73	100.0

* LULUCF: Land Use, Land Use Change, and Forestry

The GDP of Vietnam was 16.29 billion USD in 1994, and almost doubled to 31.17 billion USD in 2000. As its economy grew, GHG emissions also increased. In 2000, they were nearly 150.9 million tCO_2e, almost 1.5 times more than emissions of 103.8 million tCO_2e in 1994. The agricultural sector still emitted the largest amounts of GHGs although it accounted for a slightly smaller percentage of the total. Along with the economic growth, emissions from the energy sector were on the rise.

In 2000, the energy sector was accountable for GHG emissions of 52,773.46 $ktCO_2e$, 5,044.41 $ktCO_2e$ of which were methane gas emitted from coal mining and other mining activities. The remaining emissions of 47,729.05 ktCO_2e were gases emitted from fuel combustion. A breakdown of GHG emissions from fuel combustion is shown in Table 2.5-4. CO_2 emissions account for more than 96% of the total GHG emissions. GHG emissions from coal combustion account for approximately 38%.

Table 2.5-4 GHG emissions from combustion (of respective fuels in 2000)

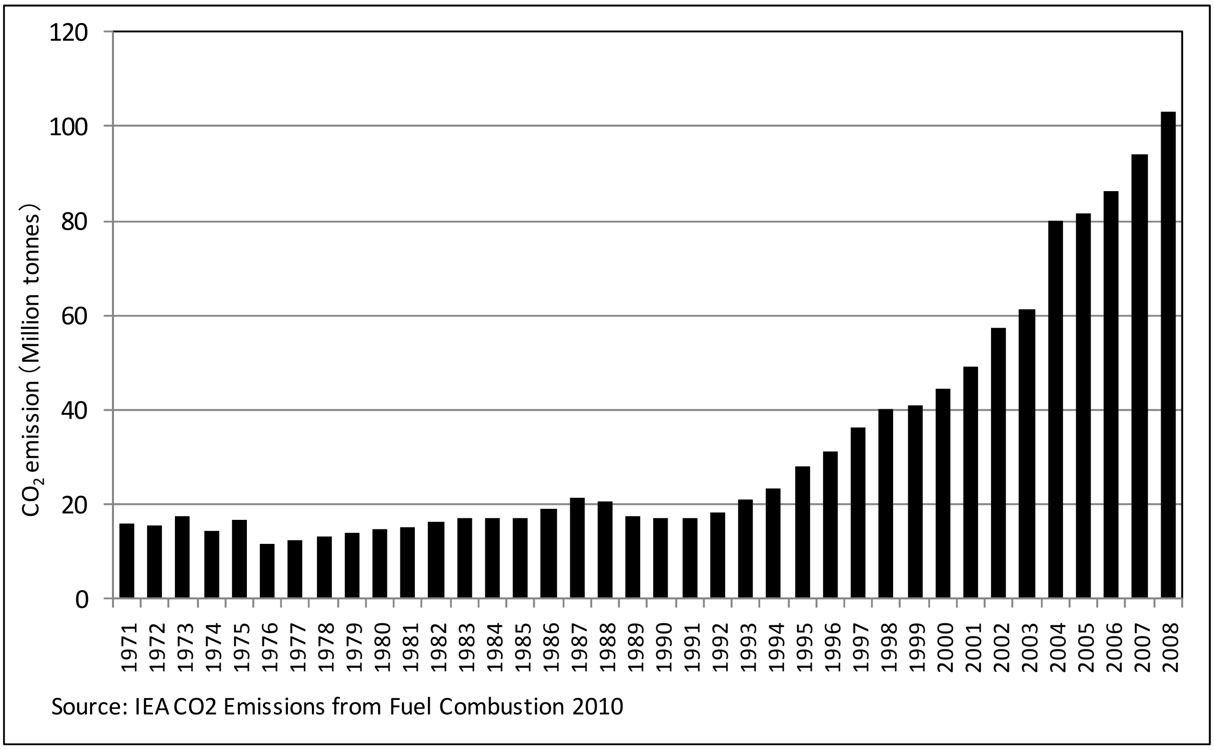
	CO_2	CH_4	N_2O	NOx	CO	NMVOC	CO_2e
Petroleum	25,426.30	1.65	0.13	145.26	485.10	92.63	25,501.25
Coal	17,879.70	4.65	0.26	49.78	69.90	7.67	18,057.95
Natural Gas	2,607.10	0.04	0.01	5.34	0.71	0.18	2,611.04
Biomass		62.02	0.87	21.86	1,053.45	123.91	1,572.12
Total	45,913.11	68.36	1.27	222.24	1,609.16	224.39	47,742.36

Unit: kilotons
NMVOC: Non-Methane Volatile Organic Compounds
NOx, CO and NMVOC are precursors of GHGs.

The International Energy Agency (IEA) also provides the statistics of CO_2 emissions from Vietnam as shown below.

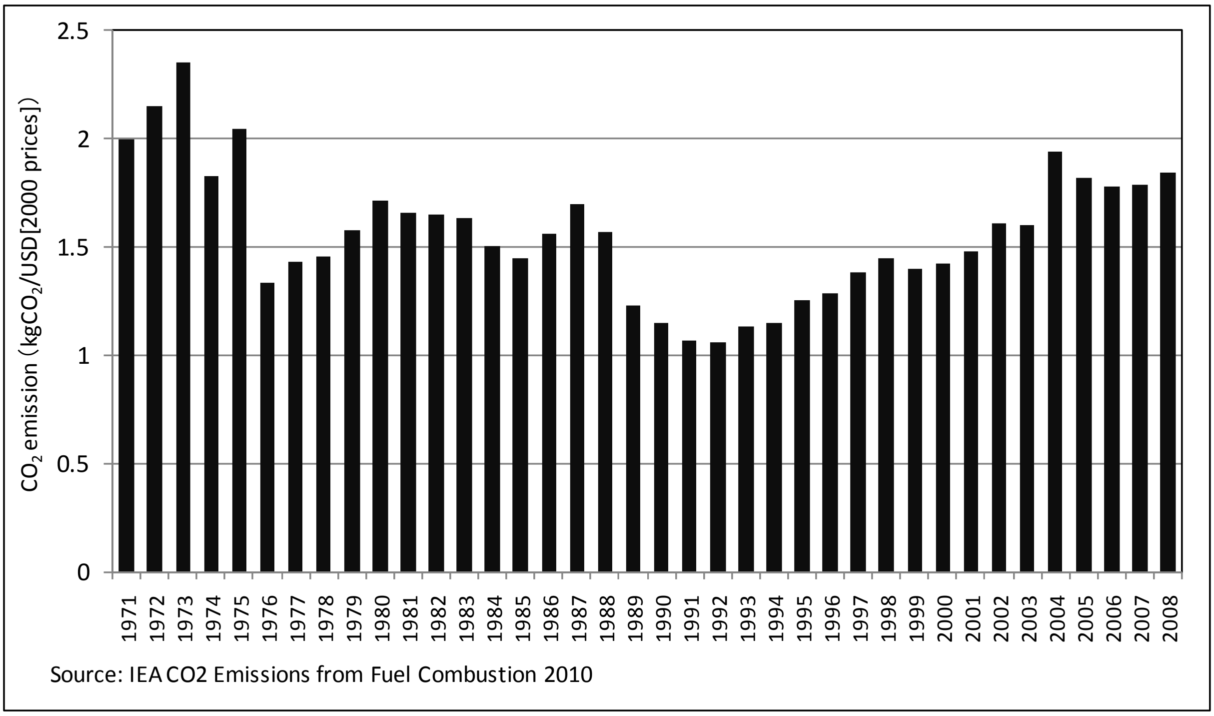
Figure 2.5-2 shows the estimates of CO_2 emissions from Vietnam that are provided in IEA CO_2 Emissions from Fuel Combustion. (The data were calculated using a Sectoral Approach.) CO_2 emissions started to increase considerably in the 1990s, and showed sharp increases after 2000. They were approximately 20 million tons per year in the 1970s and 1980s, increased to 28 million tons per year in 1995, 44.5 million tons per year in 2000, and 103 million tons per year in 2008. Vietnam was ranked 36th in CO_2 emissions in the world in 2008.

CO_2 emissions per unit of GDP, per capita, and per unit of generating capacity are also shown in Figure 2.5-3, Figure 2.5-4, and Figure 2.5-5. The data for 2008 are summarized in Table 2.5-5. The Vietnamese GDP was 55.8 billion USD (on 2000 prices) in 2008. Vietnam was ranked 56th in GDP in the world, while it was ranked 23rd in CO_2 emissions per unit of GDP. This indicates that energy was not efficiently consumed in GDP generation, and that CO_2 emissions resulting from economic activities in Vietnam can be further reduced. CO_2 emissions per capita, however, were very small. CO_2 emissions per unit of generating capacity were also as small as 413 gCO2/kWh, with Vietnam ranked 78th in the world. Its CO_2 emissions per unit of generating capacity were smaller than any of the world average of 502 gCO_2/kWh, the non-OECD average of 567 gCO_2/kWh, and the OECD average of 433 gCO_2/kWh, which means that the power generation sector of Vietnam has fully utilized generation resulting in low CO_2 emissions, such as hydropower generation, and has achieved limitations on GHG emissions. Fewer hydropower generation developments, however, will be feasible, and coal-based thermal power generation will play a key role in response to growing demand in electric power. It is important to prepare for the introduction of coal-based thermal power generation that can not only meet cost requirements but also achieve low CO_2 emissions.



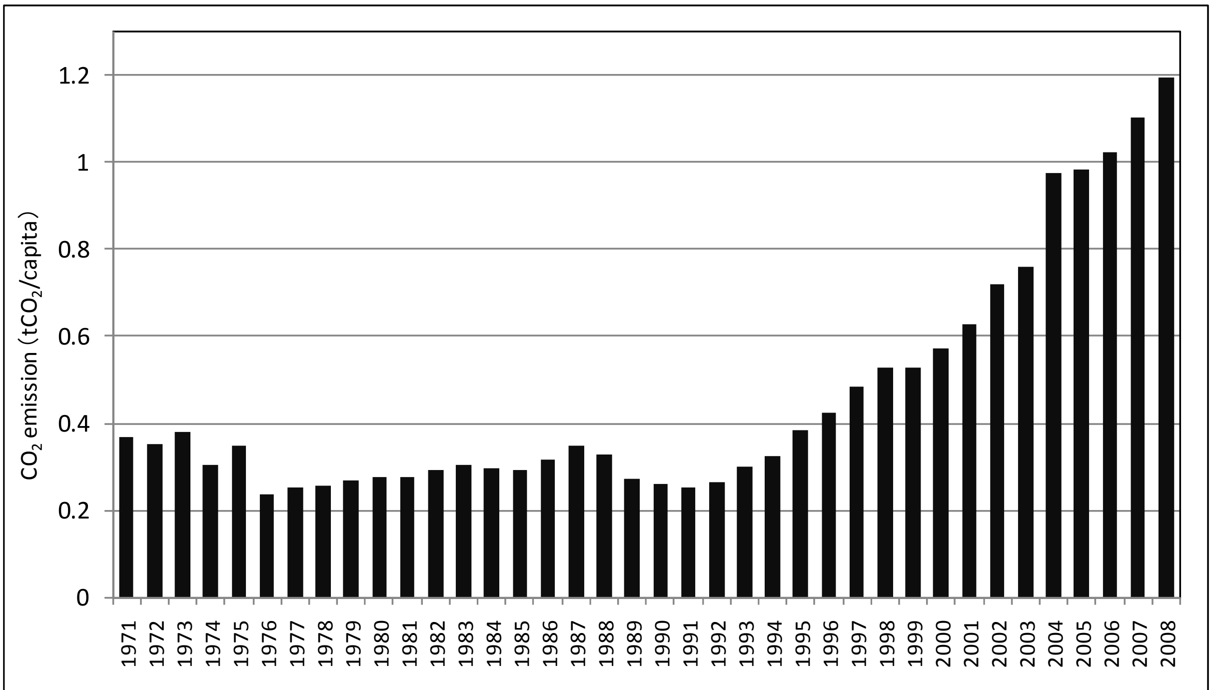
Source: IEA CO2 Emissions from Fuel Combustion 2010

Figure 2.5-2 CO_2 emissions from Vietnam



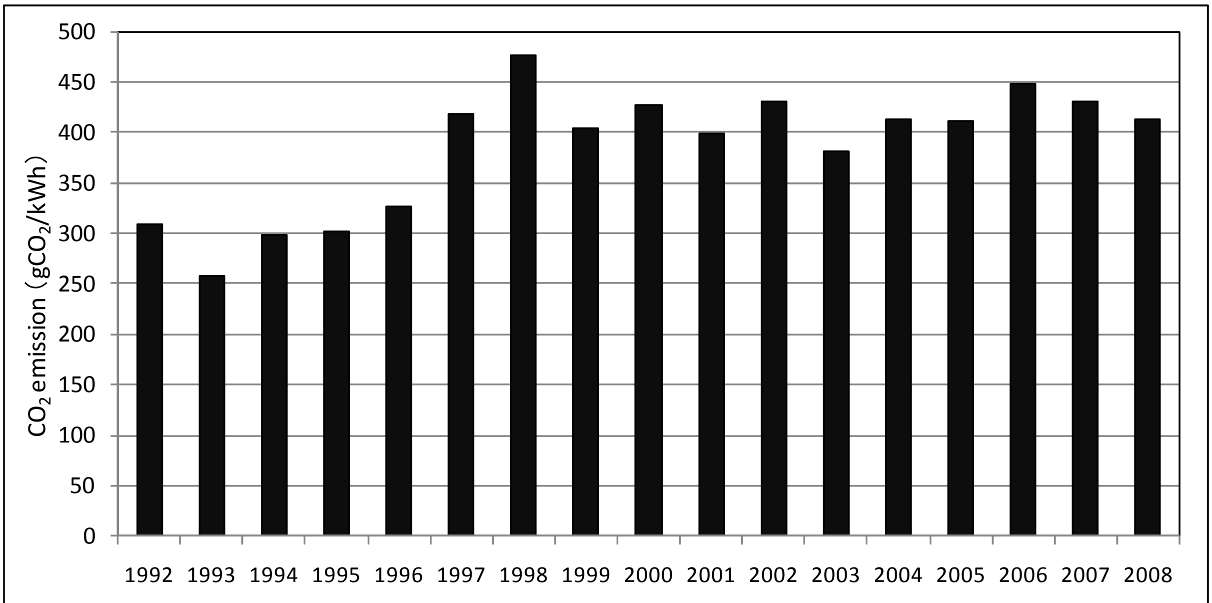
Source: IEA CO2 Emissions from Fuel Combustion 2010

Figure 2.5-3 CO_2 emissions per unit of GDP from Vietnam



Source: IEA CO2 Emissions from Fuel Combustion 2010

Figure 2.5-4 CO$_2$ emissions per capita from Vietnam



Source: IEA CO2 Emissions from Fuel Combustion 2010

Figure 2.5-5 CO$_2$ emissions per unit of generating capacity from Vietnam

Table 2.5-5 CO_2 emissions from Vietnam (in 2008)

	Data for 2008	World Rankings
CO_2 emissions	103 million tons	36
CO_2 emissions per unit of GDP (GDP expressed on 2000 prices)	1.85 $kgCO_2$/USD (on 2000 prices)	23
CO_2 emissions per capita	1.19 tCO_2/capita	102
CO_2 emissions per generating capacity (kWh)	413 gCO_2/kWh	78

Source: IEA CO_2 Emissions from Fuel Combustion 2010

(2) Measures to be implemented by Vietnam to limit greenhouse gas emissions

Having promoted CDM projects under the Kyoto mechanisms, Vietnam has 54 projects that were approved at the United Nations by March 2011 (Table 2.5-6). From a sectoral viewpoint, Vietnam has 40 hydropower generation projects, 7 biogas projects, 3 methane recovery and utilization projects, 1 biomass utilization project, 1 afforestation project, 1 waste gas and heat utilization project, and 1 wind power generation project. Most projects involve hydropower generation. Vietnam plans to implement energy-saving/environmental measures through technological and financial assistance provided by CDM projects.

Table 2.5-6 CDM projects in Vietnam (as of March 2011)

Ref No.	Project Title	Registered	Sector	Other Parties	Estimated Reductions (tCO2e/ year)
0152	Rang Dong Oil Field Associated Gas Recovery and Utilization Project	Feb 4, 2006	Waste gas and heat utilization	Japan, UK	677,000
0435	Song Muc Hydro Power Station Regeneration Project in Viet Nam	Jun 26, 2006	Hydropower	Japan	4,306
1910	Dong Thanh Landfill gas CDM Project in Ho Chi Minh City	Jan 17, 2009	Methane recovery and utilization		147,618
2228	Wind Power Plant No. 1—Binh Thuan 30 MW	Apr 6, 2009	Wind power	UK	57,988
2363	Cao Phong Reforestation Project	Apr 28, 2009	Afforestation		2,665
2367	Phu Mau Hydropower Project	Jun 5, 2009	Hydropower	Switzerland	13,634
2371	Muong Sang Hydropower Project	Jun 5, 2009	Hydropower	Switzerland	5,008
2368	Suoi Tan Hydropower Project	Jul 27, 2009	Hydropower	Switzerland	15,076
2372	So Lo Hydropower Project	Aug 17, 2009	Hydropower	Switzerland	16,346
2627	Nam Pia Hydropower Project	Sep 5, 2009	Hydropower	Japan	34,103
2571	Wastewater Treatment with Anaerobic Digester at Truong Thinh Starch Processing Plant in Tay Ninh, Vietnam	Oct 20, 2009	Biogass	Japan	42,389
2572	Wastewater Treatment with Anaerobic Digester at Viet Ma Starch Processing Plant in Tay Ninh, Vietnam	Oct 20, 2009	Biogass	Japan	39,814
2891	Ta Niet Hydro Power Project	Nov 21, 2009	Hydropower	Sweden	10,176
1913	Phuoc Hiep I sanitary Landfill gas CDM project, Ho Chi Minh city	Nov 25, 2009	Methane recovery and utilization		132,351
2878	An Diem 2 Hydropower Project	Dec 14, 2009	Hydropower	UK	39,554

Table 2.5-6 CDM projects in Vietnam (as of March 2011) (continued)

Ref No.	Project Title	Registered	Sector	Other Parties	Estimated Reductions (tCO2e/ year)
2636	AVN08-S-01, Methane Recovery and Biogas Utilization Project, Nghe An Province, Vietnam	Dec 21, 2009	Biogass	Netherlands	51,460
2637	AVN08-S-02, Methane Recovery and Biogas Utilization Project, Nghe An Province, Vietnam	Dec 21, 2009	Biogass	Netherlands	31,011
2639	VN08-WWS-04, Methane Recovery and Biogas Utilization Project, Lao Cai Province, Vietnam	Dec 21, 2009	Biogass	Netherlands	45,353
2638	VN08-WWS-03, Methane Recovery and Biogas Utilization Project, Yen Bai Province, Vietnam	Dec 22, 2009	Biogass	Netherlands	39,618
2640	VN08-WWS-05, Methane Recovery and Biogas Utilization Project, Quang Tri Province, Vietnam	Dec 22, 2009	Biogass	Netherlands	40,824
2971	Nam Gion Hydropower Project	Mar 7, 2010	Hydropower	France	41,156
2978	Nam Khoa 3 Hydropower Project	Mar 12, 2010	Hydropower	Switzerland	46,290
3034	Nam Khot Hydropower Project	Apr 2, 2010	Hydropower	France	27,924
3051	Yan Tann Sien Hydropower Project	May 8, 2010	Hydropower	France	39,751
3255	Ha Rao Quan Hydropower Project	May 27, 2010	Hydropower	UK	12,228
3256	Coc Dam Hydropower Project	May 30, 2010	Hydropower	UK	16,472
3482	Lap Vo Rice Husk Biomass Power Plant	Aug 17, 2010	Biomass utilization	Germany	39,506
3457	Chieng Cong Hydropower Project	Aug 20, 2010	Hydropower	Japan	23,707
3514	Pa Khoang Hydropower Project	Aug 27, 2010	Hydropower	Switzerland	7,080
3484	Dak Ne Hydropower Project	Aug 28, 2010	Hydropower	Germany	20,594
3589	Ea Drang 2 Hydropower Project	Sep 3, 2010	Hydropower	Netherlands	13,769
3505	Dak Rung Hydropower Project	Sep 4, 2010	Hydropower	Germany	17,257
3530	Suoi Sap 3 Hydropower Project (Son La Province)	Sep 11, 2010	Hydropower	UK	27,774
3442	Nam Chien 2 Hydropower Project	Oct 11, 2010	Hydropower	UK	66,563
3733	Landfill gas recovery and utilization in Nam Son, Tay Mo landfills in Hanoi	Oct 16, 2010	Methane recovery and utilization	Netherlands, UK	373,696
3667	La Hieng 2 Hydropower Project	Oct 27, 2010	Hydropower	Netherlands	30,869
3711	Thai An Hydropower Project	Oct 29, 2010	Hydropower	Japan	180,643
3421	Song Quang Hydropower Project	Nov 3, 2010	Hydropower	Switzerland	28,135
3682	Nam Tang and Na Hau Hydropower Bundled Projects	Nov 6, 2010	Hydropower	Switzerland	21,422
3745	Su Pan 2 Hydro Power Project	Nov 27, 2010	Hydropower	Japan	82,363
3810	Tra Linh 3 Hydropower Project	Dec 2, 2010	Hydropower	Germany	15,083
3858	Nam Ngan Hydropower Project	Dec 13, 2010	Hydropower	Germany	29,322
3872	Ngoi Phat Hydropower Project	Dec 18, 2010	Hydropower	UK	168,597
3942	Dak N'Teng Hydropower Project	Dec 18, 2010	Hydropower	Germany	27,323
3944	Dak Nong 2 Hydropower Project	Dec 18, 2010	Hydropower	Germany	31,839
3396	Chau Thon Hydropower Project	Dec 25, 2010	Hydropower	Switzerland	44,076
3980	Da Den Hydropower Project	Jan 8, 2011	Hydropower	Switzerland	17,442
3532	Song Chung Hydropower Project	Jan 20, 2011	Hydropower	UK	26,337
4117	Song Ong Hydropower Project	Feb 4, 2011	Hydropower	Denmark	21,416
3552	Dak Rung 1 Hydropower Project	Feb 19, 2011	Hydropower	UK	14,213
3557	Ngoi Hut 1 Hydropower Project	Feb 19, 2011	Hydropower	UK	19,267
3389	Dak Srong 2 Hydropower Project	Feb 23, 2011	Hydropower	Switzerland	44,466
4156	Nam Mu & Khuoi Luong Hydropower Bundled Project	Mar 5, 2011	Hydropower	UK	30,371
4259	Nam Tha Hydropower Project	Mar 10, 2011	Hydropower	UK	35,356

Source: the website of the Kyoto Mechanisms Information Platform

Since Vietnam has experienced serious power shortage, securing electric power tends to be given priority. On the other hand, the Vietnamese government has recognized the need to limit CO_2 emissions because sea-level rise and other phenomena due to global warming require urgent attention.

The Vietnamese government enacted the Law on Environmental Protection in 1993, and revised it in 2005 to make a commitment to GHG emission reduction. Article 84 of the revised Law on Environmental Protection mentions GHGs, and prescribes that the Ministry of Natural Resources and Environment (MONRE) shall be responsible for statistics on GHG emissions, that the prime minister shall regulate international trade, such as CDM projects, and that the government shall promote GHG emission reduction.

Based on the Law on Environmental Protection, some new environmental standards were established. As to emissions from thermal power plants, QCVN22: 2009/BTNMT (the National Technical Regulation on Emission of Thermal Power Industry) was enacted to present standards on maximum permissible concentrations of dust, NOx and SO_2, and their calculations. According to QCVN22, the maximum permissible value of an emission concentration is calculated as follows:

$$C_{max} = C \times K_p \times K_v$$

In the equation, C is an emission concentration as defined in Table 2.5-7; Kp is a factor varying with the installed capacity and running from 0.7 to 1 based on the power generating capacity of a power plant; and Kv is a factor varying from 0.6 to 1.4 based on the location of a power plant.

Table 2.5-7 Standards of emission concentrations at thermal power plants

Parameter	Emission Concentration C (mg/Nm^3)			
	A	B		
		Coal	Petroleum	Natural Gas
Dust	400	200	150	50
NOx (Calculated as NO_2 equivalent)	1,000	650 (more than 10% volatile matter) 1,000 (10% or less volatile matter)	600	250
SO_2	1,500	500	500	300

Source: QCVN 22: 2009/BTNMT National Technical Regulation on Emission of Thermal Power Industry

As shown in Table 2.5-7, there are two standards, A and B. Standard B is more stringent. Standard A is applicable to power plants that were in operation on October 17, 2005. Standard B is applicable to power plants that started their operations after October 17, 2005, or plan to start their operations. Applying two different standards is a provisional step. From January 1, 2015, Standard B will also be

applied to those which have met Standard A.
Further, QCVN05: 2009/BTNMT (the National Technical Regulation on Ambient Air Quality) and QCVN06: 2009/BTNMT (the National Technical Regulation on Hazardous Substances in Ambient Air) specify permissible concentrations of various substances and their measurements.

For Vietnam to take measures for climate change as a nation, MONRE's Hydrometeorology and Climate Change Department directed the development of the National Target Program to Respond to Climate Change (NTP). It was approved as 158/QD-TTg by the prime minister on December 2, 2008. The NTP is overviewed as follows:

- Investments in response to climate change are an important factor to ensure sustainable development. The society and all individuals shall cooperate in the response. Under UNFCCC, Vietnam shall effectively implement a program to reduce GHG emissions with support from developed countries and other organizations. (Article 1.1.1)
- The Government supervises activities in response to climate change. The Ministry of Natural Resources and Environment (MONRE) especially has responsibility to assist the Government with supervision in this area. (Article 1.1.2)
- The NTP shall be implemented in the following three phases. (Article 1.1.3)
  - First Phase (2009-2010): Launch
  - Second Phase (2010-2015): Implementation
  - Third Phase (after 2015): Development
- Targets to be achieved by 2010 and 2015 (Article 1.3)
  - Targets to be achieved by 2010
    - Construct a sea-level rise scenario from 2010 to 2100.
    - Establish a basis of response to climate change, and launch pilot projects.
    - Determine basic components of climate change data.
    - Develop a framework for and policies on response to climate change, and a framework for cooperation between a ministry, a sector or locals and an organization implementing a program.
    - Raise awareness of climate change, and develop human resources. Over 10% of individuals and over 65% of government employees shall be aware of climate change.
    - Ensure cooperation with foreign countries and international organizations, contribute to agreement preparation, and encourage investments in CDM and other projects aiming at responding to climate change.
    - Complete the assessment of a climate change impact and a sea-level rise impact, and enact legislation and guidelines on the formulation of development plans.
    - Formulate action plans for ministries, sectors or locals to respond to climate change.
  - Targets to be achieved by 2015
    - Update a sea-level rise scenario.
    - Create climate change measures for specialties, sectors or locals to take.

  - ✧ Complete and update a climate change database.
  - ✧ Establish a framework for and priority policies on activities to be done in response to climate change.
  - ✧ Raise awareness, and develop more human resources. Over 80% of individuals and 100% of government employees shall be aware of climate change.
  - ✧ Establish a framework for cooperation with international donors, and promote effective development.
  - ✧ Establish a framework for cooperation with international donors, and promote effective development.
  - ✧ Implement action plans for ministries, sectors or locals to respond to climate change.
- More international investments shall be encouraged from 2009 to 2015. NTP implementation costs shall be approximately 1,965 billion VND (50% covered by international investments, 30% by the Vietnamese government budget, 10% by local government budgets, and 10% by the private sector). (Article 1.4)
- The National Steering Committee for the National Target Program to Respond to Climate Change (Chairman: the prime minister, Standing Vice Chairman: the minister of MONRE), and the Executive Board of the NTP (Chairman: the minister of MONRE, Vice Chairmen: a vice minister of the Ministry of Planning and Investment and a vice minister of the Ministry of Finance) shall be established with the Standing Office of the NTP located at MONRE. (Article 2.1)
- MONRE shall manage the overall NTP. The Ministry of Planning and Investment shall develop a framework for incorporating climate change issues into socio-economic development planning, and shall supervise implementation. Each ministry shall formulate and implement an action plan to respond to climate change. (Article 2.2)

As described above, the NTP requires each ministry to formulate an action plan to respond to climate change. The Ministry of Industry and Trade (MOIT) enacted its action plan as 4103/QD-BCT on August 3, 2010. It is summarized as follows:

- Consideration of both short-term and long-term impacts of climate change is required. Current response to climate change will minimize future loss. (1.1)
- Assess impacts of climate change and sea-level rise, and formulate feasible measures. Aim for low-carbon economic development in implementing related programs. (2.1)
- Targets to be achieved by 2010 (launch stage, 2.2.1)
  - ➢ Be aware of the impacts of industrial and commercial activities on climate change, and discuss practical and feasible steps.
- Targets to be achieved from 2011 to 2015 (implementation stage, 2.2.2)
  - ➢ Raise awareness of climate change due to industrial and commercial activities, and disseminate information.
  - ➢ Assess the impacts of industrial and commercial activities on climate change and sea-level rise by 2013.

  - Formulate strategies and plans so that industries and sectors to be affected by climate change and sea-level rise can be developed.
  - Monitor GHG emissions resulting from industrial and commercial activities.
  - Launch pilot projects aiming at limiting GHG emissions from the industrial and commercial sectors.
- Targets to be achieved after 2015 (development stage, 2.2.3)
  - Develop further climate change measures following the launch and implementation stages.
- Provide and disseminate information about climate change. Exchange information in seminars and the like. Increase the capacity of the industrial and commercial sectors, and develop human resources through programs to respond to climate change. (3.1)
- Assess and analyze the impacts of climate change and sea-level rise on industrial and commercial activities, and discuss applicable steps. (3.2)
- Manage a database of climate change information, and research and develop technologies suitable for Vietnam. (3.3)
- Enact legislation on and establish a framework for the development of programs to respond to climate change. (4.1)
- The budget for program implementation shall be covered by the national budget, funds from MOIT, and ODA. Every year, MOIT has an allocation for its scientific and technological activities in the national budget, and shall use part of the fund to research and develop climate change measures. (4.2)
- Improve the capabilities of human resources through education provided by industry- and commerce-related organizations. Invest in equipment, such as instruments for measuring GHG emissions. (4.3)
- Focus on the research on low carbon emission technologies, especially those applicable to conditions in Vietnam. To create a program for managing a database of GHG emissions. (4.4)
- MOIT's Supervisory Committee for the National Target Program to Respond to Climate Change is responsible for supervising MOIT's implementation of the action plan to respond to climate change. The Supervisory Committee is assisted by the Standing Office. Each department shall fulfill its allocated tasks. (5.1)
- By March 15 of the year, each organization or department shall assess the outcomes of its implementation in the previous year, and submit a plan for its implementation in the following year. (5.2)

As described above, Vietnam has already taken actions to limit GHG emissions, which is very laudable. Vietnam was just positioned in the above way in 2010. It is important to see how their actions will actually be taken.

2.5.3 Situations of Other Donors' Assistance in Greenhouse Gas Emission Limitation

The report presented by Vietnam to COP 16 contains information about international projects involving global warming measures. Reported international projects are shown in Table 1.1 8.

Table 2.5-8 International projects involving global warming measures in Vietnam

Project Title	Donors	Implementing Agency
Vulnerability Assessment for Vietnam Coastal Zones	Netherlands	MONRE
Impacts of Climate Change on Water Resources and Adaptation measures	Denmark	MONRE
Ho Chi Minh City Adaptation to Climate Change	Asian Development Bank (ADB)	Ho Chi Minh City
Asian Cities Climate Change Resilience Network	Rockefeller Foundation	Can Tho City, Binh Dinh Province, Da Nang Province
Climate Change Impacts in Huong River Basin and Adaptation in its Coastal District Phu Vang	Netherlands	MONRE
Developing & Implementing CC Adaptation Measures to Increase Resilience	United Nations Development Programme (UNDP)	MONRE
Reforestation for Adaptation to Climate Change in Quang Binh Province	Germany	Vietnam Red Cross
Benefits on Climate Change Adaptation from Small and Medium scale Hydropower Plants	Denmark	MONRE
Vietnam–Netherlands Integrated Coastal Zone Management	Netherlands	MONRE
Climate Change Adaptation and Mitigation Program	Denmark	MONRE, others
Supporting Program to Respond to Climate Change	Japan, France	MONRE
Vietnam National Strategy Study on Clean Development Mechanism	Australia	MONRE
Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA)	ADB	MOIT
Biogas Program for the Animal Husbandry Sector in Vietnam (piloting in three provinces of Bac Ninh, Hai Duong and Nghe An)	Netherlands	Ministry of Agriculture and Rural Development (MARD)
Livestock Waste Management in East Asia	Global Environment Facilities (GEF), World Bank (WB)	MONRE
National Action Framework for Reduction of Emission from Deforestation and Degradation	UNDP	MARD
Vietnam Energy Efficiency Public Lighting	GEF	Vietnam Academy of Science and Technology
Energy Conservation and Efficiency in Small and Medium Scale Enterprises	GEF	Ministry of Science and Technology (MOST)
Sustainable Land and Forest Management	UNDP	MARD
Capacity Building for Clean Development Mechanism in Vietnam	Netherlands	MONRE
Community-based Adaptation to Climate Change	Canada	Thu Thien Hue Province
Expedited Financing for Measures for Capacity Building in Priority Areas	United Nations Environment Programme (UNEP)	MONRE

Table 2.5-8 International projects involving global warming measures in Vietnam (continued)

Project Title	Donors	Implementing Agency
Capacity Development for National Climate Change Focal Point	Denmark	MONRE
Mainstreaming CC into Socio-economic Development Planning	UNDP	Ministry of Planning and Investment (MPI)
Preparedness for Disasters Related to Climate Change	Netherlands	Vietnam Red Cross
Community-based Natural Disaster Risk Management	Netherlands	Vietnam Red Cross
Strengthening National Capacities to Respond to Climate Change in Vietnam, Reducing Vulnerability and Controlling GHG Emissions	UNDP	MONRE
Capacity Building Project on Climate Change for Civil Society Organizations	Finland	Civil Society Organizations (CSO)
MediaNet Program	United Kingdom	Vietnam News Agency
Community-based Adaptation to Climate Change in Quang Tri Province	UNEP	Vietnam Union of Science and Technology Associations
Vietnam's Initial Communication to UNFCCC	UNEP	MONRE
Enabling Activities for the Preparation of National Communication Related to the UNFCCC	UNEP	MONRE
Vietnam's Second Communication to UNFCCC	UNEP	MONRE
Seal-level rise Scenarios and Possible Disaster Risk Reductions in Vietnam	Denmark	MONRE

To take further global warming measures, Vietnam seems to be seeking international cooperation on nuclear power generation and CCS. Although their projects aiming for nuclear power generation are still in the pre-feasibility study stage, Vietnam plans to build and operate Reactor No. 1 in cooperation with Russia and Reactor No. 2 in cooperation with Japan in the near future, so that nuclear power generation will cover 20% of their total generating capacity.

As to CCS, Vietnam has been collecting information and discussing storage potentials in cooperation with Asian Development Bank (ADB). In a workshop held in Hanoi in January 2011, opinions were exchanged regarding current situations of CCS in the world and its technological information. According to people concerned with the Institute of Energy (IE), MOIT and MONRE, the Vietnamese government thinks that since thermal power plants are located near the shore in Vietnam, they have conditions favorable for CCS implementation. Overall, Vietnam seems to be in favor of CCS. Its current costs, however, make it difficult to commercialize CCS. Therefore, Vietnam seems to plan for the collection of information and the assessment of domestic potentials. Phu My in southern Vietnam has a fertilizer factory running a CO_2 capture project. The CO_2 capture technology used for the project is provided by Mitsubishi Heavy Industries, Ltd.

Chapter 3 Proposal of measures to curtail GHG emissions at coal-fired thermal power plants

3.1 Proposal of measures to curtail GHG emissions by improvement in the operation aspect

At present, the supply of electrical power in Vietnam is extremely tight. Because of chronic supply shortage, it is difficult for plants to shut down for durations long enough for periodic inspections which ought to be implemented. It is clear that, under these circumstances, equipment is not able to deliver the performance for which it was designed.

Taking full account of this situation, this section concerns measures that are effective for curtailment of greenhouse gas (GHG) emissions in the operation aspect. More specifically, it surveys approaches to effective utilization of energy and the factors behind them at thermal power plants (TPPs) in Japan, and sets forth cautions and points to be borne in mind for efficient operation of plants.

3.1.1 Rationalization of energy use at TPPs and approaches to curtail GHG emissions

In Japan, GHG emissions from TPPs, other plants, and other business or industrial establish-ments are regulated by the Act on Rational Use of Energy and the System for Calculation, Reporting and Public Disclosure of GHG Emissions. This section begins with a description of these two arrangements as measures for curtailment of GHG emissions in TPP operation as viewed from the perspective of laws and regulations. This is followed by a description of approaches at TPPs in Japan.

The Act on Rational Use of Energy (hereinafter referred to as the "Act"), was enacted in response to the jump in oil prices as a result of the First Oil Crisis in the 1970s. It grew out of recognition of the need to improve utilization efficiency for ability to supply the energy required for economic advancement while addressing the instability and higher prices surrounding energy supply. It provides for measures required for more efficient energy utilization in plants, transportation, buildings, machinery, and equipment, as well as measures needed for comprehensive promotion of efficient utilization, toward the objective of assisting the country's sound economic advancement.

Thereafter, as awareness of environmental problems rises, response to global warming, which is caused mainly by emissions of carbon dioxide, became a major agendum. In this atmosphere, the adoption of the Kyoto Protocol in 1997 was followed by amendment of some legislation in 1998 to make regulations in the industrial sector tougher and wider.

Approaches in the industrial sector, which includes TPPs, began with the erection of energy management systems by each enterprise to ascertain the facts of daily energy use, examine ways of making it more efficient, and promoting improvements to this end. The enterprises also are required to submit both yearly and medium-to-long-term targets for energy utilization to the regulatory agency. As this exemplifies, the hallmark of the Act is its stipulation of promotion of efficient energy utilization by the public and private sectors working together, as opposed to efforts to the same end at each plant by enterprises acting alone.

The Act prescribes items that must be addressed by enterprises utilizing energy. More specifically, it includes provisions for rationalization of energy use (Paragraph 2, Article 3), de-signation of plants for which promotion of more efficient energy utilization is particularly necessary (Article 6), and the appointment of full-time energy officers whose duties include maintenance of energy-consuming facilities, improvement and supervision of methods of energy utilization, and preparation of periodic reports and documentation related to reports on the business status (Article 7).

Figure 3.1-1 shows the general flow for rationalization of energy utilization based on the Act. The enterprises are required to prepare organizations for proper performance of energy management and take routine action to rationalize their energy utilization, beginning with the determination of the own amounts of use.

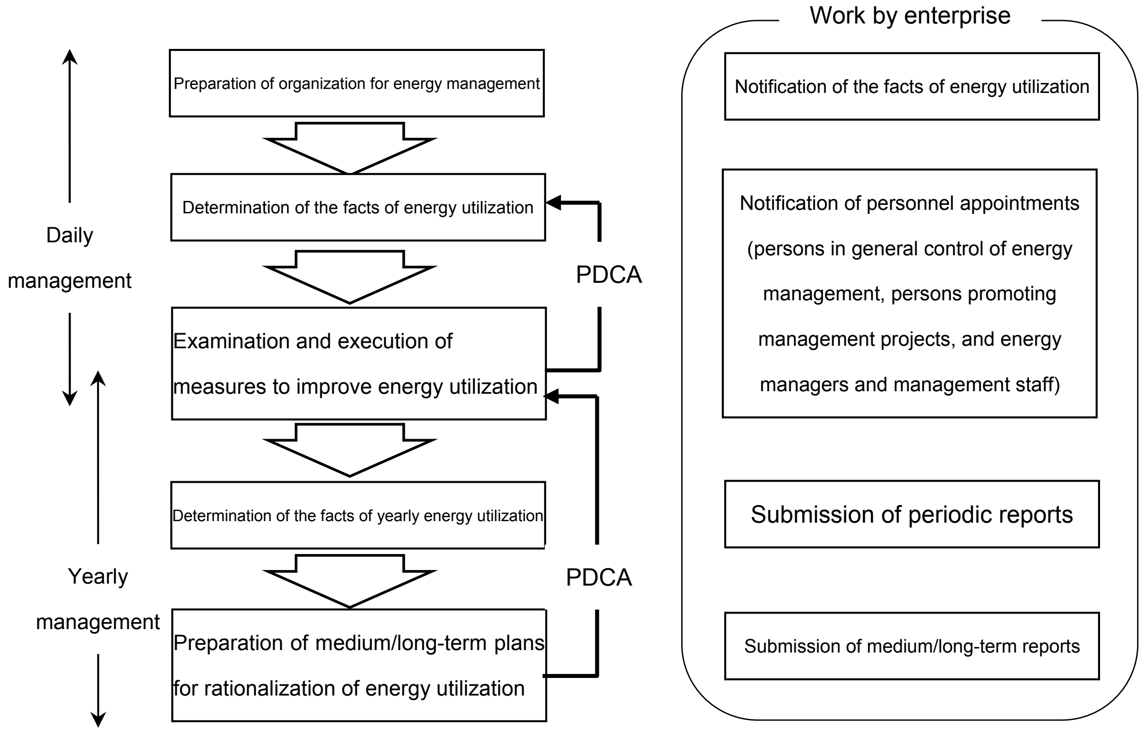


Figure 3.1-1 Flow of work related to rationalization of energy utilization (example)

In addition to the Act, Japan has introduced the System for Calculation, Reporting and Public Disclosure of GHG Emissions (hereinafter referred to as the "System") for prevention of global warming. The following is an outline of the System and the related steps being taken at TPPs.

The System requires enterprises with GHG emissions beyond a certain level to calculate the emission amounts and report them to the national government, which then compiles the reported data and announces them to the public. It has two aims, as follows.

1) Establishment of the foundation for voluntary initiatives by the emitting enterprises, by having them calculate their own emissions

Besides calculating and determining the GHG emissions, both direct and indirect, derived from their activities, the enterprises are encouraged to make ongoing efforts to curtail their emissions by performance of the PDCA cycle of drafting plans for reduction, implementing them, and checking the results.

2) Breeding of an atmosphere favoring promotion of voluntary action by the citizenry and business as a whole through information disclosure and transparency (totalization and announcement of the calculated/determined emission levels, under a certain set of rules)

The System makes the emitting enterprises aware of their own emissions and the effectiveness of their measures, to assist determination of the need for further measures and state of progress while making the status of emissions from all enterprises visible. This helps to breed an atmosphere favoring action to curtail emissions and to deepen understanding of the same.

Figure 3.1-2 shows the flow of work by enterprises in line with the System.

The System is also characterized by its coverage of non-CO_2 gases emitted in the process of fuel combustion. Enterprises must also report on their emissions of methane (CH_4), dinitrogen oxide (NO_2), hydro-fluorocarbons (HFC), perfluorocompound (PFC) gas, and sulfur hexafluoride.

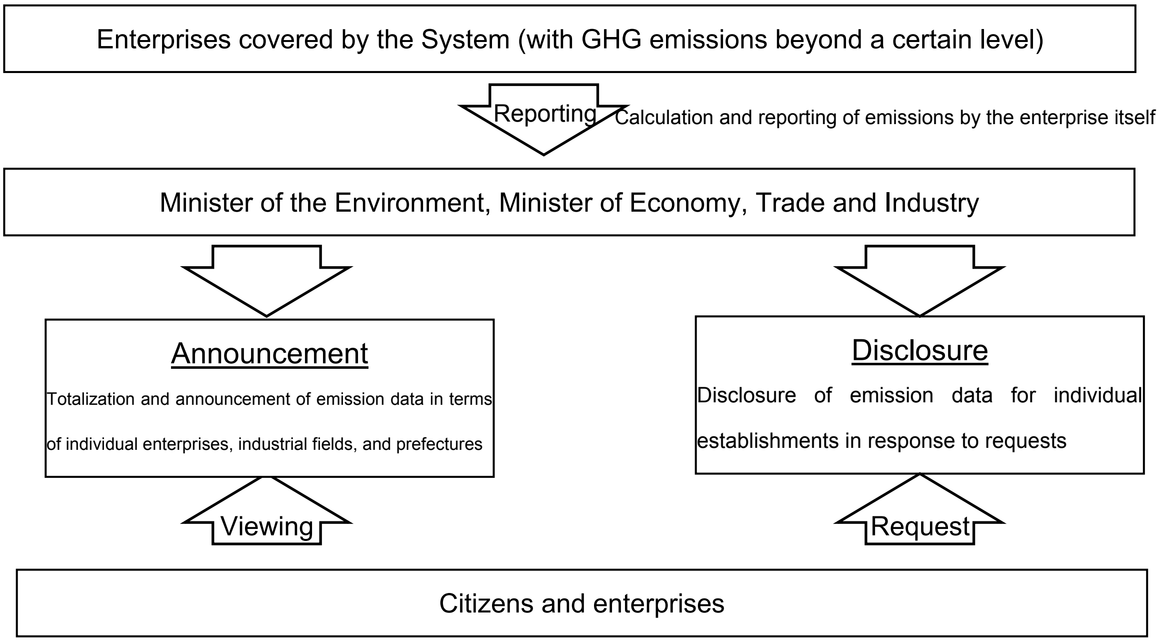
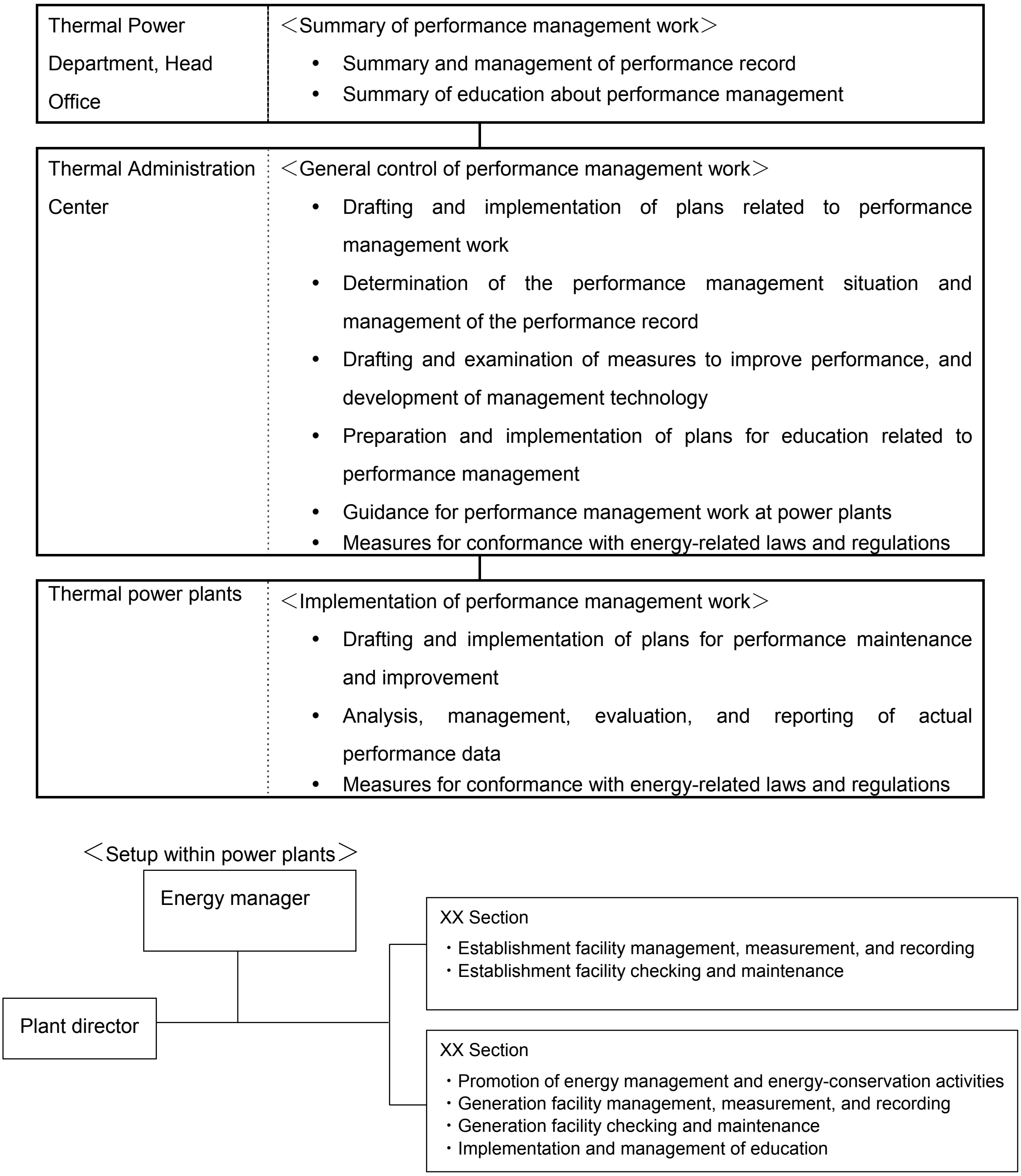


Figure 3.1-2 Flow of the System for Calculation, Reporting and Public Disclosure of GHG Emissions

The following is a profile of actual approaches being taken by Chubu Electrical power Conpany in this area.

At Chubu EPCo, the head office, the organizational unit in general charge of thermal power plants (the Thermal Power Center), and the individual power plants work together in taking ongoing approaches to effective utilization of energy. Figure 3.1-3 shows the roles of each unit involved.

Each thermal power plant has constructed a setup headed by the director of the plant, who appoints personnel to the post of energy manager, which requires certification by the national government. Each organizational unit within the plant formulates its plans for improvement of energy utilization and constantly promotes measures to save energy. To these ends, the units strive to detect abnormalities by determination of the current status and analysis of related data, and to make improvements accordingly. They are also actively providing education to heighten awareness of the need for effective use of energy.



Thermal Power Department, Head Office	＜Summary of performance management work＞ • Summary and management of performance record • Summary of education about performance management
Thermal Administration Center	＜General control of performance management work＞ • Drafting and implementation of plans related to performance management work • Determination of the performance management situation and management of the performance record • Drafting and examination of measures to improve performance, and development of management technology • Preparation and implementation of plans for education related to performance management • Guidance for performance management work at power plants • Measures for conformance with energy-related laws and regulations
Thermal power plants	＜Implementation of performance management work＞ • Drafting and implementation of plans for performance maintenance and improvement • Analysis, management, evaluation, and reporting of actual performance data • Measures for conformance with energy-related laws and regulations

＜Setup within power plants＞

Energy manager

Plant director

XX Section
・Establishment facility management, measurement, and recording
・Establishment facility checking and maintenance

XX Section
・Promotion of energy management and energy-conservation activities
・Generation facility management, measurement, and recording
・Generation facility checking and maintenance
・Implementation and management of education

Figure 3.1-3 Energy management setup

The table below shows specific items of performance evaluation.

Items of performance evaluation for whole units	• Generating-end thermal efficiency and specific heat consumption (heat rate) • Transmission-end thermal efficiency and specific heat consumption
Items of performance evaluation for major facilities	• Boiler efficiency, turbine efficiency, generator efficiency • Turbine high-pressure internal efficiency, high-pressure stage-1 internal efficiency, medium-pressure internal efficiency • Make-up water heater efficiency (TD) • Air heater temperature efficiency, leak O2, etc.

3.1.2 Instatement of target-based operation management

To a certain degree, a decline in efficiency at all of the TPPs covered in this study is unavoidable given the deterioration of their facilities with age and other issues. The Study Team would nevertheless like to propose target-based operation management as a means of curtailing GHG emissions.

Target-based operation management begins with the advance establishment of target values for major parameters such as main steam temperature and reheat steam temperature in generator output. Comparisons are then made between the actual operating values and the target values. In the event of significant discrepancy between the two, steps are taken to bring the former closer to the latter. The point is to operate the facilities so that the unit efficiency is constantly at its highest.

When the gap between the actual and target values cannot be narrowed by measures taken by the controllers, an examination is made to ascertain the facts and the cause, and to make plans for repair etc. Generally speaking, the targets are indicators for the maximum values for plant efficiency. As such, there is no need to shut down the plant immediately even if gaps open up between the target and actual values for some reason. To a certain extent, studies can be made to determine the cause of the gap while keeping the unit in operation in some cases. This approach therefore has a big effect for allowing contribution to the stability of power supply from the plant.

Table 3.1-1 shows examples of items of target-based operation management.

Table 3.1-1 Items of target-based operation management

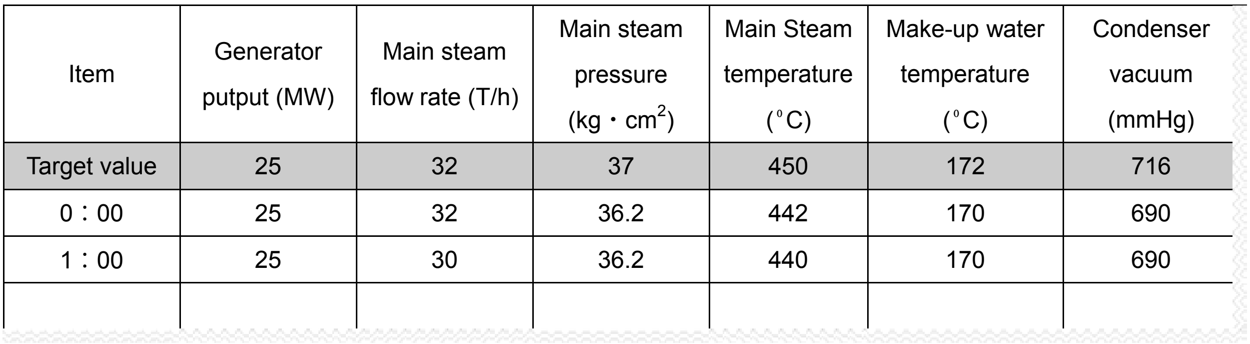
Items	Management targets	Prospective influence
Main steam pressure	Rated pressure	Increase in loss due to pressure drop
Main steam temperature	Rated temperature	Increase in loss due to temperature drop
Reheat steam temperature	Rated temperature	Increase in loss due to temperature drop
O2 consentration of ECO exhaust gas	Rated concentration	Increase in loss due to concentration increase
Electric energy output	Rated output	Definition of shortage from the target as loss
Degree of condenser vacuum	Rated value	Increase in loss due to drop in vacuum
RH spray flow rate	0 t/h	Increase in loss due to spray injection

Specifically, operators record values for the items in the table every hour, on the hour. Each time, they check these values against the targeted ones. If there is a significant gap, they take appropriate measures to improve the status of the operation, and otherwise endeavor to keep the facilities operating in a manner that maximizes efficiency.

The following are the key points in the aforementioned checks of items made by operators.

- Determination of values for the operating status in correspondence with electric energy output on a daily basis
- Determination of target values in every output range to provide the basis for comparison
- If the actual value differs significantly from the target and ordinary values: investigation to determine the cause, taking account of the possibility of some abnormal occurrence
- If the gap between the actual and target values cannot be narrowed by measures taken by operators: investigation to determine the circumstances and cause, and forwarding of a request for repair to the unit in charge of repair

At all of the TPPs covered in the study, operators record values for the major parameters every hour, on the hour. The log sheet could be improved as shown in Figure 3.1-4 to make the target values clear at a glance. This would facilitate decision on whether the recorded values are appropriate at the time they are taken.



Item	Generator putput (MW)	Main steam flow rate (T/h)	Main steam pressure (kg・cm^2)	Main Steam temperature (°C)	Make-up water temperature (°C)	Condenser vacuum (mmHg)
Target value	25	32	37	450	172	716
0：00	25	32	36.2	442	170	690
1：00	25	30	36.2	440	170	690

Figure 3.1-4 Improvement of operating log sheets (example)

While it is extremely important to ascertain the status of the operation in correspondence with electric energy output on a daily basis, understanding of methods for obtaining approximate values is also an effective means for early detection of abnormalities in the operation.

The following are examples of formulas for calculation of approximate values at Chubu EPCo.

* Examples

- Make-up water flow rate electrical energy output (MW) × 3

- Condensed water flow rate electrical energy output ×2

- Fuel flow rate electrical energy output ×0.2

- Nth-stage extraction pressure N - 1-stage extraction pressure × 0.5

The following are perspectives on the management of condenser vacuum as one of the means of dealing with departures from target values.

The propriety of the condenser vacuum value is ordinarily assessed with reference to the vacuum deviation value. Two conceivable factors behind the worsening of the vacuum deviation value are suction of air into the condenser and grime in the condenser capillary tubes.

Generally speaking, suction of air into the condenser is manifested in a rapid worsening of the vacuum deviation value, and grime in capillary tubes is usually reflected in a comparatively moderate trend of decline in the vacuum deviation value.

If the capillary tubes are grimy, it may be possible to improve the vacuum deviation value by steps such as increasing the frequency of cleanings with the condenser ball cleaning unit or changing the material used in the cleaning balls (i.e., using hard balls).

If such steps fail to improve the vacuum deviation value, a request may be made to the maintenance division for washing of the capillary tubes for attainment of a certain deviation, for example, the vacuum deviation value after the previous ball washing.

It is comparatively easy to recover the vacuum deviation value by washing the capillary tubes. Therefore, it may be effective (as viewed from the perspective of supply stability) to execute the cleaning before summer or other times of heavy load, as a kind of preventive maintenance.

If the values for main steam pressure, main steam temperature, and reheat steam temperature depart significantly from the target values, settings can be adjusted upon confirmation of the gap and detection error. If the value for ECO exhaust gas O_2 departs significantly from the target value, it may be possible to make adjustments with the burner damper in addition to setting adjustments, provided that there is a gap in terms of the A/B furnace.

3.1.3 Management procedure for storage of coal

The Ninh Binh plant burns anthracite. Upon extraction from mines in the northern part of Vietnam, this anthracite is transported to the plant by river. In northern Vietnam, the rainy season lasts from May to around September, and a stable supply of fuel is assured during this period by keeping a constant pool of 30,000 tons of coal in the roofed coal yard. The main change in properties that could conceivably occur after storage is an increase in moisture due to rain. Excessive moisture could cause a decline in the mill temperature. To prevent this from happening, it is important to determine a procedure for management upon storage of the coal. Table 3.1-2 introduces major rules.

Table 3.1-2 Cases of procedure for coal storage management

Type of management			Items	Examples of items of confirmation and rules
Coal loading	Coal storage	Coal conveyance		
○			Check of packing in transport from the mine	Whether the load is securely covered to protect it from rain on the ship or not.
○			Confirmation of properties of fuel purchased	Confirmation of fuel condition and properties. Whether the load meets the purchasing specifications or not.
○		○	Operation in correspondence with the amount of rain water	Example: temporary suspension of loading at a rain intensity averaging 2 mm in 10 min., and total suspension of loading and masking of loads on the ship in the case of continuing rain at an intensity of 3mm in 10 min. Whether the judgmental standards applied by superiors being followed by personnel on the site or not.
	○		cope of stowage in the roofed coal yard	Whether the stowage scope is large enough so that loads fit completely under the roof and are not exposed to rain or not.
	○		Establishment of the storage period	Prevention of changes in properties by contraction of the period from completion of stowage to conveyance
	○		Monitoring of temperature	There are no apprehensions about generation of heat because the volatility is low, but caution must be exercised when the type of coal changes
○		○	Confirmation of the belt conveyor status	Operation without coal to decide whether or not the belt is dry enough.
○		○	Comparison of coal properties	- Comparison of the fuel condition at the time of loading and the time of conveyance - Establishment of an operation procedure adapted to the fuel condition

It is important to make rules for storage of the fuel used, in order to keep it in optimal condition. Operation of a high-efficiency plant requires clear definition of judgmental standards extending to detailed items.

3.1.4 Construction of a setup for management of the performance of auxiliary machinery

Thermal power plants have many pieces of auxiliary machinery. These pieces influence each other in operation, and collectively make up the overall operation of the plant. As a result, even if efficiency is maintained in the turbine proper, for example, a decline in the efficiency of related auxiliary machinery can possibly bring down the turbine efficiency. At the Ninh Binh plant, operators make a record of the operating status of major equipment every hour, on the hour (with reference to items such as electrical current, flow rate, pressure, and temperature). The effective use of these data is linked to improvement of the plant operation and efficiency, and the following are some examples.

Make-up water heaters have an immense influence on thermal efficiency in the turbine cycle, and they are a type of equipment that is critically important for improvement of plant efficiency. It is comparatively easy to manage the performance of make-up water heaters, and the Study Team therefore decided to propose the related management procedure.

With the passage of time, scales build up in the capillary tubes of the make-up water heaters. This can cause trouble, such as a reduction in the amount of heat exchange and leakage from capillary tubes.

In the ideal status, make-up water heaters transfer all of the heat without any temperature difference. In other words, the most ideal status would be to have no difference of temperature between the steam inside the heaters and the make-up water at the heater outlet. Nevertheless, in the process of the transfer of heat between the steam and the make-up water, which actually have different temperatures, there is a substantial loss of heat. This loss is worsened by a decline in the heat transfer rate due to factors such as grime accumulating within pipes with the passage of time.

The performance of make-up water heaters can be assessed with reference to the terminal temperature difference (TD), drain cooling approach (DCA), and water temperature rise (WTR).

In the case shown in Figure 3.1-5, these indicators can be defined as follows.

The TD value indicates the difference between the saturation temperature relative to the make-up water heater inlet steam temperature and the make-up water temperature at the heater outlet. A decline in the make-up water heater performance lowers the rise in temperature of the make-up water at the heater outlet (condenser side), and this shifts the TD in the positive direction.

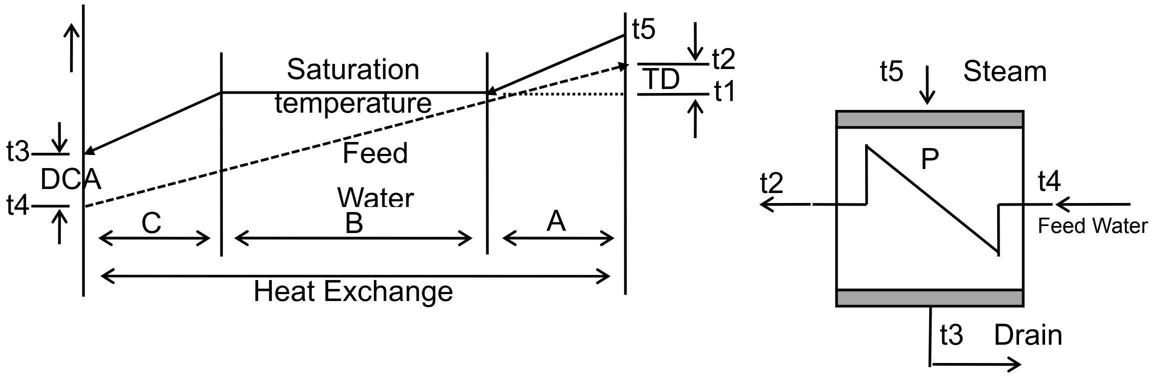
The DCA value is defined as the difference between the make-up water outlet drain temperature and the make-up water heater inlet temperature. If this difference is small, the loss may be considered low. The value can be obtained with comparative ease. In general, the DCA value's degree of influence on the make-up water heater is about 10 percent as high as the TD value. It is handled as a reference.

The WTR value is defined as the difference between the make-up water heater outlet feed-water temperature and the inlet temperature. By monitoring the change over time in this difference, the plant can apprehend the decline in performance of the make-up water heater (i.e., the decline in heat exchange efficiency).

Of these three values, determination of the change in the TD value is the most effective way to assess performance of make-up water heaters. In addition, a comprehensive assessment can be made by ascertaining the DCA value, which has a comparatively wide range of fluctuation.

Table 3.1-3 shows other indicators for management of auxiliary machinery performance.

$$TD = t1 - t2 \qquad DCA = t3 - t4 \qquad WTR = t2 - t4$$



A:de-super Heating zone B:Condensing zone   C:Drain Cooling zone
t1: Saturation temperature to water feed hnlet steam pressure(degree) t2: Water feed outlet temperature(degree）t3:Drain outlet temperature(degree) t4:Water feed inlet temperature(degree) t5:Inlet extracttion temperature(degree)

Figure 3.1-5 Calculation of performance in make-up water heaters (example)

Table 3.1-3 Examples of indicators for management of auxiliary machinery performance

Auxiliary machinery name	Performance management indicator	Outline
Air Heater	Air preheater temperature efficiency	Control of the amount of change in inlet and outlet temperatures on the air and gas sides
	Air preheater leakage O_2	Management of O_2 at the stack inlet and ECO outlet
	Air preheater cold end temperature	Management of the average value for the air heater outlet exhaust gas temperature and inlet air gas temperature
Condenser	Degree of condenser vacuum	Management of deviation from the prescribed standard value
	Degree of condenser washing	Management of the ratio of the actual overall heat transmission rate and standard overall heat transmission rate; the overall heat transmission rate declines due to the influence of sludge and grime building up on the inner walls of condenser pipes with the passage of time.
Major ventilators and pumps	Ventilator and pump efficiency	Management of the ventilator and pump efficiency on major auxiliary machines

3.2 Recommendation of measures to curtail GHG emissions through improvement in the maintenance aspect

The Study Team checked the external appearance of the facilities, questioned plant personnel about them, and examined the records of checks and repairs. As a result, there was found to be room for improvement for the reduction of GHG emissions with respect to certain items. The following sections present recommendations for each of the items.

3.2.1 Boilers and environmental facilities

(1) Boilers

-Chemical cleaning of boilers

In and before 2000, the Ninh BinhThermal Power Plant frequently experienced unit suspension due to the rupture of furnace wall pipes. This can be traced to the high level of impurities contained in boiler water, which led to the adherence of scales inside the furnace wall pipes. The scales not only lowered the heat transfer efficiency but also ultimately caused the rupture of pipes because of overheating of the walls. In response, the plant made a large-scale replacement of pipes in 2000 while adding an ion exchange tower to the water treatment facilities to raise the quality of make-up water and to curtail the formation of scales on inner pipe walls. These steps reduced the frequency of pipe ruptures.

At the Uong Bi Thermal Power Plant, boilers were cleaned through alkaline washing every 2 years regardless of the amount of scale adherence. Alkaline washing was selected mainly to minimize the impact of cleaning on boiler tubes, but the cleansing ability was weak compared with acid washing.

As a result of investigation, it was confirmed that each power plant was using a different method with regard to chemical cleaning of boilers. Although all the plants were measuring the amount of scale adherence on inner pipe walls and removing them by cleaning them with air blowers on the occasion of periodic checks, it was difficult to remove the scales only by this cleaning method. Because it is also difficult to replace the piping, it would be most effective to remove scales by chemical cleaning at an optimal interval. The following shows the recommendable chemical cleaning method (alkaline copper removal [ACR]) for boilers.

The timing of chemical cleaning is decided by the scale thickness and amount of adherence.

The standards shown in Table 3.2-1 have been set for each unit.

Table 3.2-1 Boiler type and scale adherence standards

Output (MW)	Type	Fuel	Pressure - Class	thickness (microns)	Amount of scale adherence (mg/cm^2)
375	Forced circulation	LNG	critical	200	45
375	Forced circulation	Heavy crude oil	critical	200	45
375	Natural circulation	Heavy crude oil	Critical	232	52

Before the chemical cleaning, examinations are made to determine the most effective and appropriate duration for it. This is done by, among other things, preparing forecast curves for scale adherence based on the operating duration using the future unit operating rate as well as on overall data for items such as the scale status (amount and constitution) as determined by samples cut off from pipes, the temperature of metal on the furnace wall, and operation duration.

It is also necessary to make comprehensive judgments on matters such as the extent of increase, if any, in pressure loss from steam generator tubes, whether or not the coal economizer inlet feed water pressure is approaching the limit, and the relative size of pressure loss due to the scale status.

For additional information, Figure 3.2-1 shows the relation between operating duration and scale thickness at a coal-fired thermal power plant under the jurisdiction of Chubu EPCo. Even if it is confirmed that the amount of scale adherence has not reached the chemical cleaning target at the time of regular checking, chemical cleaning should be performed as a preventive means if it is predicted that the amount will exceed the target during operation before the time of next checking.

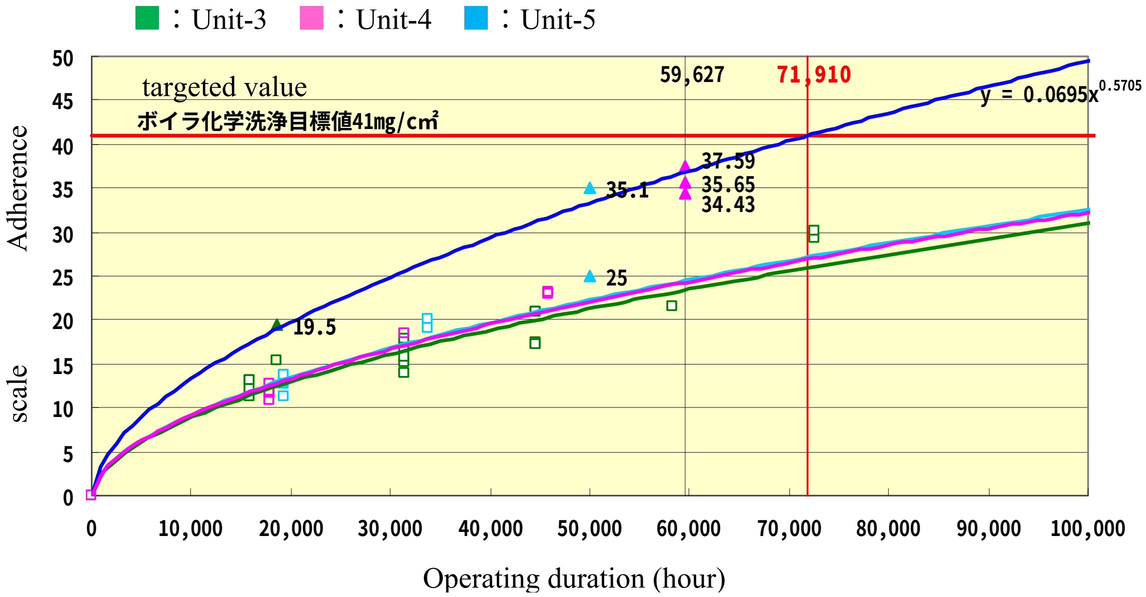


Figure 3.2-1 Relation between operating duration and scale adherence (HekinanTPP, units 3 - 5)

Figure 3.2-2 shows the workflow for the chemical cleaning of boilers. At the Uong Bi Thermal Power Plant, alkaline washing, which was weak in cleansing ability, was selected in consideration of the impact of cleaning on boiler tubes, but acid washing can also be conducted without problems by cleaning sample tubes in a solubility test and examining the optimal duration of acid cleaning in detail.

Step-1 ↓	Preliminary study	Specimen taken from the pipe, scale examination, and liquefaction test
Step-2 ↓	Preliminary work	Examination of chemicals, installation of provisional equipment and piping
Step-3 ↓	Chemical washing	Filling of the boiler with water, temperature increase, injection of chemicals, washing, cooling, rinsing with water, interior inspection, final rinsing with water
Step-4	Post-washing work	Removal of the provisional equipment and piping, and treatment of the waste liquid

Figure 3.2-2 Flow of chemical washing of boilers

As a representative example, the duration of chemical cleaning required for the unit 1 of Ninh Binh Thermal Power Plant, where the inlet gas temperature on the secondary air preheater was slightly high at 485 °C as compared to the design value of 467 °C. This indicates that the absorption heat performance of the boiler is low.

The replacement of furnace wall pipes at the Ninh Binh Thermal Power Plant was made about 10 years ago, and the plant operates for an average of about 8,000 hours a year. Hekinan Unit 4 has about the same number of annual operating hours, and its boiler was chemically washed about 8 years after it commenced operation. Assuming that the amount of scale adherence at the unit 1 of Ninh Binh Thermal Power Plant is about the same as at Hekinan Unit 4 (scale adherence: about 38 mg/cm2), chemical cleaning for about 9 hours could presumably remove all of the scales on inner pipe walls. Including the time required for preparations, the whole process could be completed in about 3 days. Figure 3.2-3shows the results of scale removal at the Hekinan Unit 4.

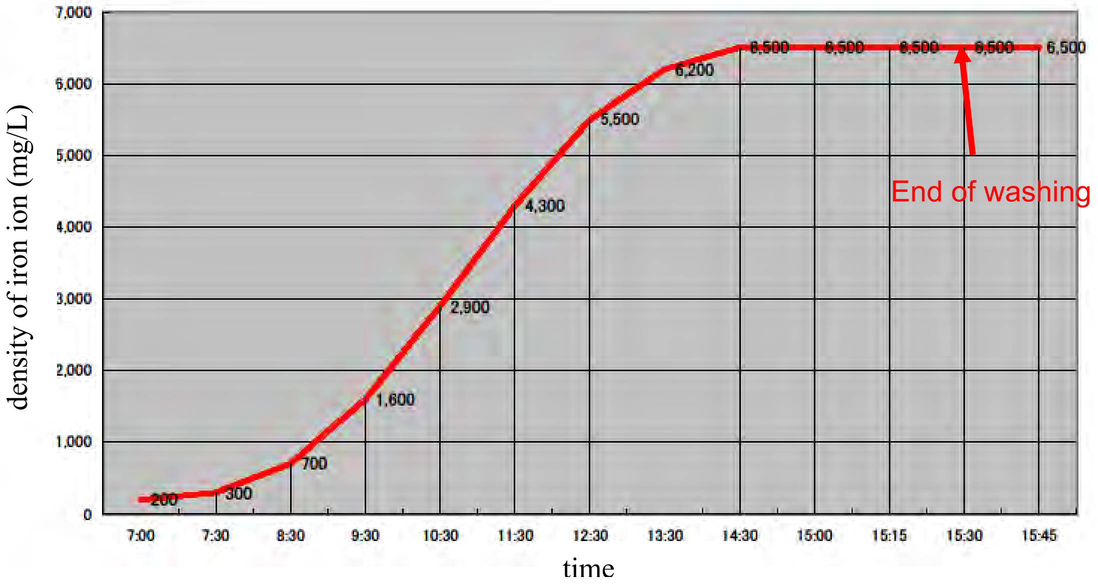


Figure 3.2-3 The results of scale removal (Hekinan Thermal Power Plant, unit 4)

-Combustion simulation

At the Uong Bi Thermal Power Plant, the combustion efficiency and operation rate have been remarkably declining due to problems caused by the adherence of ash inside the furnace, and problems due to defective designing and manufacturing such as the lack of detailed design for the coal to be used, have been identified. Moreover, it is difficult to identify the optimal combustion condition because of large variations in the quality of coal to be used, and problems related to boiler operation seem to be contributing to lower efficiency. To solve these problems, the equipment could be repaired or remodeled to substantially improve the efficiency, which however requires huge cost and a long work period.

On the other hand, improvement by changing the operating condition can be made at a lower cost with immediate effects.

Based on this recognition, the Study Team proposes to carry out combustion simulation analysis with a view to improving combustion efficiency by reviewing the present operating condition of each boiler.

The FLUENT thermo-fluid analysis software for general use represents high-precision simulation technology that incorporates a coal combustion model built independently by Idemitsu Kosan Co., Ltd. and is widely utilized for thermo-fluid analysis including the analysis of reactions.

A standard combustion model adopts a sequential reaction model in which char combustion begins after volatile emission, and if this model is applied to pulverized coal combustion, it would be difficult to predict the unburnt carbon rate in high precision because of the frequent blow-off of flames. In contrast, the FLUENT additionally incorporates a parallel reaction model in which char combustion takes place in parallel with the volatilization process as in real pulverized coal combustion. Figure 3.2-4 shows an analysis example.

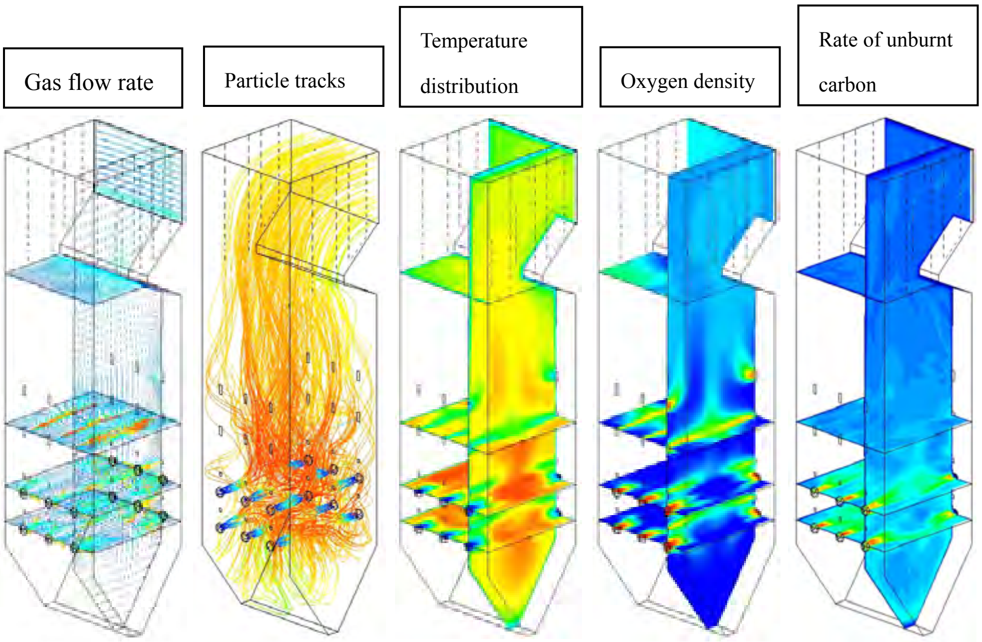


Figure 3.2-4 Combustion simulation-based boiler analysis example

The steps for combustion simulation analysis are shown in Figure 3.2-5. As the first step, a geometric structure (grid) is to be established based on the boiler dimension as well as on the burner and air port alignments and structures in order to obtain structural data for the targeted boiler. Next, the pulverized coal supply amount and the flow volume and temperature of combustion air will be set as boiler operating values. Based on these conditions, a range of data, including the gas flow rate and particle tracks will be obtained through flow calculation, heat-transfer calculation, and combustion-reaction calculation.

Because it is very risky to make substantial changes to the operating condition of an actual boiler, it is difficult to identify the optimal operating condition and find out the methods to prevent problems only based on actual operation data. In contrast, combustion simulation analysis enables to make various simulations for the gas flow rate, particle tracks, temperature distribution, oxygen density, and rate of unburnt carbon as shown in Figure 3.2-4, which in turn will make it possible to quantify the influence of changing the operating condition and examine the optimal combustion condition.

Input of the boiler structural data	···	Boiler dimension and burner and air port alignments and structures
⇩		
Settings for boiler operation	···	Pulverized coal supply amount, particle size distribution, combustion air flow volume and temperature, coal property Burning rate constant, heat transfer coefficient of the furnace heat transfer surface, tube surface temperature
⇩		
Simulation calculation	···	Flow calculation, heat transfer calculation, combustion reaction calculation
⇩		
Output	···	Gas flow rate and status, particle tracks, furnace temperature distribution, gas temperature, unburnt carbon distribution
⇩		
Verification of prediction accuracy	···	Boiler outlet temperature, oxygen density, rate of unburnt carbon (combustion efficiency), NOx and SOx concentration
⇩		
Utilization	···	udgment of optimal operating condition, prediction of the impact of changing coal types, reduction of unburnt carbon (higher efficiency), reduction of NOx and reduction of clinker problems

Figure 3.2-5 Steps for combustion simulation analysis

-Reviewing the performance management method for air preheaters

As for heat exchange in a single air preheater, the performance management method differs by power plant, but generally, there was no major change in the gas and air inlet and outlet temperatures as compared to the time of normal operation, but limit values have not been established for checks and cleaning. In the management of preheater performance, the Study Team recommends the adoption of efficiency obtained by the equation shown below as an indicator to be used in examining the need for cleaning when the unit is shut down.

$$\eta_G = \frac{Tg_1 - Tg_2}{Tg_1 - Ta_1}, \quad \eta_A = \frac{Ta_2 - Ta_1}{Tg_1 - Ta_1}$$

η_G : Temperature efficiency on the AH gas side
η_A : Temperature efficiency on the AH air side
Tg_1 : AH inlet gas temperature (°C)
Tg_2 : AH outlet gas temperature (°C)
Ta_1 : AH inlet air temperature (°C)
Ta_2 : AH outlet air temperature (°C)

It may also be noted that, at the low-temperature part of the rear side inside the air preheater, temperatures approach the exhaust gas dew point temperature, and inspection found pipe and element damage due to corrosion and a decline in heat transfer efficiency. The Study Team recommends that the average temperature at the air preheater low-temperature end as shown by the equation below be kept above the exhaust gas dew point temperature in normal operation. This will help to prevent corrosion on the low-temperature part.

Average temperature at the AH low-temperature end =
((AH outlet exhaust gas temperature) + (AH inlet air temperature)) / 2

As for units that adopt heat-conduction, tube-type air preheaters, pipes are damaged by corrosion on the low-temperature parts even at present. The unit must be shut down if holes open in the pipe as a result. The air preheater efficiency could also conceivably be lowered by the leakage of air into the gas side due to minor damage that goes unnoticed in operation. To prevent this from happening, it would be effective to inspect the interior of pipes using a CCD camera or fiberscope on the occasion of periodic checks and make an assessment of the remaining pipe service life based on inspection for damage by eddy-current or ultrasonic testing. Several such inspections will provide footing for the calculation of the speed of pipe thinning. The standard for replacement must be established using the following equation.

Replacement standard : 0 > Remaining wall thickness – ((Designed thickness – remaining thickness) / operating time) × Estimated operating time until the next checking

As for regenerative air preheaters, it is necessary to number each of the baskets and check their deterioration tendency to identify the element deterioration levels. Also by inspecting the representative baskets in detail and set the evaluation indexes (1 to 100), it is possible to set clear criteria, such as “to be replaced in the next checking if the index is 50 or higher” and “to be replaced now if the index is 70 or higher.”

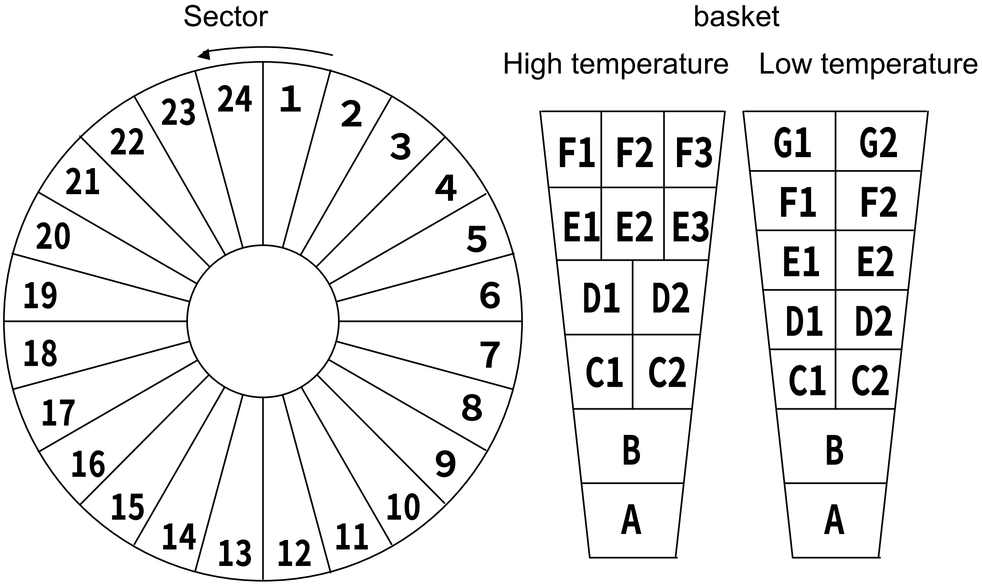


Figure 3.2-6 Element management

-Reviewing the checking interval for machinery

At present, values and pipes are checked at the same interval as machinery, and are not managed separately. For this reason, there is some excessive maintenance: parts that were repaired during normal operation are rechecked on the occasion of periodic checks. Furthermore, because a clear definition has not been made of the scope of parts belonging to a given machine, there arise differences of checking scope depending of the checker, and some parts go unchecked as a result. To resolve these problems, the plant should prepare a management table for each and every part checked, inclusive of values and pipes, and properly manage maintenance. This is important to prevent the action of factors reducing unit efficiency, such as steam and gas leaks. In management of each part that undergoes checking, it is important to establish a checking interval for each with consideration of the degree of deterioration associated with the frequency of failures, based on past experience and differences of site (indoors versus outdoors), and to carry out the checks accordingly.

As a reference, with regard to the machines that have often caused problems at power plants in Vietnam, the following shows a checking management table used by Chubu EPCo.

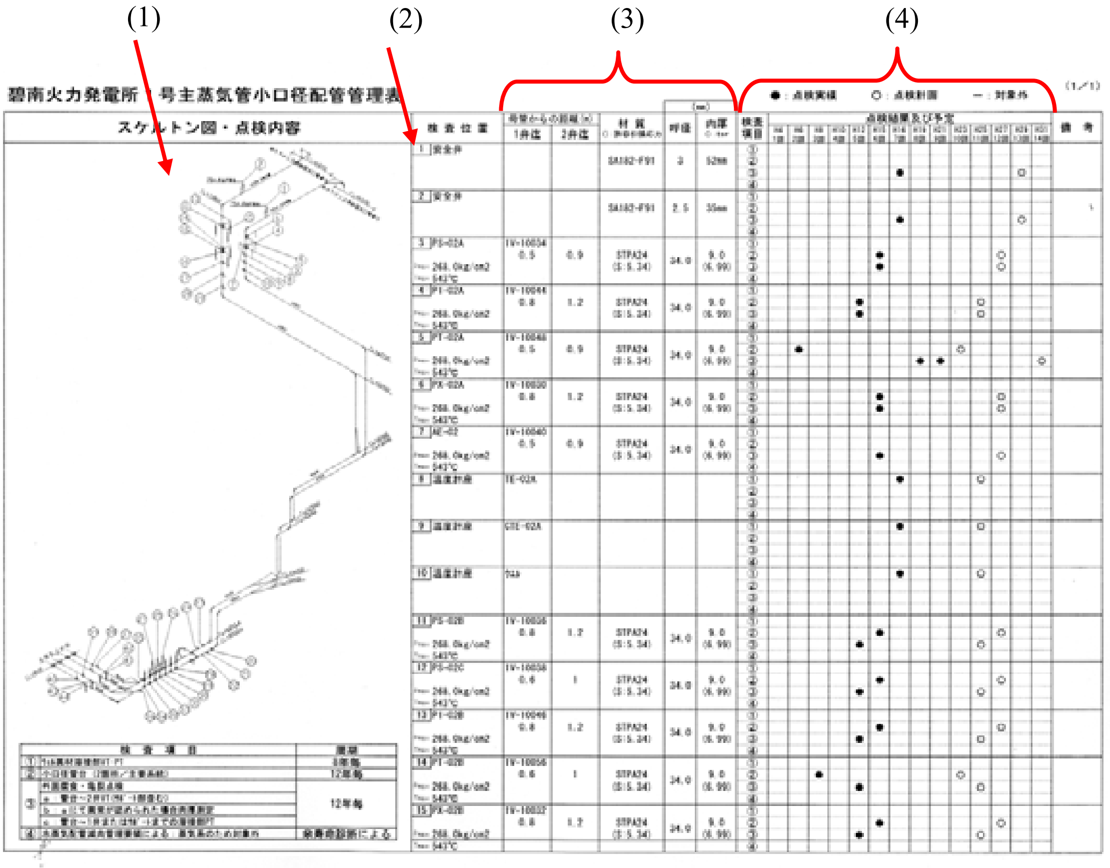


Figure 3.2-7 Pipe checking management table at Chubu EPCo

Figure 3.2-7 shows a pipe checking management table and (1) in the table shows the shapes of the pipes. In (2), the pipe welded parts and others that need to be checked are numbered to clearly show the points to be inspected. (3) shows the specifications of materials, dimensions and others of the points to be inspected and (4) shows the checking history and future checking schedule.

As for a checking management table for pulverized coal pipes that have often caused leak problems at power plants in Vietnam, it is necessary to add pipe thickness measurement data and thinning speed to the data to be included in the table to make it possible to examine the timing of next checking based on the table.

As for valves for which steam leaks have been frequently identified, it would be effective to record the leaks in the checking history and set the checking intervals in consideration of the problem frequency and operational importance and to conduct checking in a planned manner. This will improve equipment reliability and unit efficiency by preventing any part from being left unchecked.

3.2.2 Turbines

(1) Main turbines

The Study Team did not confirm the record for the management of the erosion status of rotor and stator blades. At each power plant, the final stage of rotor blades has been replaced. It is consequently thought that there is erosion also on other rotor and stator blades. Scales might also be attached to rotor and stator blades. Turbine efficiency can be improved by managing records for the erosion status in the form of charts and executing systematic replacements, repair of stator blade welded parts, and blast processing of rotor and stator blades. The following shows the management items as well as checking and repair methods for stator blades.

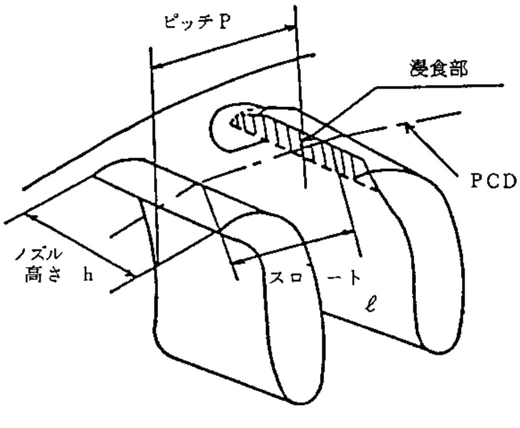
i. Management items and checking and repair methods

The table below summarizes the important points.

Table 3.2-2 Management items and checking and repair methods for stator blades

Management item	Checking method	Repair method
Nozzle plate cracking	Visual check and PT	(1) Cutback (2) Cutback and weld shaping (3) Cutback for GE's crack length=below 1/8 inch and weld shaping for the case of over 1/8 inch
Nozzle plate erosion	Visual check and dimension measurement	(1) Cutback (2) 10% or more increase in nozzle area: weld shaping
Nozzle plate deformation and dent	Visual check and dimension measurement	(1) Adjustment by cutting/shaping

ii. Nozzle area



Throat length l:

Minimum dimension part between the nozzle plate steam outlet end and nozzle back side on PCD

Figure 3.2-8 Nozzle area calculation method

(1) Nozzle area (S)

$S = l \times h$……………… (1)

(2) Increase in nozzle area ($\triangle S$)

$\triangle S = ((l_1 \times h_1) / (l \times h) - 1) \times 100\ (\%)$

l_1 , h_1 : Actual value

l , h : Design value

(3) Tolerance for increase in nozzle area

Recommendation by a manufacturer (Toshiba): 10% per piece
5% per layer

iii. Nozzle plate weld surfacing frequency

Increase in welding frequency leads to material deterioration due to the removal of stress and thermal impact from annealed welding, and the hardness of the base material decreases. The welding repair frequency should therefore be limited.

- (1) Recommendation by Toshiba: Up to 5 times
- (2) Recommendation by Hitachi: Up to 3 times
- (3) Target set by Chubu EPCo: Up to 4 times

(2) Feed water heater

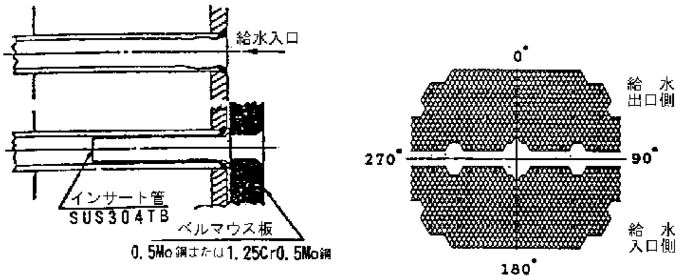
Implementation of preventive maintenance by means such as eddy-current probes and advance plugging of problem tubes at the time of periodic checks could reduce the loss of efficiency due to tube leakage and to operation bypassing the feed water heater, as well as hindrance of the unit operation due to output curtailment. The phenomena of leakage from heater tubes, the factors behind them, and the inspection procedures may be broadly classified as shown in Table 3.2-3. For each phenomenon, eddy-current testing is an effective inspection method.

Table 3.2-3 Factor analysis table for use in the event of feed water heater leakage

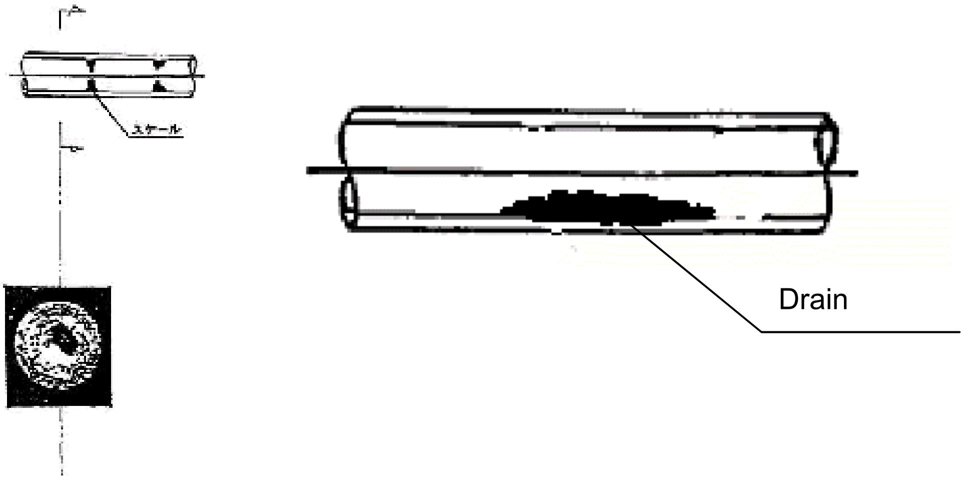
Phenomena	Factors	Items of inspection and confirmation
Erosion on the inner wall of tubes at the feed water inlet	Inlet attack due to feed water	• Leak test • Eddy-current test • Inner UT • Check by fiberscope
Stress corrosion cracks (SCC)	SCC near the U-vent	• Leak test • Eddy-current test
Thinning and pitting on the inner wall of tubes	Corrosion and thinning due to standing water on the inner wall during shutdown	• Leak test • Eddy-current test • Inner UT • Checking by fiberscope
Tubes at the bleeder inlet Erosion on the outer surface	Thinning and erosion due to the flow of steam at the bleeder inlet etc.	• Leak test • Eddy-current test • Inner UT • Checking by fiberscope (Opening of holes in the shell)
Outer surface of tubes Drain attack	Erosion due to the flow of steam in the condensation drain etc.	• Leak test • Eddy-current test • Inner UT • Checking by fiberscope (Opening of holes in the shell)

Figure 3.2-9 below shows the parts where these various phenomena arise.

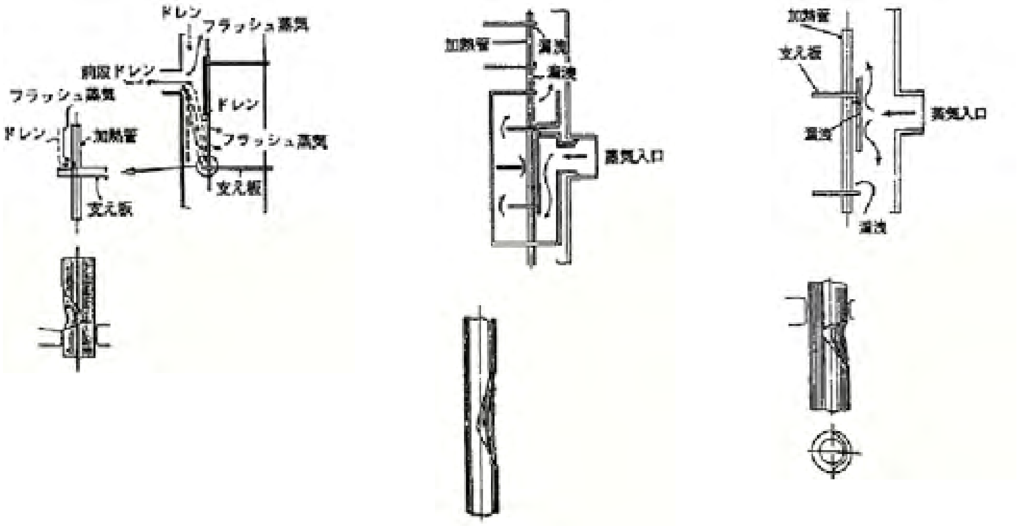
< Inlet attack >



< Corrosion and thinning due to standing water on the inner wall during shutdown >



< Drain attack >



< Inlet drain >　　　< DSZ outlet >　　　< Heating steam inlet >

Figure 3.2-9 Outline of phenomena in the event of occurrence of tube leakage

< Eddy-current test >

Eddy-current test is the test that checks the material properties or finds defects etc. The test is a detection method that utilizes electromagnetic induction. There are two methods: synchronized detection and phase analysis. As shown in Figure below, passing an alternative current through a coil situated near a metallic material causes an eddy current in it due to electromagnetic induction. Such defects as cracks or any variation in the material properties would change the eddy current, changing the impedance of the coil.

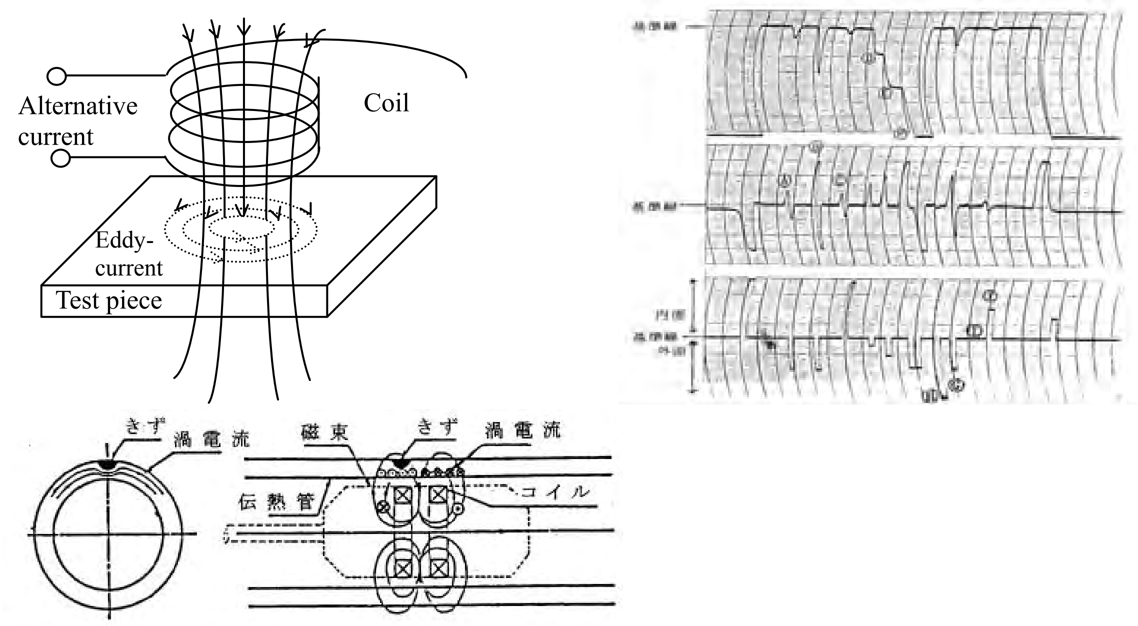


Figure 3.2-10 Outline diagram of eddy-current testing

In the case of the water feed outlet terminal temperature difference (T.D.) of feed water heater increases, cleaning inside capillary tubes will improve thermal efficiency. The washing procedures may be broadly classified as shown in Table 3.2-4.

Table 3.2-4 Procedure for washing of capillary tubes

Mechanical cleaning	Water jet washing
	Sponge washing
	Brush washing (including washing by hand Cleaner)
Chemical cleaning	Alkali washing
	Acid washing

Of these washing procedures, the Study Team recommends water jet washing, which is adopted by Chubu EPCo and is yielding favorable results.

< Outline of water jet washing >

The plunge pump on a super high-pressure washing car is used to raise the water pressure to around 25.0MPa (the pressure is selected in line with the withstand pressure of the heater). The high-pressure water is sprayed from the jet nozzle, and the force of impact by this water removes the scales on the inner walls of capillary tubes.

Jet washing has the benefit of enabling removable of even fairly hard scales.

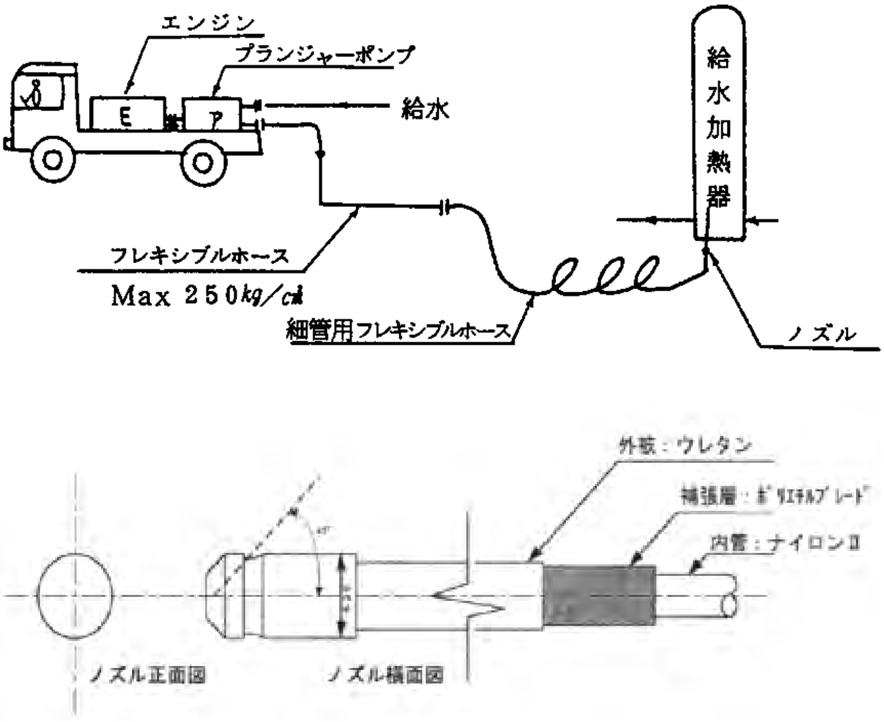


Figure 3.2-11 Outline diagram of water jet washing

In implementation, attention must be paid to the following points.

- If an insert pipe has been installed to prevent inlet attack in the heating tube, do not directly spray the tube plate surface of the insert pipe (in order to prevent deformation etc.)
- Check the record to see whether or not there are unwashed tubes, by the notation of the number of tubes washed.
- Check the amount of scale noted in the record.

(3) Condensers

The degree of vacuum in condensers may not recover even after ordinary washing with brushes. In this case, performance can be improved by water jet washing, as for feed feed water heaters.

At some power plants, the amount of air sucked into the condenser was being measured and the excessive suction amount was considered a problem. Nonetheless, it seems that none of such plants were recording the suction amount and points for management. In consideration of this fact, the Study Team introduces a method to identify air leakage points and amounts by the use of helium and the management method using a management table. The following shows an example helium detector. Through management by the use of a management table, changes in the suction amount over time can be managed, which enables the prioritization of repair works and judgment of the necessity of such works.

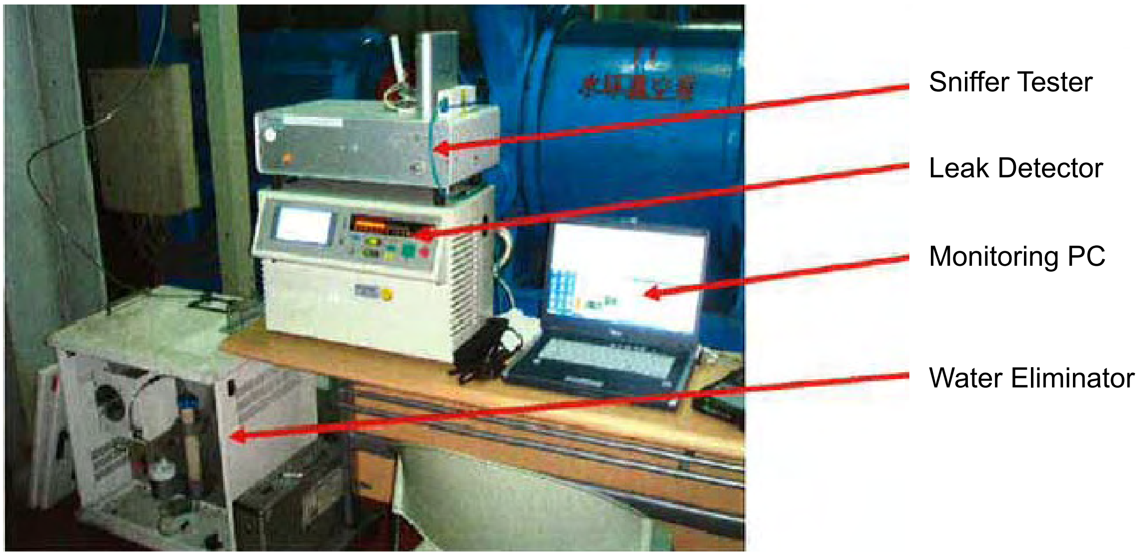


Figure 3.2-12 Helium detector

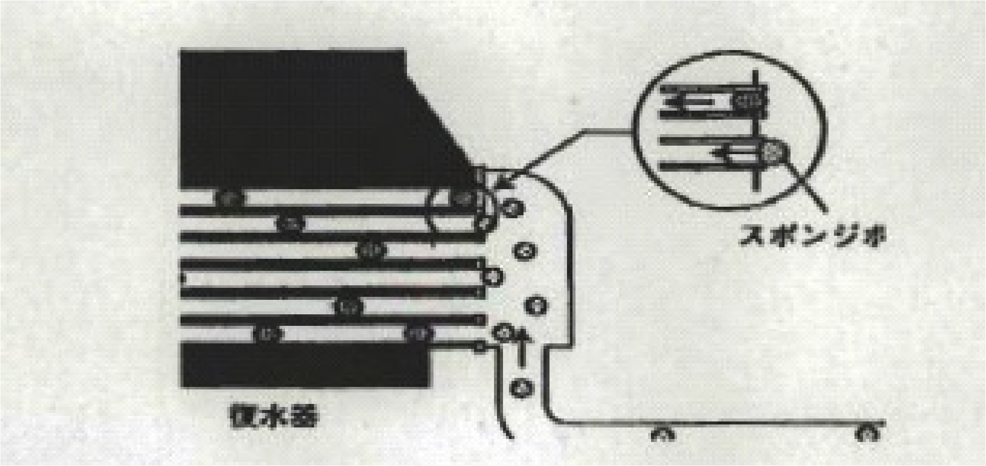
Air suction point confirmation list (example)

Floor	No.		Air suction part	Date	Leakage	System diagram etc.
3F	1	Low-pressure turbine gland packing				
		1-1	Turbine side			
		1-2	Boiler side			
・・・	2	Upper part of the low-pressure turbine				
・・・	3	Vacuum breaker valve				
・・・	4	Low-pressure heater				
・・・	5	High-pressure heater				
・・・	6	Deaerator				
・・・	7	Condensate pump				
・・・	8	Vacuum pump inlet piping				
・・・	・・・	・・・				
・・・	・・・	・・・				

Ball cleaning system for condensers

The Pha Lai II and Uong Bi No. 7 units are equipped with ball cleaning systems for condensers, but the ball management method seems to be not clearly understood. The following shows the ball management method adopted in Japan.

A ball cleaning system is designed to clean the inside of tubes by floating in cooling water sponge balls that are in a size bigger than the inner diameter of the tubes by about 10%. These balls are compressed and flow through with the cooling water.



The balls to be used for continuous cleaning must have appropriate diameters in relation to the inner diameters of the condenser tubes to ensure the planned effect. In Japan some power plants use balls that are different from those daily used for the removal of hard scales at the frequency of once per week or month. The following shows the materials and features of balls used for condenser cleaning.

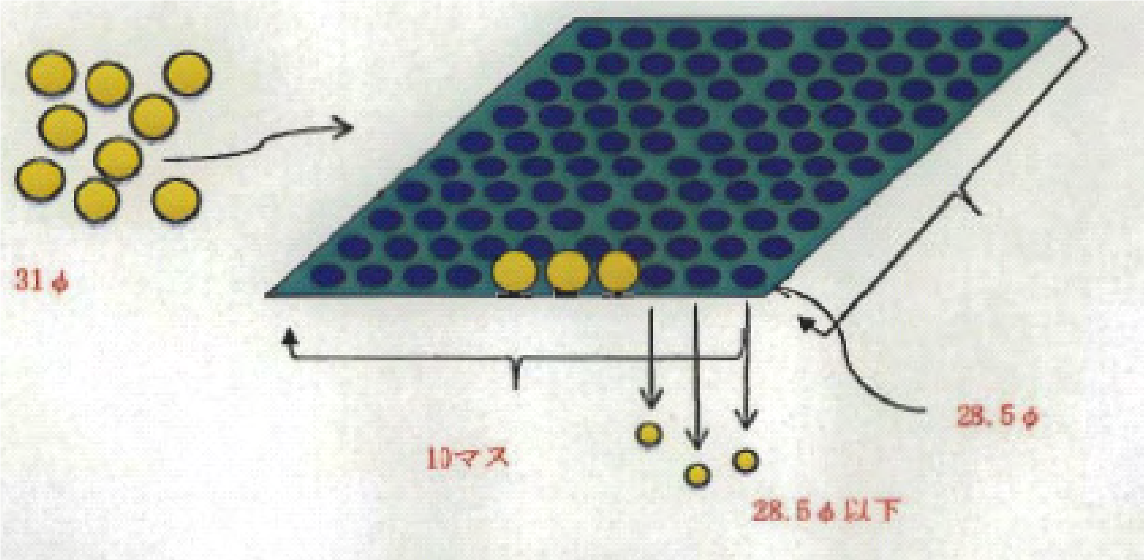
Polishing ball (PB)	Used for ordinary cleaning. Usable up to about 10,000 times (about 3 months)
Granulated ball (GB)	Has higher cleaning power compared with PB due to surface coating (but less durable than PB)
Carborundum ball (CB)	Coated by emery sand for the removal of hard scales. Has higher cleaning power than GB (but usable only several times)

< Types and use examples of balls >

- PBs are used for cleaning in regular operations at the frequency of once per day to week.
- GBs or CBs are used for cleaning for the removal of hard scales once per week to month.

< Management of the lives of balls used for the cleaning of condensers (ball diameter management) >

At the Pha Lai II and Uong BI No. 7 units, the cleaning ball diameters were not managed. When balls got smaller due to abrasion and could filter through the screen designed to catch the balls, these balls were automatically discarded. In Japan, a filter as shown below is used to screen and manage balls, thereby ensuring their cleansing ability.



3.3 Proposal of measures to curb greenhouse gas emissions from the standpoint of coal properties

From the standpoint of the evaluation of coal properties, the following measures had initially been considered as measures to curb greenhouse gas emissions.

- Micronization of grain size pulverized by mill
- Blending of imported coal with high volatile matter content
- Use of coal with low ash content (Reduction of ash content through coal preparation)
- Collection of unburnt carbon in ash by employing oil agglomeration process

However, we propose "the use of coal with low ash content (reduction of ash content through coal preparation)" in light of the following: The actual grain size pulverized by mill is sufficiently small; The blending of imported coal with high volatile matter content will change the current coal specifications defined in the boiler design conditions; A flotation which is on the same principle as the oil agglomeration process has already been in practical use; Further deterioration and fluctuations of coal quality due to the increase in underground coal mining in the future.

3.3.1 Use of coal with low ash content (Reduction of ash content through coal preparation)

(1) Effects of the use of coal with low ash content

Table 3.3-1 shows the effects of the use of coal with low ash content. This is the results of the analysis conducted in India.

Table 3.3-1 Merits of using coal with low ash content

Area of Influence		Effects
Transportation	Reduction in Transportation costs	Depends on distance and ash reduction (e.g.1000km distance and ash reduction from 41% to 30% results in savings of 7.5%)
	Reduction in CO2 emissions due to reduced fuel consumption in transportation	Depends on distance and ash reduction (e.g., 1000km distance and ash reduction from 41% to 30% results in 15% reduction in CO2 for the same delivered heating value).
Power Plant Site	Decrease in auxiliary power	10% decrease for every 10% reduction in feed coal ash
	Decrease in auxiliary fuel	50% reduction when using washed coal (present avg. is 4ml/kwh) having 10% reduction in ash
	Improvement in thermal efficiency	3.0% improvement for every 10% reduction in feed coal ash
	Improvement in plant load factor	10% improvement for every 10% reduction in feed coal ash
	Reduction in O&M costs	2% cost reduction for every 10% reduction in feed coal ash
	Reduction in capital investment for new power projects	8% reduction in capital investment when using coal with 30% ash instead of 41%
Environmental	Reduced land requirement for ash disposal	12% reduction in land requirement when using coal with 30% ash instead of 41%
	Reduced water consumption for ash disposal	12% reduction in water consumption when using coal with 30% ash instead of 41%
	Reduction in CO2 emission	Reduction in the range of 2-3% when using washed coal
	Improvement in ESP efficiency	Using washed coal improves ESP efficiency from 98 to 99%

Ph.D. Craig D. Zamuda "A case for Enhanced Use of Clean Coal in India" Aug. 2007

The ash content in Indian coal is high at 40 to 50%. Because coal field areas are unevenly distributed, the percentage of coal that requires a long-distance shipment of over 1,000 km exceeds 40%. In these circumstances, the lowering of ash content is being implemented in India under the government's initiative and there has been a rush to build coal preparation plants.

Table 3.4-1 analyzes the effects of the case in which ash content was reduced from 40% to 30% through coal preparation from the standpoint of shipping, power plants and environment. In the case of Vietnam where the distance of transportation is short, benefits in terms of transportation is not as tangible as in India. In terms of power generation, the following effects have been reported: "10% decrease in fuel ash content => 10% decrease in auxiliary power," "10% decrease in fuel ash content => 3.0% increase in thermal efficiency" and "10% decrease in fuel ash content => 2% decrease in operation and maintenance costs." For Vietnam, impacts of decreased ash content on unburnt carbon content in ash also needs to be analyzed. In terms of environment, use of coal with low ash content apparently reduces the amount of ash produced, and the improved efficiency in power plants also reduces CO_2 per unit amount of power generated, thereby reducing the load of ESP and improving trapping efficiency.

(2) Gravity separation

Coal is composed of groups of particles with different specific gravity. Figure 3.3-1 shows an example of the groups of particles that comprise coal produced in Vong Bi district whose average ash content is 30% (the bar chart section). The specific gravity of the particle that makes up the largest number is 1.65, which accounts of nearly 45% of the whole particles.

On the other hand, particles with a smaller specific gravity have lower ash content, and ash content increases as specific gravity increases (the red line graph). The figure indicates that the particle with the specific gravity of 1.65 has an ash content of 5%, the particle with the specific gravity of 1.95 has 40% ash content and that it reaches as high as 80% when the particle with the specific gravity is 2.35.

If these groups of particles are separated by the specific gravity of 2.0, the particles with specific gravity of lower than 2.0 can be obtained as coal with low ash content, and the particles with specific gravity larger than 2.0 can be obtained as coal with high ash content.

Figure 3.3-2 is the same graph showing an example of the coal in the Cam Pha district, whose average ash content is 30%.

Table 3.3-2 shows the weight and ash content of the coal with low ash content and the coal with high ash content, both of which can be obtained when coal is separated at a specific gravity of 2.0. In the case of Uong Bi district, the coal with a weight of 100% and ash content of 30% is separated into the coal with low ash content having a weight of 66% and an ash content of 13% and the coal with high ash content having a weight of 34% and an ash content of 66%. In the case of Cam Pha district, the coal with a weight of 100% and ash content of 30% is separated into the coal with low ash content having a weight of 76% and ash content of 12% and the coal with high ash content having a weight of 24% and ash content of 80%.

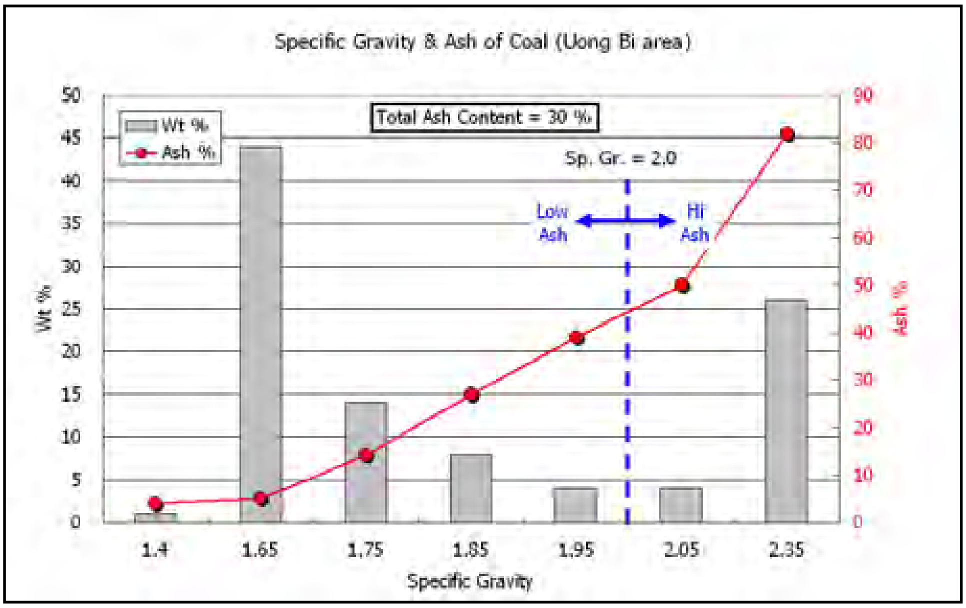


Figure 3.3-1 Composition of groups of coal particles (Uong Bi district)

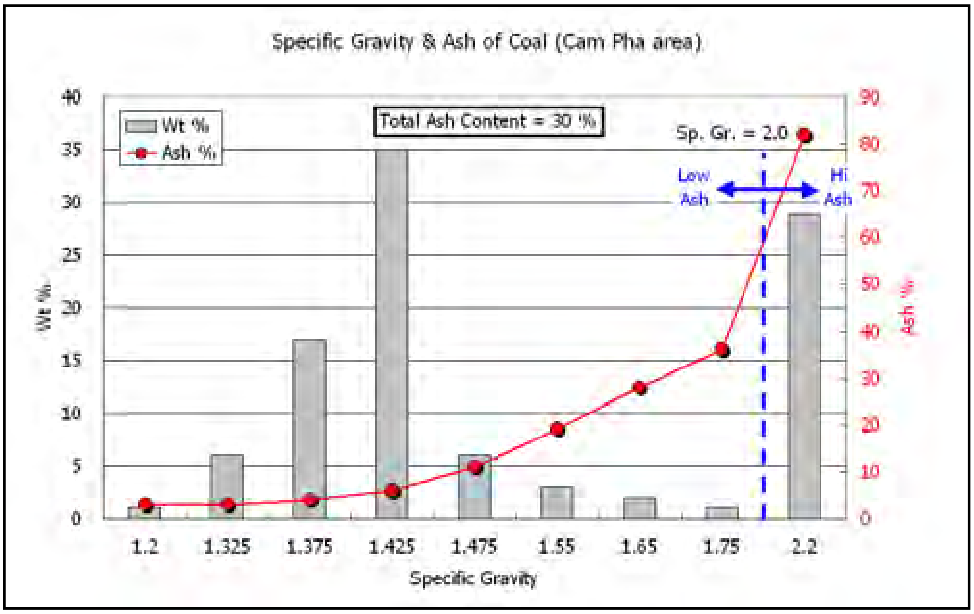


Figure 3.3-2 Composition of groups of coal particles (Cam Pha district)

Table 3.3-2 Results of separation by specific gravity

Coal Mine	Coal No. 5	
	Wt %	*Ash %*
Uong Bi area	100	*30*
Cam Pha area	100	*30*
Average	100	*30.0*

Separating at Sp. Gr. 2.0

Light Product = Low Ash Coal		Heavy Product = Hi Ash Coal	
Wt %	*Ash %*	Wt %	*Ash %*
66	*13*	34	*66*
76	*12*	24	*80*
71.0	*12.5*	29.0	*71.8*

The place where the separation by specific gravity takes place is the "coal preparation plant." At present, there are three large-scale coal preparation plants—the Cua Ong preparation plant, Hon Gai preparation plant and Vang Danh preparation plant—operating in Vietnam.

Specific gravity separators that are commercially in use at coal preparation plants include "jig." Figure 3.3-3 shows the principle of selection by jig.

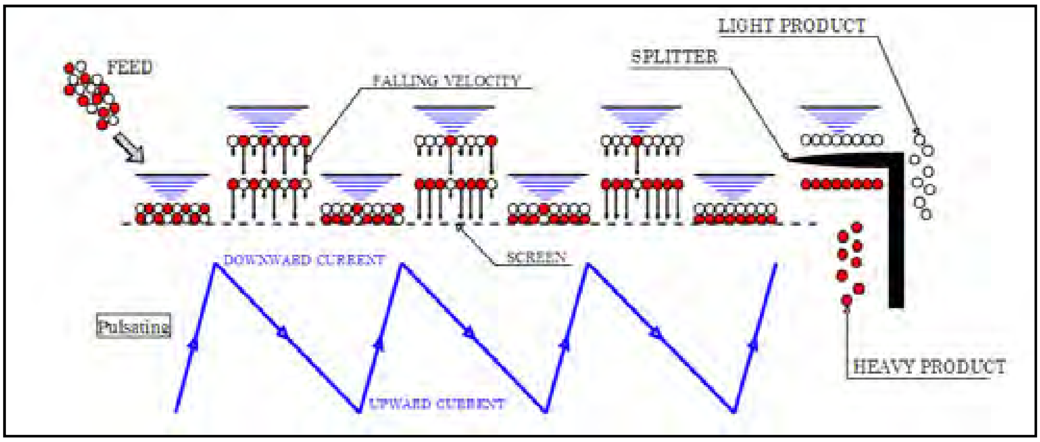


Figure 3.3-3 JIG separation principle

The settling velocity of particles with light specific gravity (coal with low ash content) is small, whereas the settling velocity of particles with heavy specific gravity is large. Therefore, by precipitating coal particles in the water a number of times, particles with light specific gravity stratify on top and particles with heavy specific gravity stratify at the bottom. By separating the particles when the stratification is completed, the two products of coal with low ash content and high ash content are obtained. Figure 3.3-4 is the JIG installed in the Cua Ong coal preparation plant.

Figure 3.3-4 JIG (Cua Ong preparation plant)

(3) Production of coal with low ash content

Table 3.3-3 shows expected yields of coal with an ash content of 25% and 20%. In this case, they will be produced by blending the coal with low ash content (ash content of 12.5%) obtained by specific gravity separation using part of the average coal (ash content of 30%) and the original coal (ash content of 30%) of Uong Bi district and Cam Pha district explained in Table 3.3-2. Given the weight of the coal with ash content of 30% is 100%, the coal with ash content of 25% can be produced with the yield of 90%, and the coal with ash content of 20% can be produced with the yield of 81%.

Where should the production of this coal with low ash content (specific gravity separation + coal blending) take place? The existing three coal preparation has no more available capacity as their operation has been overloaded. A possible option may be to incorporate this low ash coal production into a new coal preparation plant that is planned by VINACOMIN, or for EVN itself to establish a new preparation plant used exclusively for the production of low ash coal for power generation.

Table 3.3-3 Yields of production (by coal ash content)

		Coal ash		
		30%	25%	20%
Coal	Wt %	100	90	81
	Ash %	30	25	20
Others	Wt %	0	10	19
	Ash %		72	72
Total	Wt %	100	100	100
	Ash %	30	30	30

(4) Amount of coal used (by coal quality level)

Table 3.3-4 shows the amount of coal used when the ash content is 30%, 25% and 20%. The results are based on the assumption that the electricity of 1000 kWh is transmitted, using the gross power generation efficiency of 35% at the Pha Lai-2 power plant, "10% decrease in fuel ash content => 10% decrease in auxiliary power" and "10% decrease in fuel ash content=> 3.0% increase in thermal efficiency" shown in Table 3.3-1. The size of the content of unburnt carbon in ash is set to 10% for all cases because the corresponding impacts of fuel ash content are unknown.

Table 3.3-4 Amount of coal used (by coal quality level)

			Fuel Coal Ash (%)			Remarks
			30.0	25.0	20.0	
Fuel Coal		kg	522	463	415	
		Ratio	1.000	0.887	0.795	
		Kcal/kg	5,500	6,000	6,500	Non-Ig. Loss
		kcal	2.871E+06	2.778E+06	2.698E+06	
Generationg	Available Heat Value	kcal	2.730E+06	2.674E+06	2.623E+06	excl. Ig. Loss
	Generated End Eff.	%	35.0	35.5	36.1	3%/Ash-10%
	Generated Energy	kWh	1,111	1,105	1,099	
	Auxiliary Power	%	10.0	9.5	9.0	-10%/Ash-10%
		kWh	111	105	99	
	Sending Energy	kWh	1,000	1,000	1,000	
	Sending End Eff.	%	30.0	30.9	31.9	
Ash Disposal	Pure Ash	kg	157	116	83	
	Ig. Loss	%	10.0	10.0	10.0	
		kg	17	13	9	
		kcal	1.409E+05	1.042E+05	7.470E+04	8100kcal/kg
	tot	kg	174	129	92	
		Ratio	1.000	0.739	0.530	

From the table, given that the ash content of 30% is 1, the amount of coal used will be 0.887 when the ash content is 25%, and 0.795 when the ash content is 20%. Also, given that the ash content of 30% is 1, the amount of ash generated will be 0.739 when the ash content is 25% and will be halved to 0.530 when the ash content is 20%.

(5) Comparison of costs

Figure 3.3-5 shows how much is the unit price of coal with ash content of 25% and 20% when they are equivalent to the total amount of money for the purchased coal with ash content of 30%, given that the unit price of coal with ash content of 30% (CIF) is 1.

The figure does not project "a 10% decrease in fuel ash content =>a 2% reduction in operating and maintenance costs" and a decrease of costs for ash disposal. It only took the reciprocal numbers of the ratio of the amount of coal used shown in Table 3.3-4.

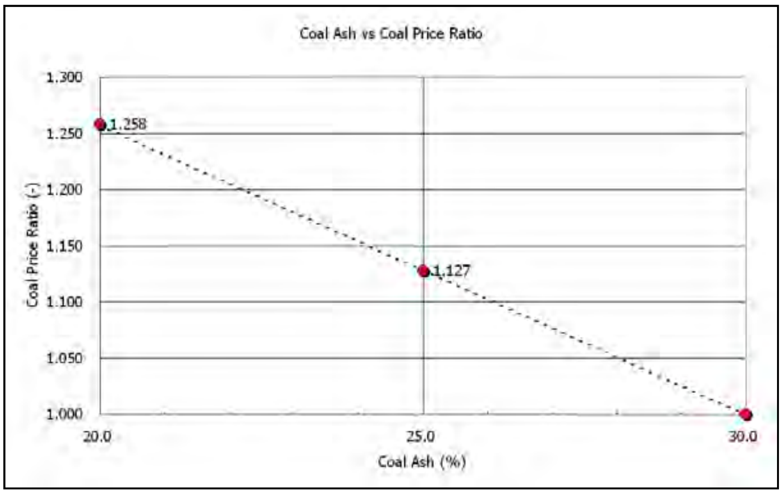


Figure 3.3-5 Coal price ratio

3.3.2 Greenhouse gas reduction effects

(1) Project boundary

Figure 3.3-6 shows a project boundary, covering coal mines => coal preparation plants (including refuse dumping) => shipping => power plants (including ash disposal).

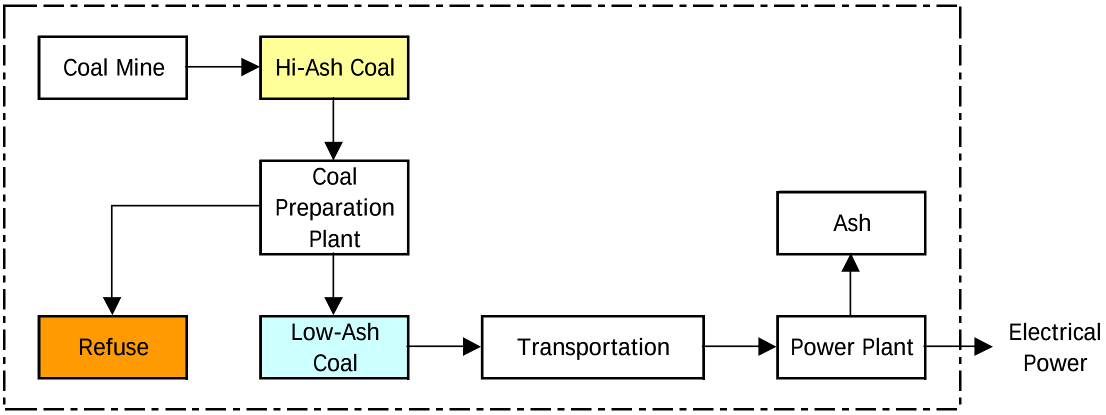


Figure 3.3-6 Project boundaries

(2) Baseline scenario and project scenario

In a baseline scenario, the coal with high ash content (ash content of 30%) is continued to be used in power plants. In a project scenario, part of coal with high ash content is cleaned and the resulting coal with low ash content of 25% and 20% is used.

Table 3.3-5 shows the amount of coal used, quality and basic rate of energy consumption for both scenarios. This is based on the case shown in Table 3.3-4 in which the electricity of 1,000 kWh is transmitted. Based on this table, the amount of energy consumption is calculated.

Table 3.3-5 Baseline scenario and project scenario

			Base Line Scenario	Project Scenario		Remarks
			30%	25%	20%	
Coal Mine	Product	kg	522	514	512	65 kWh/t ※1
Coal Preparation Plant	Feed	kg		514	512	10 kWh/t ※2
	Low-Ash Coal	kg		463	415	
	(Yield)	%		90	81	Table 3.4-2
	Hi-Ash Coal	kg		51	97	1.052 kWh/t km ※3
Transportation	Fuel Coal	kg	522	463	415	0.566 kWh/t km ※4
Power Plant	Generated Energy	kWh	1,000	1,000	1,000	
	Ash Disposal	kg	174	129	92	1.052 kWh/t km ※3

※ 1), 2) Source "LCI comparison among petroleum, LNG and coal" Japan Petroleum Energy Center 1998

※ 3) Source "Handbook for the Rational Use of Energy" The Energy Conservation Center, Japan 2000

※ 4) Source "Evaluation of the Applicability to CDM of Efficient Steam Coal Utilization Technology in India" Makoto Uchida et al., The University of Tokyo

Set 50 % for rail (0.08 kWh/t km) + 50 % for truck (1.052 kWh/t km).

(3) Energy consumption in the baseline scenario and project scenario

Table 3.3-6 shows the energy consumption in both scenarios. Comparing the project scenario with the baseline scenario, when ash content in coal is 25% or 20%, the energy consumption in both cases slightly increased. Compared to India where transportation of over 1,000 km is common, the distance of coal transportation in Vietnam is short, which diluted the effects of lower ash content in terms of energy consumption

Table 3.3-6 Energy consumption

		Energy Consumption (Ref. T 3.4-4)	Dis.	Base Line Scenario		Project Scenario			
				Ash=30%		Ash=25%		Ash=20%	
				t	kWh	t	kWh	t	kWh
Coal Mining		65 kWh/t		0.522	33.930	0.514	33.410	0.512	33.280
Coal Preparation	Plant Operation	10 kWh/t				0.514	5.140	0.512	5.120
	Trans. of Refuse	1.052 kWh/t km	2 km			0.051	0.107	0.097	0.204
Trans. of Coal		0.566 kWh/t km	60 km	0.522	17.727	0.463	15.723	0.415	14.093
Ash Disposal		1.052 kWh/t km	10 km	0.174	1.830	0.129	1.357	0.092	0.968
Total					53.488		55.738		53.665

(4) Emissions in the baseline scenario and in the project scenario (CO_2+CH_4+N_2O)

Table 3.3-7 shows GHG emissions in both scenarios. Emission coefficient by IPCC was used and CO_2

involved in power generation is not included in the calculation. Comparing the project scenario with the baseline scenario, emissions deteriorated when coal ash content was 25%, and remained almost the same when the coal ash content was 20%. As was explained earlier, the short distance of coal transportation diluted the effects of lower ash content with GHG emission.

Table 3.3-7 GHG emissions

		Emission Factor (10^{-3} kg-CO2/MJ)	MJ/kWh	Base Line Scenario		Project Scenario			
				Ash=30%		Ash=25%		Ash=20%	
				Kwh	kg-CO2	Kwh	kg-CO2	Kwh	kg-CO2
Coal Mining		75+0.004*21+0.002*310	11.08	33.930	28.460	33.410	28.024	33.280	27.915
Coal Preparation	Plant Operation	(Ref. ※1)				5.140	4.112	5.120	4.096
	Trans. of Refuse	56.1+0.61*21				0.107	0.082	0.204	0.156
Trans. of Coal		75+0.006*21+0.002*310		17.727	14.878	15.723	13.196	14.093	11.828
Ash Disposal		56.1+0.61*21		1.830	1.398	1.357	1.036	0.968	0.739
Total					44.736		46.451		44.734

※1) 0.8t-CO2/MWH

(5) Future issues

As previously stated, what is supplied to power plants is not ash, but mineral matter. The transformation from mineral matter to ash is a chemical reaction that involves heat absorption, to which calories generated by organic coal matter is used. Therefore, the calorific value that can be used for power generation decreases as the amount of mineral matter increases. On the other hand, regardless of the size of mineral matter, organic coal matter generates a certain amount of CO_2. This means that the amount of CO_2 generated per calorific value that can be used for power generation is greater in proportion to the size of mineral matter (ash content). Therefore, when generating the same amount of power, use of low ash coal should significantly curb GHG emissions. Figure 3.3-7 shows this logic in diagram. Unfortunately, there is no research material related to this theory and therefore it is not incorporated in GHG emissions this time. Research on this issue is needed in the future.

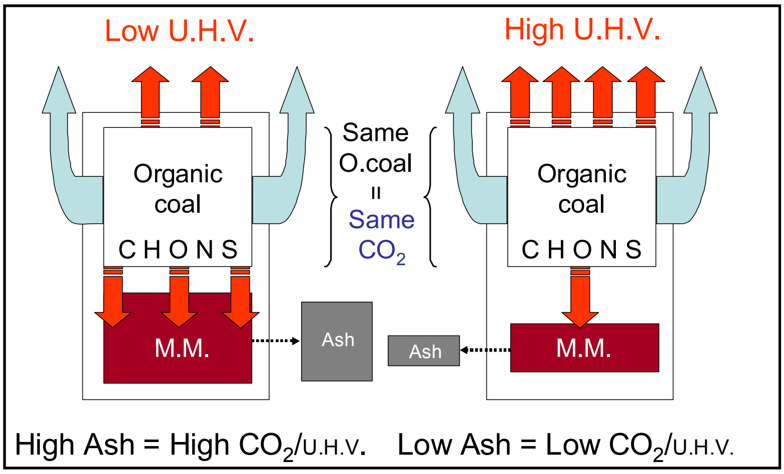


Figure 3.3-7 Mineral matter and effective calorific value

Chapter 4 Effects of Initiatives to Curtail GHG Emissions

4.1 Verification of the long-term roadmap to curtail GHG emissions

In Vietnam, where the supply of electricity power is tight, power plants cannot readily be shut down, and facility maintenance is consequently not as meticulous as it should be. As a result, the efficiency of individual pieces of machinery has been declining since the start-up of its operation. In the operational aspect, there is incentive for the maintenance of output on the designed level, but awareness of the need to maintain and improve efficiency cannot be said to be high enough. Furthermore, plants burn domestic coal, which can be obtained at a relatively low price (at half the price of imported coal). This leads to a tendency of not placing emphasis on operation oriented toward lower fuel consumption (and higher efficiency).

In order to reduce GHG (CO_2) emissions, it is vital to increase efficiency.

Specifically, it is essential to introduce highly efficient systems, including the supercritical (SC) pressure technology and operation and maintenance (OM) technologies to maintain efficiency as proposed in Chapter 3.

In formulating a roadmap, it was planned to introduce the initiatives to curtail GHG emissions based upon the presumption that the construction of subcritical power plants, which would use cheap domestic (anthracite) coal based on existing technologies, would be fostered.

【Short-term targets】

i. Introduction of operational management and performance management
ii. Introduction of maintenance improvement measures to be implemented in regular inspections
iii. Introduction of high-performance devices at new subcritical power plants
iv. Improvement of coal quality

【Medium-term targets】

v. Introduction of the SC pressure technology

*The (i) and (ii) above can be applied also to SC pressure equipment.

【Long-term target】 In and after 2030

vi. Introduction of advanced CCT such as CCS and IGCC

The following shows a macroscopic evaluation of the effects of the long-term roadmap.

4.1.1 Verification of input of OM technology to maintain efficiency

Based on the procedure for trail calculation of CO_2 emissions presented in 2.4.6, a trial calculation was made on the amount of CO_2 emissions taking account of the decline in efficiency as facilities age. In the "Status quo case," the calculation was premised on a 10 % decline in relative efficiency over a period of 20 years (e.g., a 35% rate of efficiency at the time of start-up will decline to 31.5% in the 20th year). This premise is based on the average figures obtained from actual data for efficiency rates at the Ninh Binh and Pha Lai Thermal Power Plants.

Actual data for the coal-fired thermal power plants of Japanese electrical power companies performing OM to maintain efficiency indicate a relative efficiency decline of 5% over a period of 20 years. It was therefore assumed that application of OM technology for the maintenance of efficiency at coal-fired thermal power plants in Vietnam would hold the rate of decline to 5% ("Improved OM case").

Table 4.1-1 compared the results of the trial calculation of CO_2 emissions in the Status quo and Improved OM cases.

Table 4.1-1 Total amount of reduction of CO_2 emission and coal fuel consumption (Total)

Item		Total (2011-2030)
CO_2 (1,000tons)	Status quo case (A)	3,982,387
	Improved OM case (B)	3,917,148
	(A)-(B)	65,239
Coal fuel consumption (1,000tons)	Status quo case (A)	1,931,870
	Improved OM case (B)	1,900,223
	(A)-(B)	31,648

In the Status quo case, the total CO_2 emissions and coal consumption in Vietnam over the years from 2011 to 2030 came to 3,982.39 and 1,931.87 million tons, respectively, while in the improved OM case, the corresponding figures reached 3,917.15 and 1,900.22 million tons, respectively.

If the OM technology for maintaining efficiency is introduced, CO_2 emissions and coal consumption would reduce by 65.23 million tons (about 1.6 %) and by 31.65 million tons (about 1.6 %), respectively over the period from 2011 to 2030.

Table 4.1-2 shows the results for EVN's power plants. Total CO_2 emissions and coal consumption were estimated to reduce by 31.76 million tons and by 15.41 million tons, respectively over the period from 2011 to 2030, if the OM was improved at the plants.

Based on these results, savings through decreased fuel consumption due to improved OM were estimated to total about 462.18 million US dollars over 20 years, if calculated at the unit coal price of 30 US dollars per ton.

Table 4.1-2 Total amount of reduction of CO2 emission and coal fuel consumption (EVN)

Item		Total (2011-2030)
CO_2 (1,000tons)	Status quo case (A)	1,774,798
	Improved OM case (B)	1,743,040
	(A)-(B)	31,758
Coal fuel consumption (1,000tons)	Status quo case (A)	860,961
	Improved OM case (B)	845,555
	(A)-(B)	15,406

The effects of improved OM are evaluated in a macroscopic manner here, and the evaluation of the specific measures proposed in Chapter 3 will be made separately in 4.2.

4.1.2 Verification of input of high-efficiency technology (SC pressure technology)

In the calculation presented in 2.4.6, the thermal efficiency of plants placed into operation in and after 2012 was assumed to be 35% ("35% case"). Table 4.1-3 shows the results of calculation made based on the assumption that the introduction of SC pressure equipment (with thermal efficiency of 40%) will be promoted in and after 2015 following the full-scale use of imported coal ("40% case").

As a result of calculations, total CO_2 emissions and coal consumption over the period from 2011 to 2030 came to 3,495.18 million tons and 1,695.52 million tons, respectively, while total CO_2 emissions and coal consumption by EVN's power plants came to 1,581.31 million tons and 767.10 million tons, respectively.

Table 4.1-3 Result of annual CO_2 emission of coal-fired thermal power plants (40% case)

Year		2011	2015	2020	2025	2030
CO_2 (1,000tons)	Total	26,802	69,509	162,381	242,561	387,086
	EVN	20,290	37,509	76,063	100,186	164,490
Coal fuel consumption (1,000tons)	Total	13,002	33,719	78,772	117,667	187,777
	EVN	9,843	18,196	36,899	48,601	79,795
Generation by fossil fuel (GWh)	Total	25,172	71,055	174,615	265,248	428,695
	EVN	18,747	36,990	79,622	107,258	180,099

With regard to the estimated CO_2 emissions and coal consumption, comparisons were made between the 35 % case and the 40% case (Figure 4.1-1 and Figure 4.1-2). Compared with the 35% case, CO_2 emissions and coal consumption were smaller in the 40% case by 360.08 million tons and 174.67 million tons, respectively, for the period from 2011 to 2030 (Table 4.1-4). The reduction rate was equally 9.3 %. CO_2 emissions and coal consumption of EVN's power plants were smaller by 131.70 million tons and 63.89 million tons, respectively in the 40 % case, and the reduction rate was 7.7 % (Table 4.1-5).

Over 20 years, the fuel cost was estimated to decrease by 3,833 million US dollars through the introduction of SC pressure equipment based on the aforementioned estimates and on the unit price of imported coal at 60 US dollars per ton.

On the other hand, the installed capacity of EVN's coal-fired thermal power plants in and after 2015 was estimated to be 26,190 MW. If it is assumed that the difference in unit construction cost between subcritical pressure equipment and SC pressure equipment is 100 US dollars per kilowatt, the construction cost will increase by 2,619 million US dollars by changing the specifications from subcritical pressure to SC pressure. This increase, however, can be offset by a decrease in the coal fuel cost.

The introduction of SC equipment is effective for the reduction of CO_2 emissions and it is desirable for

SC pressure power plants to be constructed even if anthracite coal is used as fuel. In Vietnam, however, no SC pressure power plants have been constructed and it would be difficult for such a power plant that will use anthracite coal to be constructed in the country now because of the lack of technical information. In consideration of the present tense electricity situation in the country, it is reasonable for subcritical power plants, which have already been constructed in Vietnam and technologically reliable to be constructed in the country on the premise that anthracite coal is used as fuel. In constructing such a power plant, it is desirable to adopt high-performance devices to be introduced in 4.3 to ensure that the plant will be highly efficient subcritical facilities.

Challenges regarding the introduction of the SC pressure technology will be described separately in 4.1.5.

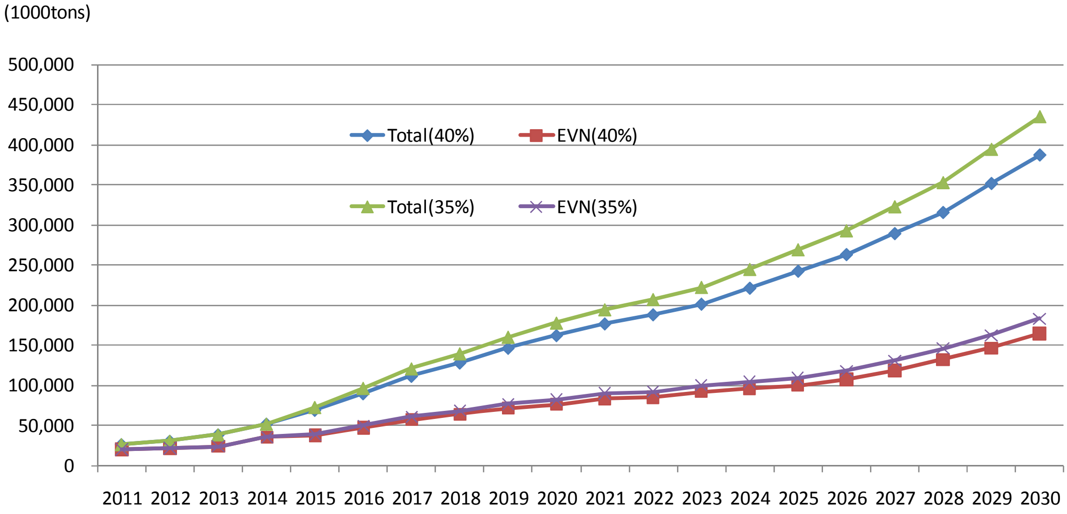


Figure 4.1-1 Result of CO_2 emission of coal-fired thermal power plants

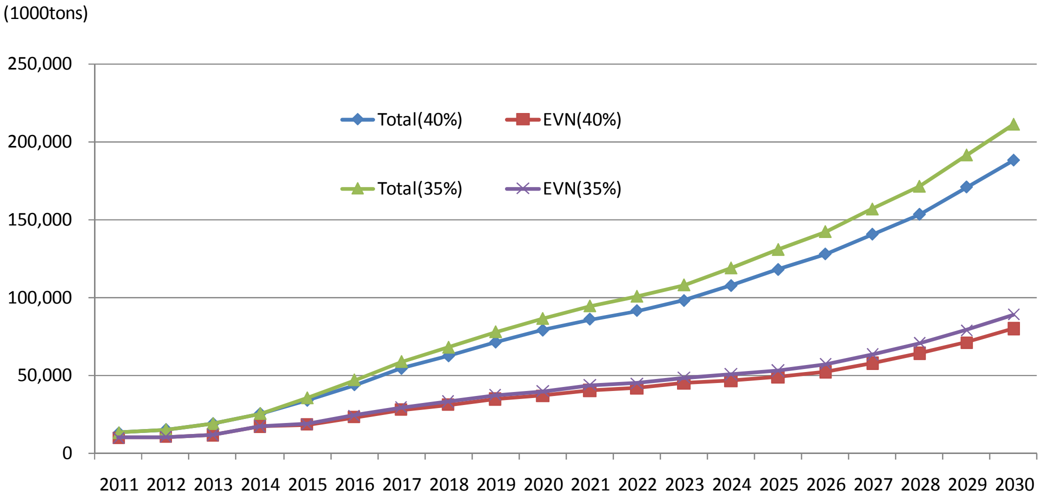


Figure 4.1-2 Result of coal fuel consumption of coal-fired thermal power plants

Table 4.1-4 Total amount of reduction of CO_2 emission and coal fuel consumption (Total)

Item		Total (2011-2030)
CO_2 (1,000tons)	35% case (A)	3,855,252
	40% case(B)	3,495,177
	(A)-(B)	360,075
Coal fuel consumption (1,000tons)	35% case (A)	1,870,197
	40% case(B)	1,695,523
	(A)-(B)	174,674

Table 4.1-5 Total amount of reduction of CO_2 emission and coal fuel consumption (EVN)

Item		Total (2011-2030)
CO_2 (1,000tons)	35% case (A)	1,713,015
	40% case(B)	1,581,312
	(A)-(B)	131,703
Coal fuel consumption (1,000tons)	35% case (A)	830,990
	40% case(B)	767,100
	(A)-(B)	63,890

4.1.3 Low-efficiency power generation equipment

As described in 2.4.4, the construction of new power plant has not been promoted as planned. As a result, Vietnam is facing tight electricity supply and the operation of power plants cannot be suspended even for regular inspections.

The Ninh Binh Thermal Power Plant is old, but is well maintained and has shown no remarkable decline in output. In consideration of the tight electricity situation, it is better to continue operating the plant, although it is a low-efficiency plant, by introducing the OM technology for the maintenance and improvement of efficiency and implementing measures to reduce CO_2 emissions.

4.1.4 Introduction of new technologies

In Vietnam, no projects to introduce technologies such as CCS and IGCC have been implemented. According to the IE's CO_2 emissions reduction scenario, the CCS technology will be introduced in and after 2030. In 2030 when the introduction will be started, 5 % of CO_2 emitted from all coal-fired thermal power plants will be stored and the percentage will be raised to 50 % by 2050. The CO_2 storage cost is estimated to be 60 US dollars per ton-CO_2.

4.1.5 Challenges regarding the introduction of the SC pressure technology

The introduction of high-efficiency plants equipped with the SC pressure technology will be very effective for the reduction of CO_2 emissions, but there are some concerns regarding this matter in

Vietnam.

Specifically, for the country to shift from subcritical to SC pressure plants, there are following challenges to be met. Specifically, compared with subcritical pressure plants, SC pressure plants need:

i. Strict water quality management

   Unlike the drum boiler from which impurities can be blown down to outside, all impurities in supplied water will remain in a once-through boiler (SC pressure boiler) in the form of scale. Scale in the boiler tube will cause the tube to be heated excessively, which will in turn damage the tube.

   In order to prevent this, it is necessary to establish a water quality management system (including the setting of measurement items and locations as well as management values, continuing monitoring, and the appropriate maintenance of instruments).

ii. Sophisticated control because of the small heat storage capacity of the boiler

   A once-through boiler has no drums and has a smaller heat storage capacity. In order to maintain the steam pressure, temperature, and excess air ratio at fixed levels, it is necessary to keep the balance between load, water supply, fuel amount and air amount in a more precise manner, for which sophisticated automatic control is necessary.

   To meet this requirement:

   - Instruments including a temperature transmitter and pressure transmitter should be maintained and managed appropriately.
   - Automatic valves (to control the flow volume) also need to be appropriately maintained and managed.
   - It will become necessary for operators and maintenance and repair staff to understand the control logic to deal with troubles related to the control system.

iii. Smaller tolerance to tube leaks

   It is not recommendable for any boilers to be operated with tube leaks, and especially for a once-through boiler this should be avoided. Tube leaks cause the flow volume to decrease, which in turn overheats the tube. Because a once-through boiler has a long tube, if it continues to be operated with tube leaks, the tube will subsequently be overheated in a wide range, which will cause damage to a wider area.

   It is therefore important to prevent tube leaks during operation, for which it is necessary to appropriately check and manage the tube thickness.

iv. Necessity of appropriate maintenance by the use of the remaining life evaluation method due to high-temperature and high-pressure steam

   Compared with a subcritical plant, the temperature and pressure of steam is higher at a SC pressure plant. This imposes more loads on the components over time, and if the plant continues to be operated without appropriate inspections and maintenance, the turbine blades and rotor will get damaged or there will be frequent boiler tube leaks. These will cause great damage to the plant, and so the possibility of long-term suspension and expensive repair cost is higher for SC pressure plants than subcritical pressure plants.

At present in Vietnam:

- The water quality management systems have been established but many of them depend on manual analysis. At recently constructed plants, automatic analyzers have been introduced, but these devices need appropriate maintenance and there are cases in which the devices are not appropriately maintained and fully utilized.
- There are cases in which the maintenance of instruments and automatic valves is not sufficient.
- Recently constructed plants are equipped with the automatic start-up function, but some plants are not making full use of the automation function.
- The remaining life management method is not generally used, including the management of the tube thickness.

Based on the aforementioned facts, there are some concerns about the adoption of SC pressure plants in Vietnam now. In order to eliminate such concerns, it is necessary to establish appropriate maintenance and management systems for automatic valves as well as for instruments such as instruments for water quality management, to improve the ability of operators and maintenance and repair staff, and to spread the use of the remaining life management method. As specific means to meet these requirements, the following methods could be proposed:

- Introduction of overseas technologies by independent power producers (IPPs)
- Improvement of EVN’s technologies through technology support by JICA and others

In the following, the remaining life management method, which is not generally implemented in Vietnam, will be introduced.

<Outline of the remaining life management>

Machines and devices that comprise a plant are deteriorated for various reasons, but the following three can be listed as main reasons.

- ➢ Creep and creep fatigue
- ➢ Fatigue (low-cycle fatigue and high-cycle fatigue)
- ➢ Corrosion, erosion, and wastage due to abrasion

The remaining life management and evaluation means to evaluate the degree of equipment deterioration for the following two purposes: to predict the remaining life of equipment in a more precise manner to use it for a longer period of time; and to replace equipment with new one before it breaks down. A range of evaluation technologies have been developed and used to identify deterioration factors. The evaluation methods for each deterioration factor will be described below.

(1) Creep and creep fatigue

At high temperatures, metal materials on which load is imposed continuously are deformed over time and are finally broken. This phenomenon is called “creep failure.” Creep fatigue is a combination of fatigue phenomenon (described later) and creep phenomenon caused by stress given to metal at high temperatures repeatedly. At thermal power plants, boiler superheaters, reheaters, high-pressure turbines, and others used at a temperature of 450 °C or higher may be deformed or destroyed through different mechanisms depending upon materials, operating temperatures, and stress. The creep testing method, however, is the same for all the mechanisms. The method can be roughly divided into the following three.

- Nondestructive testing
- Destructive testing
- Analysis method

i. Nondestructive testing

In nondestructive testing, various changes that are followed by the progress of creep of the metallographic structure are used as parameters to indicate the degree of damage. In this testing method, microscopic changes of materials, changes in hardness, and changes in electric resistance values are used as parameters and the data obtained from the targeted equipment are compared with the master curve created based on experimental data to evaluate the length of the remaining life.

ii. Destructive testing

In the destructive testing, a sample is collected from the targeted equipment to create a test specimen. The specimen is then tested in various ways to evaluate the length of the remaining life, including a creep test to indentify the creep rupture time of the sample as well as a test to identify the mechanical strength such as tension strength.

iii. Analysis method

The analysis method is an indirect evaluation method, in which the length of the remaining life of the targeted equipment is evaluated based on the conditions under which the equipment is used (temperature and pressure conditions) and on the material’s deterioration characteristic (relationship of temperatures and pressures with destruction) by the use of the finite element method, etc.

Destructive testing is excellent in evaluation precision and is used for testing boiler tubes from which samples can be easily collected. A creep test, however, requires very long time and for other mechanical tests it is necessary to prepare test specimens. Destructive testing is therefore expensive compared with nondestructive testing and the analysis method.

It is easy to collect data for nondestructive testing, but because microscopic changes of the metallographic structure need to be used as parameters, it is difficult to quantify damage.

(2) Fatigue

Low-cycle fatigue due to heat is generally considered to be a problem in the remaining life evaluation made at thermal power plants. Generally, thick components such as boiler drums, metal parts for the fire furnace tubes, rotors of steam turbines, main valves, and cylinders are the targets of fatigue testing. Due to temperature changes following start-up and shut-down of plants, such components get fatigued and eventually are broken. The remaining life evaluation with regard to fatigue is made by nondestructive testing or by the analysis method just like the case of creep fatigue. Nondestructive testing is conducted to evaluate changes in material hardness, changes in material compositions and microscopic cracks caused by the accumulation of fatigue. The analysis method is used to calculate the stress caused by temperature changes due to start-up and shut-down of plants or due to changes in loads, and to evaluate the degree of fatigue based on changes in stress and on the fatigue characteristic of the material.

(3) Corrosion, erosion, and wastage due to abrasion

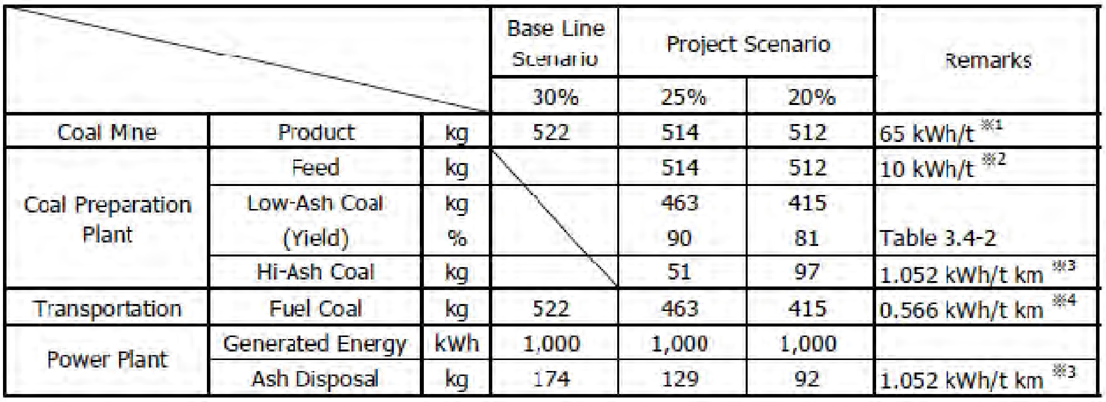
Corrosion is a phenomenon in which the surface of an object is peeled by chemical reaction while erosion is a phenomenon in which the surface of an object is peeled by physical action. Abrasion is also caused by physical action, but more strongly by collision of hard materials like coal ash to an object at a high speed. Corrosion, erosion, and abrasion can be caused by various factors. By measuring the thickness of the parts that are facing the problem of corrosion, erosion or abrasion, calculating the rate at which the thickness is decreasing, and predicting the time when the part's thickness will decrease to the minimum required for use. The thickness is measured by the supersonic thickness measuring instrument or measuring samples.

4.1.6 Proposal of measures to curb greenhouse gas emissions by producing and using low ash coal

From the aspect of coal quality, possible measures included 1) micronization of the grain size pulverized by mill, 2) blending of imported coal having high volatile matter, 3) use of low ash coal, and 4) collection of unburnt portion in ash by using oil agglomeration. Taking into consideration the applicability of technology and the future deterioration and fluctuation of coal quality, we will propose 3) the production and use of low ash coal. More specifically, effects of reducing greenhouses gases were presented, assuming that low ash coal with 25 and 20% of ash content is produced and used by blending low ash coal (ash content of 12.5%) obtained by coal preparation (separation using the difference of specific gravity) and raw coal (ash content of 30%).

A baseline scenario and project scenario are shown in Table 4.1-6, and the greenhouse gas emissions calculated based on these scenarios are shown in Table 4.1-7.

Table 4.1-6 Baseline scenario and project scenario



			Base Line Scenario	Project Scenario		Remarks
			30%	25%	20%	
Coal Mine	Product	kg	522	514	512	65 kWh/t ※1
Coal Preparation Plant	Feed	kg		514	512	10 kWh/t ※2
	Low-Ash Coal	kg		463	415	
	(Yield)	%		90	81	Table 3.4-2
	Hi-Ash Coal	kg		51	97	1.052 kWh/t km ※3
Transportation	Fuel Coal	kg	522	463	415	0.566 kWh/t km ※4
Power Plant	Generated Energy	kWh	1,000	1,000	1,000	
	Ash Disposal	kg	174	129	92	1.052 kWh/t km ※3

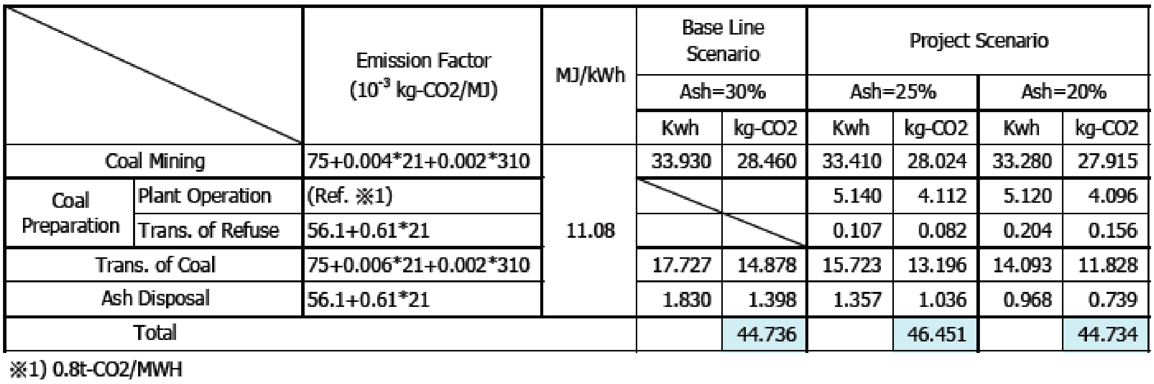
* 1), 2) Source "LCI comparison among petroleum, LNG and coal" Japan Petroleum Energy Center 1998

* 3) Source "Handbook for the Rational Use of Energy" The Energy Conservation Center, Japan 2000

* 4) Source "Evaluation of the Applicability to CDM of Efficient Steam Coal Utilization Technology in India" Makoto Uchida et al., The University of Tokyo

Set 50 % for rail (0.08 kWh/t km) + 50 % for truck (1.052 kWh/t km).

Table 4.1-7 Greenhouse gas emissions



		Emission Factor (10^{-3} kg-CO2/MJ)	MJ/kWh	Base Line Scenario		Project Scenario			
				Ash=30%		Ash=25%		Ash=20%	
				Kwh	kg-CO2	Kwh	kg-CO2	Kwh	kg-CO2
Coal Mining		75+0.004*21+0.002*310	11.08	33.930	28.460	33.410	28.024	33.280	27.915
Coal Preparation	Plant Operation	(Ref. ※1)				5.140	4.112	5.120	4.096
	Trans. of Refuse	56.1+0.61*21				0.107	0.082	0.204	0.156
Trans. of Coal		75+0.006*21+0.002*310		17.727	14.878	15.723	13.196	14.093	11.828
Ash Disposal		56.1+0.61*21		1.830	1.398	1.357	1.036	0.968	0.739
Total					44.736		46.451		44.734

※1) 0.8t-CO2/MWH

Emission coefficient by IPCC was used and CO_2 involved in power generation is not included in the calculation. Comparing the project scenario with the baseline scenario, emissions deteriorated when coal ash content was 25%and remained almost the same when the coal ash content was 20%. As was explained earlier, the short distance of coal transportation diluted the effects of lower ash content.

Meanwhile, the transformation from mineral matter to ash is a chemical reaction that involves heat absorption, to which calories generated by organic coal matter is used. Therefore, the calorific value that can be used for power generation decreases as the amount of mineral matter increases. On the other hand, regardless of the size of mineral matter, organic coal matter generates a certain amount of CO_2. This means that the amount of CO_2 generated per calorific value that can be used for power generation is greater in proportion to the size of mineral matter (ash content). Therefore, when generating the same amount of power, use of low ash coal should significantly curb GHG emissions.

However, there is no research material related to this theory and therefore it is not incorporated in GHG emissions this time.

4.2 Calculation of the effects of measures to curtail GHG emissions based on the measures for improvement

Calculations of the effects in this section are conducted based on the data from the hearing and questionnaire survey at the power plants study team visited.

4.2.1 Calculation of the effects of measures to curtail GHG emissions based on improvement in the operation aspect

As an example of target-based operation management, the Study Team calculated the fuel loss in the event of continued operation, for a duration of six hours, when the main steam temperature is five degrees (centigrade) lower than the rated value, under the conditions noted below. The results are shown in Table 4.2-1.

The subject of this calculation was loss on the limiting condition of a six-hour duration. With improvement of the status of continued operation with a main steam temperature below the rated value, such that the plant is operated with this temperature constantly kept at the rated value, the calculation shows that the Ninh Binh plant, for example, could reduce its volume of coal consumption by about 140 tons a year.

* Operating conditions
- Plant output (MW): rated output (MW)
- Main steam temperature difference (centigrade): 5 degrees below the rated temperature
- Continuous operation duration (hours): 6
- HR correction coefficient (%/degree): 0.02
- Gross HR (kcal/kWh): actual 2009 figures at each power plant
- Fuel calorific value (LHV; kcal/kg): 5,000

* Equation for calculation of the amount of coal consumption
- Amount of coal consumption (loss)

= main steam temperature × (main steam temperature HR correction coefficient/100)
×(gross HR × rated output/fuel calorific value (LHV))

Table 4.2-1 Target-based operation management - effects for curtailment of GHG emissions by improvement of main steam temperature

Plant	Unit No.	Output (MW)	G.H.R (kcal/kWh)	Heat Loss (kcal)	Coal Consumption (kg)	CO2 Emission (kg)(*)
Ninh Binh	1	25	3,130	469,500	93.9	194
	2	25	3,100	465,000	93.0	192
	3	25	3,100	465,000	93.0	192
	4	25	3,125	468,750	93.8	193
Pha Lai Ⅰ	1	110	2,530	1,670,044	334.0	689
	2	110	2,360	1,557,600	311.5	643
	3	110	2,398	1,582,475	316.5	653
	4	110	2,509	1,656,263	331.3	683
Pha Lai Ⅱ	5	300	2,043	3,676,644	735.3	1,517
	6	300	2,087	3,756,420	751.3	1,550
Uong Bi	5	55	3,638	1,200,454	240.1	495
	6	55	3,635	1,199,464	239.9	495

(*)CO2 emission factor : 98,538kg-CO2/TJ

4.2.2 Calculation of the effects of measures to curtail GHG emissions based on improvement in the maintenance aspect

4.2.2.1 Boiler facilities

(1) Effects of chemical cleaning of boilers

Perspectives on chemical cleaning currently vary depending on the power plant. Plants that do not execute chemical cleaning could expect to improve the efficiency of heat transfer by removing scales that have accumulated in tubes over the period since the facilities were replaced. Plants that have been cleaning tubes with alkali once every two years regardless of the amount of scales could reduce both the cost required for chemical cleaning and the duration of unit shutdown by implementation of the acid cleaning proposed here, which would allow a decrease in the cleaning frequency.

As for the improvement of boiler efficiency brought by chemical cleaning, there are data indicating that the last chemical cleaning at a thermal power plant operated by Chubu EPCo increased this efficiency from 89.28 to 89.94 percent. This improvement, however, includes the recovery of performance induced by the cleaning of boiler parts and internal examination of ventilation equipment during periodic inspection. The calculation of the cleaning effect here assumed that chemical cleaning accounted for 50 percent of the total improvement. This figure translates into an improvement of about 30 percent in the rate of boiler efficiency deterioration. The calculation assumed that the improvement of boiler efficiency deterioration at coal-fired power plants in Vietnam as well would be about the same percentage.

Table 4.2-2 presents the calculation results. The savings of coal varies with the plant, and would amount to about 13,000 tons of coal at the Pha Lai II.

Table 4.2-2 Reduction in the amount of coal consumption through chemical cleaning of boilers

Plant	Unit	Generating End Efficiency (%)	Boiler Efficiency (%)		Coefficience to Efficiency other than Boiler Efficiency
		A	B	C	D = A / C
		Actual	Design	Actual	
Ninh Binh TPP	1	21.29	90.1	82.39	0.258
	2	21	90.1	83.1	0.253
	3	23.02	90.1	83.66	0.275
	4	21.43	90.1	81.44	0.263
Pha Lai I TPP	1	28.3	86.06	85	0.333
	2	30	86.06	84.8	0.354
	3	29.09	86.06	85	0.342
	4	28.57	86.06	84.4	0.339
Pha Lai II TPP	5	35.18	88.5	84.8	0.415
	6	35.42	88.5	84.9	0.417

Plant	Unit	Deteriorated Boiler Efficiency (%)	Improvement of Boiler Efficiency (%)	Boiler Efficiency After Improvement (%)	Generating End Efficiency After Improvement (%)
		E = B - C	F = E * 0.3	G = C + F	H = D * G
Ninh Binh TPP	1	7.71	2.31	84.70	21.89
	2	7.00	2.10	85.20	21.53
	3	6.44	1.93	85.59	23.55
	4	8.66	2.60	84.04	22.11
Pha Lai I TPP	1	1.06	0.32	85.32	28.41
	2	1.26	0.38	85.18	30.13
	3	1.06	0.32	85.32	29.20
	4	1.66	0.50	84.90	28.74
Pha Lai II TPP	5	3.70	1.11	85.91	35.64
	6	3.60	1.08	85.98	35.87

Table 4.2-2 Reduction in the amount of coal consumption through chemical cleaning of boilers (continued)

Plant	Unit	Heat Comsumprion Before Improvement (kcal/kWh)	Heat Comsumprion After Improvement (kcal/kWh)	Heat Consumption Differennce (kcal/kWh)	Generated Electricity (MWh/year)
		J = 3600/4.1869/A*100	K = 3600/4.1869/H *100	L = J - K	M (5 Year Average)
Ninh Binh TPP	1	4,038.63	3,928.44	110	193,807
	2	4,094.40	3,993.58	101	187,354
	3	3,735.12	3,650.90	84	185,736
	4	4,012.25	3,888.30	124	177,485
Pha Lai I TPP	1	3,038.25	3,027.00	11	692,347
	2	2,866.08	2,853.43	13	652,255
	3	2,955.74	2,944.79	11	737,340
	4	3,009.54	2,991.95	18	664,810
Pha Lai II TPP	5	2,444.07	2,412.55	32	2,137,675
	6	2,427.51	2,397.08	30	2,182,308

Plant	Unit	Heat Consumption Differennce (kcal/year)	Coal Consumption Differenece (t/year)	CO2 Emission Difference (t/year) (*)
		N = L * M * 1000	O = N/5000/1000	O * 5000 * 4.184 * 98538 * 10e-9
Ninh Binh TPP	1	21,355,557,066	4,271	8,811
	2	18,889,634,217	3,778	7,793
	3	15,643,203,397	3,129	6,454
	4	21,998,195,684	4,400	9,076
Pha Lai I TPP	1	7,790,262,444	1,558	3,214
	2	8,251,582,764	1,650	3,404
	3	8,071,214,856	1,614	3,330
	4	11,688,735,897	2,338	4,822
Pha Lai II TPP	5	67,381,692,748	13,476	27,800
	6	66,418,251,778	13,284	27,402

(*)CO2 emission factor : 98,538kg-CO2/TJ

(2) Effects of management of air heater performance

This section considers the effects that could be obtained through revision of the standards for replacement and repair based on assessment of the remaining service life of conductive air heaters, and on assessment of temperature efficiency and the degree of element damage in the case of regenerative air heaters.

The air heaters in the thermal power plants operated by Chubu EPCo are of the regenerative type. Performance of the replacement and repair work by the method proposed in Chapter 3 improved the exit gas temperature by about 3 degrees as compared to before the periodic inspection. At coal-fired power plants in Vietnam with about the same design temperature, a revision of replacement and repair standards would presumably increase the proportion of heat exchange tubes and elements replaced or repaired, and consequently deliver a bigger benefit for reduction of exit gas temperature. However, it would be necessary to subtract the amount of improvement under the existing replacement/repair standards, and the amount of exit gas temperature decrease based on the proposal in this document was therefore assumed to be equivalent to that during periodic inspection at Chubu EPCo coal-fired power plants at present. The calculation consequently assumed a temperature-reducing effect of 3 degrees, regardless of the air heater type (conductive or regenerative).

First, a calculation was made of the influence on the fuel consumption rate exerted by a reduction in the temperature of air heater exit gas by implementation of the revised replacement and repair standards. The equations for exit gas heat loss and effects for reduction of the rate of fuel consumption are as follows.

$$\text{Exit gas heat loss L1} \quad = \quad \frac{C\times G+\ (Tg2-Ta1)}{H1}\times 100 \qquad (\%)$$

- C: rated pressure specific heat of air heater exit gas (kJ/m3 NK)
- G: amount of air heater exit gas (m3 N/kg)
- Tg2: air heater exit gas temperature
- Tal: external air temperature
- H1: fuel calorific value (LHV) (kJ/kg)

* Effect for reduction of fuel consumption rate (g/kWh) = design standard coal fuel consumption rate (g/kWh) x amount of change in the boiler efficiency (relative)

The calculation for the amount of change in boiler efficiency was performed for Unit 1 at the Ninh Binh thermal power plant as an example. The actual air heater exit gas temperature is 155 degrees as compared to the design value of 137 degrees. The calculation is as follows assuming a post-improvement temperature of 152 degrees.

$$\text{(before improvement)} \quad L1 = \frac{1.38^{*} \times 12^{*} \times (155-24.5)}{20934} \times 100 = 10.32\ (\%)$$

$$\text{(after improvement)} \quad L1 = \frac{1.38^{*} \times 12^{*} \times (152-24.5)}{20934} \times 100 = 10.08\ (\%)$$

The asterisks indicate use of data (reference values) at other thermal power plants because in-operation data were not available.

$$\text{Boiler efficiency after the change} = 82.39 - (10.32 - 10.08) = 82.15$$

$$\text{Amount of change in boiler efficiency} = \frac{82.39 - 82.15}{82.39} \times 100 = 0.29\ \%$$

The specific fuel consumption and specific heat consumption vary with the amount of change in boiler efficiency, and were consequently used in the calculation below. The improvement in specific heat consumption in the power plants is assumed to be on the same level.

The calculation results indicate that it would be possible to reduce the amount of coal use as shown inTable 4.2-3. The reduction would amount to a decrease of at least 3,000 tons in use of coal at the Pha Lai II.

Table 4.2-3 Reduction of the amount of coal consumption by management of air heater performance

Plant	Unit	Generating End Efficiency	Heat Consumption (kcal/kwh)	Heat Consumption Improvement (kcal/kwh)
		Actual	B = 3600 / A / 4.1868 / 100	C = B * 0.29 / 100
		A		
Ninh Binh TPP	1	21.29	4,039	11.71
	2	21	4,095	11.87
	3	23.02	3,735	10.83
	4	21.43	4,012	11.64
Pha Lai I TPP	1	28.3	3,038	8.81
	2	30	2,866	8.31
	3	29.09	2,956	8.57
	4	28.57	3,010	8.73
Pha Lai II TPP	5	35.18	2,444	7.09
	6	35.42	2,428	7.04

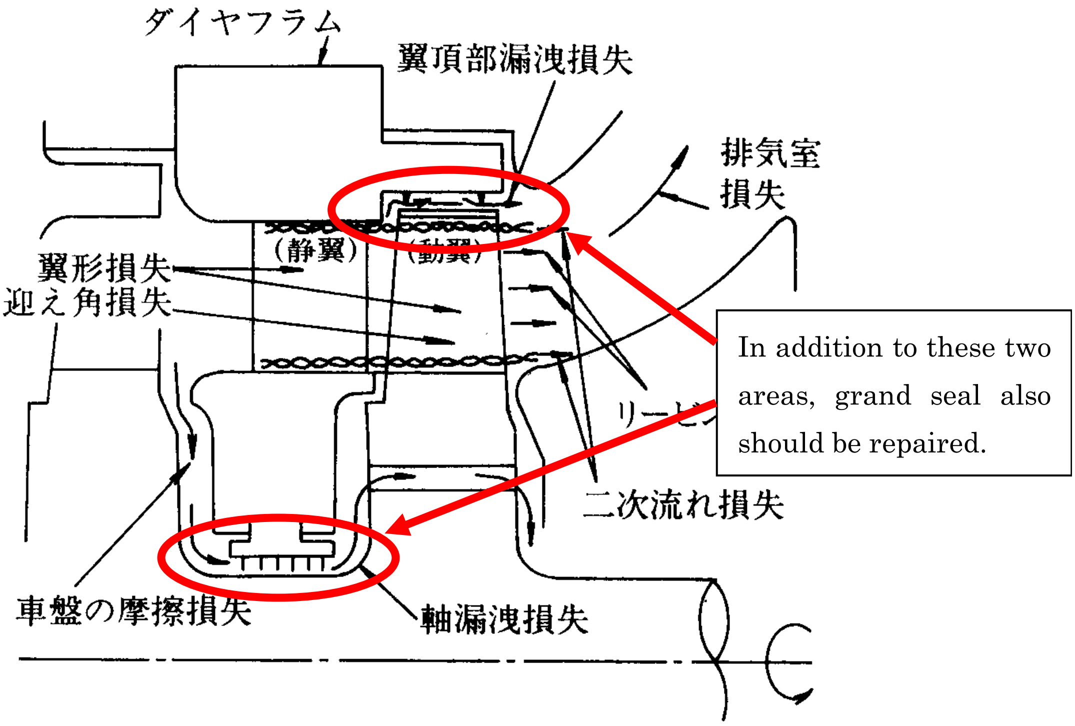
Plant	Unit	Generated Electricity (MWh/year)	Heat Consumption Differennce (kcal/year)	Coal Consumption Differenece (t/year)	CO2 Emission Difference (t/year) (*)
		D (5 Year Average)	E = C * D * 1000	F = E / 5000 /1000	F * 5000 * 4.184 * 98538 * 10e-9
Ninh Binh TPP	1	193,807	2,269,927,994	453.99	936
	2	187,354	2,224,656,103	444.93	920
	3	185,736	2,011,914,497	402.38	829
	4	177,485	2,065,176,990	413.04	853
Pha Lai I TPP	1	692,347	6,100,361,013	1220.07	2,519
	2	652,255	5,421,439,037	1084.29	2,237
	3	737,340	6,320,367,868	1264.07	2,606
	4	664,810	5,802,372,234	1160.47	2,395
Pha Lai II TPP	5	2,137,675	15,151,799,247	3030.36	6,252
	6	2,182,308	15,363,341,754	3072.67	6,339

(*)CO2 emission factor : 98,538kg-CO2/TJ

4.2.2.2 Turbine facilities

(1) Effects of replacement of parts in the main turbine seal

Under the current stage, it would be difficult to make an accurate calculation of the effects of replacement of seal parts, due to the unavailability of detailed records on items such as the damage to rotor and stator blades and seals at the power plants, and the element of uncertainty about turbine efficiency. For this reason, it was decided to make the calculation on the assumption, based on the data for turbine efficiency provided by the thermal power plants, that blade damage accounts for 60 percent of the given rate of turbine efficiency deterioration, with age-induced deterioration which cannot be reversed by repairs accounting for another 20 percent, and deterioration which can be reversed by repair of seals, for the remaining 20 percent.



In addition to these two areas, grand seal also should be repaired.

Table 4.2-4 shows the calculation results. The results indicate that plants could reduce their yearly use of coal by up to 12,000 tons.

Table 4.2-4 Reduction of the amount of coal consumption by replacement of parts in the main turbine seal

Plant	Unit	Generating End Efficiency (%)	Turbine Efficiency (%)		Coefficience to Efficiency other than Turbinne Efficiency
		A	B	C	D = A / C
		Actual	Design	Actual	
Ninh Binh TPP	1	21.29	31	27.58	0.772
	2	21	31	27.03	0.777
	3	23.02	31	28.15	0.818
	4	21.43	31	28.06	0.764
Pha Lai I TPP	1	28.3	39	34	0.832
	2	30	39	36.4	0.824
	3	29.09	39	35.8	0.813
	4	28.57	39	34.3	0.833
Pha Lai II TPP	5	35.18	45.1	42.9	0.820
	6	35.42	45.1	42.9	0.826

Plant	Unit	Deteriorated Turbine Efficiency (%)	Improvement of Turbien Efficiency (%)	Turbine Efficiency After Improvement (%)	Generating End Efficiency After Improvement (%)
		E = B - C	F = E * 0.2	G = C + F	H = D * G
Ninh Binh TPP	1	3.42	0.68	28.26	21.82
	2	3.97	0.79	27.82	21.62
	3	2.85	0.57	28.72	23.49
	4	2.94	0.59	28.65	21.88
Pha Lai I TPP	1	5.00	1.00	35.00	29.13
	2	2.60	0.52	36.92	30.43
	3	3.20	0.64	36.44	29.61
	4	4.70	0.94	35.24	29.35
Pha Lai II TPP	5	2.20	0.44	43.34	35.54
	6	2.20	0.44	43.34	35.78

Table 4.2-4 Reduction of the amount of coal consumption by replacement of parts in the main turbine seal (continued)

Plant	Unit	Heat Comsumprion Before Improvement (kcal/kWh)	Heat Comsumprion After Improvement (kcal/kWh)	Heat Consumption Differennce (kcal/kWh)	Generated Electricity (MWh/year)
		J = 3600/4.1869/A*100	K = 3600/4.1869/H*100	L = J - K	M (5 Year Average)
Ninh Binh TPP	1	4,038.63	3,940.99	98	193,807
	2	4,094.40	3,977.66	117	187,354
	3	3,735.12	3,661.08	74	185,736
	4	4,012.25	3,929.99	82	177,485
Pha Lai I TPP	1	3,038.25	2,951.51	87	692,347
	2	2,866.08	2,825.78	40	652,255
	3	2,955.74	2,903.90	52	737,340
	4	3,009.54	2,929.33	80	664,810
Pha Lai II TPP	5	2,444.07	2,419.32	25	2,137,675
	6	2,427.51	2,402.92	25	2,182,308

Plant	Unit	Heat Consumption Differennce (kcal/year)	Coal Consumption Differenece (t/year)	CO2 Emission Difference (t/year) (*)
		N = L * M * 1000	O = N/5000/1000	O * 5000 * 4.184 * 98538 * 10e-9
Ninh Binh TPP	1	18,923,773,079	3,785	7,807
	2	21,872,689,328	4,375	9,024
	3	13,752,415,621	2,750	5,674
	4	14,599,454,685	2,920	6,023
Pha Lai I TPP	1	60,051,837,178	12,010	24,776
	2	26,285,796,738	5,257	10,845
	3	38,225,657,735	7,645	15,771
	4	53,322,499,909	10,664	21,999
Pha Lai II TPP	5	52,918,443,862	10,584	21,832
	6	53,657,267,027	10,731	22,137

(*)CO2 emission factor : 98,538kg-CO2/TJ

(2) Effects of cleaning of feed water heaterrs with high-pressure water jets

The study was not able to determine the management status of feed water heater terminal temperature difference. At some coal-fired power plants in Japan, such differences have worsened by about one degree over a period of about eight years. A calculation was made of the prospective improvement in this difference by jet washing, on the assumption that it worsens by the same amount in Vietnam. Because power plants in Vietnam do not actually clean heaters with high-pressure water jets, the improvement effect is thought to be greater than shown in the table below. The influence of the terminal temperature difference on turbine specific heat consumption is obtained from the turbine manufacturer and can be calculated from the design heat balance diagram. Because these data were not available in the study, it was decided to use 0.02 percent per degree as the standard value for one heater.

Table 4.2-5 presents the calculation results. The results indicate that the cleaning of one heater could reduce consumption of coal by as much as about 200 tons per year at some plants.

Table 4.2-5 Reduction of coal consumption by cleaning of feed water heater heaters with high-pressure water jets

Plant	Unit	Generating End Efficiency	Heat Consumption (kcal/kwh)	Heat Consumption Improvement (kcal/kwh)	Generated Electricity (MWh/year)
		Actual	B = 3600 / A / 4.1868 / 100	C = B * 0.02 / 100	D (5 Year Average)
		A			
Ninh Binh TPP	1	21.29	4,039	0.81	193,807
	2	21	4,095	0.82	187,354
	3	23.02	3,735	0.75	185,736
	4	21.43	4,012	0.80	177,485
Pha Lai I TPP	1	28.3	3,038	0.61	692,347
	2	30	2,866	0.57	652,255
	3	29.09	2,956	0.59	737,340
	4	28.57	3,010	0.60	664,810
Pha Lai II TPP	5	35.18	2,444	0.49	2,137,675
	6	35.42	2,428	0.49	2,182,308

Plant	Unit	Heat Consumption Differennce (kcal/year)	Coal Consumption Differenece (t/year)	CO2 Emission Difference (t/year) (*)
		E = C * D * 1000	F = E / 5000 /1000	O * 5000 * 4.184 * 98538 * 10e-9
Ninh Binh TPP	1	156,546,758	31.31	65
	2	153,424,559	30.68	63
	3	138,752,724	27.75	57
	4	142,425,999	28.49	59
Pha Lai I TPP	1	420,714,553	84.14	174
	2	373,892,347	74.78	154
	3	435,887,439	87.18	180
	4	400,163,602	80.03	165
Pha Lai II TPP	5	1,044,951,672	208.99	431
	6	1,059,540,811	211.91	437

(*)CO2 emission factor : 98,538kg-CO2/TJ

(3) Effects of cleaning of condensers with high-pressure water jets

Cleaning of condensers with high-pressure water jets can remove grime that cannot be removed by cleaning with balls or brushes (such as silica or other hard scales), and thereby reduce condenser loss. The study was unable to confirm the management status as regards the degree of condenser vacuum and the connection with grime. The calculation of effect was based on actual data from removal of hard scales in Japan. In Vietnam, condensers are not cleaned with high-pressure jets, and it is consequently estimated that there is the same degree or more of hard scale adherence, depending on the power plant. If so, the effect would probably be even greater than shown in the calculation below. In the precedent case, the condenser vacuum improved from -94.22 kPa before cleaning to -94.77 kPa after it, and the corresponding improvement in the specific heat consumption was 0.07 percent. The calculation shown below used this figure.

Table 4.2-6 presents the calculation results. The results indicate that the cleaning could reduce the yearly consumption of coal by up to about 740 tons.

Table 4.2-6 Reduction of coal consumption by cleaning of condensers with high-pressure water jets

Plant	Unit	Generating End Efficiency	Heat Consumption (kcal/kwh)	Heat Consumption Improvement (kcal/kwh)	Generated Electricity (MWh/year)
		Actual	B = 3600 / A / 4.1868 / 100	C = B * 0.07 / 100	D (5 Year Average)
		A			
Ninh Binh TPP	1	21.29	4,039	2.83	193,807
	2	21	4,095	2.87	187,354
	3	23.02	3,735	2.61	185,736
	4	21.43	4,012	2.81	177,485
Pha Lai I TPP	1	28.3	3,038	2.13	692,347
	2	30	2,866	2.01	652,255
	3	29.09	2,956	2.07	737,340
	4	28.57	3,010	2.11	664,810
Pha Lai II TPP	5	35.18	2,444	1.71	2,137,675
	6	35.42	2,428	1.70	2,182,308

Plant	Unit	Heat Consumption Differennce (kcal/year)	Coal Consumption Differenece (t/year)	CO2 Emission Difference (t/year) (*)
		E = C * D * 1000	F = E / 5000 /1000	O * 5000 * 4.184 * 98538 * 10e-9
Ninh Binh TPP	1	547,913,654	109.58	226
	2	536,985,956	107.40	222
	3	485,634,534	97.13	200
	4	498,490,998	99.70	206
Pha Lai I TPP	1	1,472,500,934	294.50	608
	2	1,308,623,216	261.72	540
	3	1,525,606,037	305.12	629
	4	1,400,572,608	280.11	578
Pha Lai II TPP	5	3,657,330,853	731.47	1,509
	6	3,708,392,837	741.68	1,530

(*)CO2 emission factor : 98,538kg-CO2/TJ

4.3 Recommendation of measures for curtailment of GHG emissions at subcritical coal-fired thermal power plant, which will be newly built

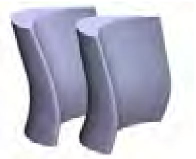
As a first step, it is vital to operate power plants at higher levels of efficiency by implementing the recommendations noted in sections 3.1 (for curtailment of GHG emissions through improvement in the operation aspect) and 3.2 (for curtailment of GHG emissions through improvement in the maintenance aspect).

The following section describes other measures that could contribute to higher plant efficiency.

4.3.1 Adoption of the latest type of blade and tip seal for steam turbines

(1) Adoption of the latest type of blade

The adoption of high-performance 3-Dimensions blades could reduce loss due to secondary flow arising at the blade base and tip, as well as profile loss due to incidence of abrasion on the blade surface and eddies in the vicinity of the trailing edge. This reduction of loss can improve turbine efficiency.



CFD (Computational Fluid Dynamics) Model

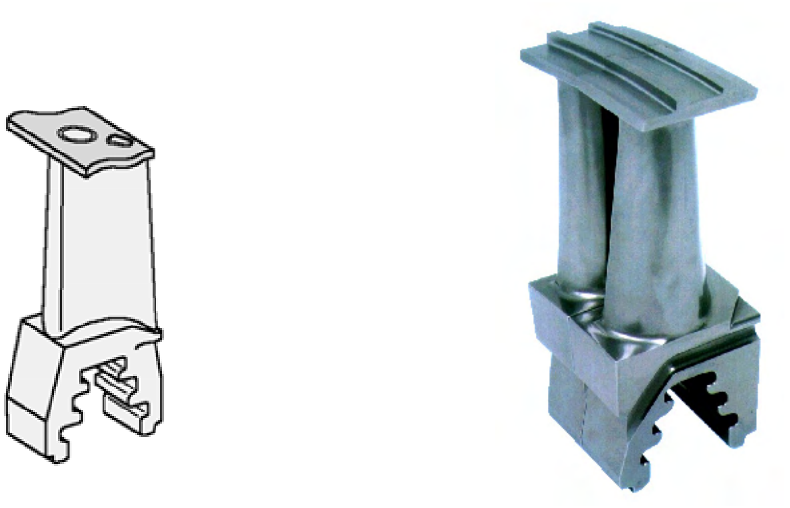
High-performance 3D nozzles

High-performance 3D blades

Figure 4.3-1 High-performance 3-Dimensions blades

(2) Adoption of the latest type of blade tip seal

The main type of seal between rotor and stator blades is the labyrinth seal. Sealing of the blade tips, however, presents structural difficulties, and the conventional approach is to seal the tips only with one or two fins, which is a factor behind a drop in efficiency. This situation led to the development of the continuous cover blade (CCB) structure, in which the whole circumference is covered with an interlocked shroud integrated with the rotor blades. As shown in the Figure 4.3-2, in the CCB structure, the separate shrouds are interlocked with each other in a circumferential orientation, and form a ring structure over the entire circumference. This makes it possible to attach labyrinth packing on the outer surface of the shroud, for an improvement of seal performance and turbine efficiency.



Conventional type blade

CCB blade

CCB blades

◆ Integrated circumference gives high-performance and high-reliability

Figure 4.3-2 Latest blade tip seal

4.3.2 Adoption of titanium pipe for condenser tubes and washing of the tubes every day with a ball cleaning unit

The Study Team recommends the adoption of titanium pipe for the condenser tubes and installation of a ball cleaning system to clean the tubes every day. These steps will curtail the drop in the degree of condenser vacuum due to grime in the tubes and, by extension, reduction in plant efficiency. As compared to aluminum brass tubes, which are conventionally used for cooling pipes, titanium tubes offer a lower heat radiation rate (about 80 percent). It is therefore necessary to increase the cooled area or in-tube flow rate. Nevertheless, titanium tubes eliminate concerns about corrosion and enable frequent performance of ball cleaning. This makes it possible to keep the degree of vacuum on a high level as compared to aluminum brass tubes.

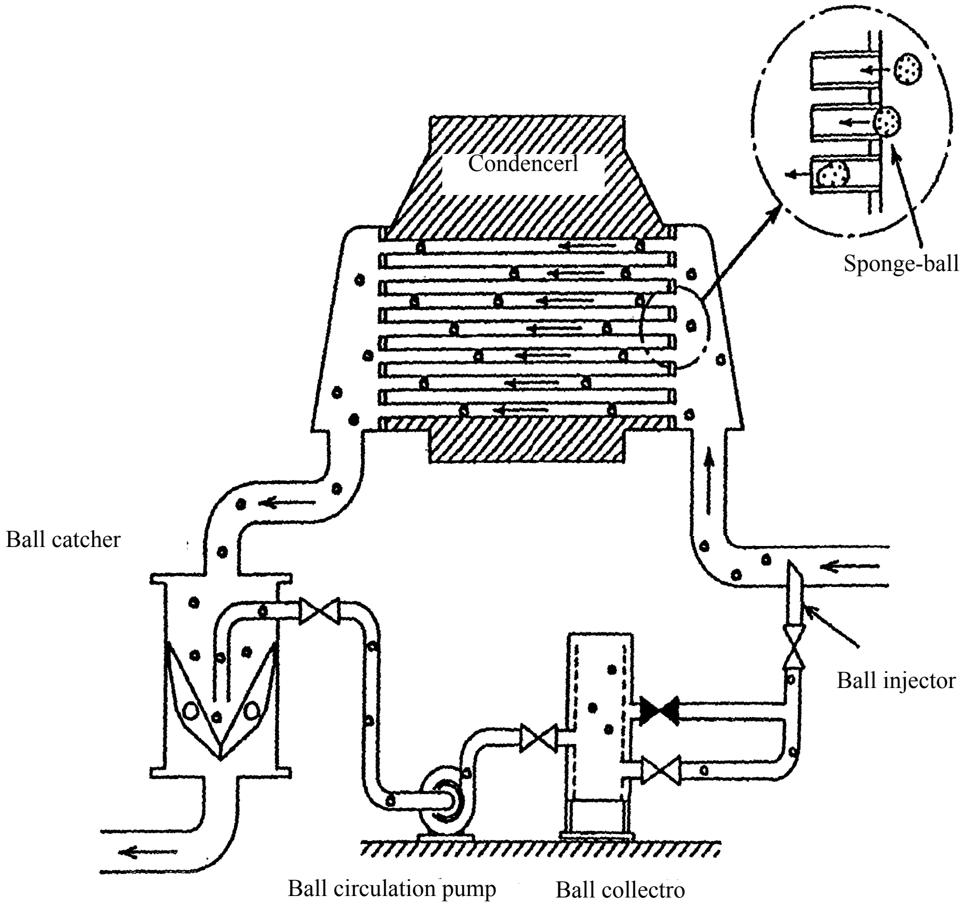
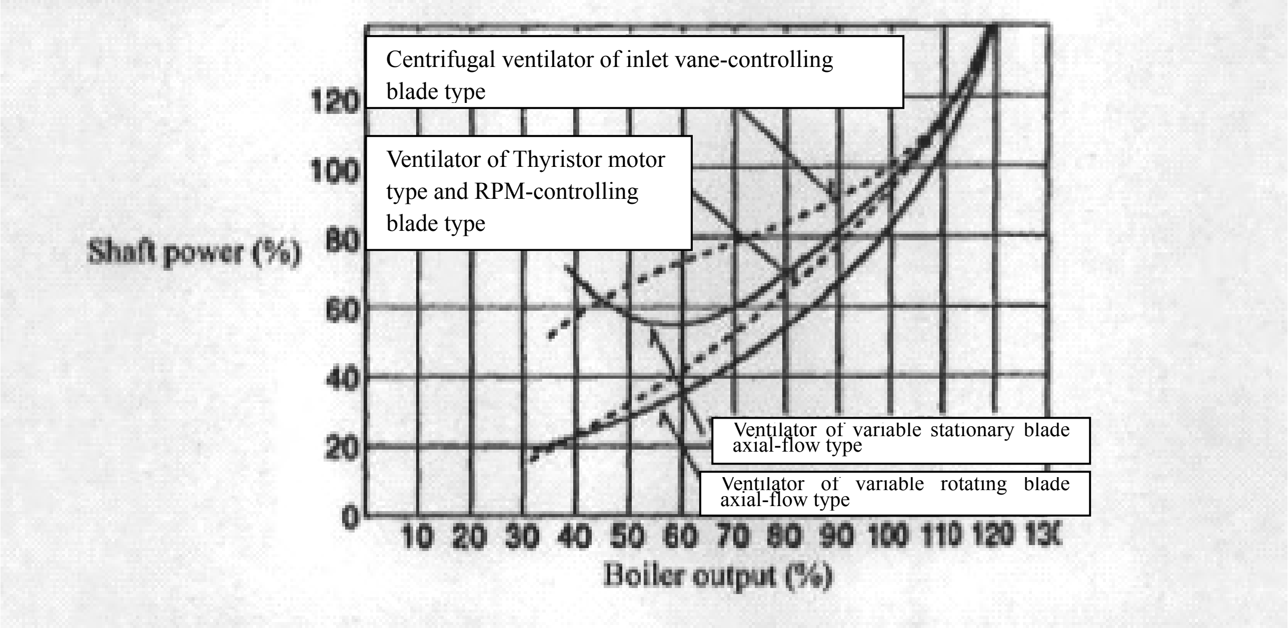


Figure 4.3-3 Ball cleaning system

4.3.3 Adoption of axial flow for large fans

Large fans (e.g., FDF, IDF, and PAF) occupy a large share of the in-plant power. Reduction of power use by them is an effective way of reducing the in-plant power and improving plant efficiency. The main types of fans are centrifugal and axial flow. In terms of the method of controlling the amount of air flow at partial load, the centrifugal type is further divided into the rpm control type and the inlet damper control type. The axial flow type is similarly subdivided into the movable stator blade type and movable rotor blade type. As shown in Figure 4.3-4, axial flow fans with movable rotor blades can keep high efficiency in all the boiler load zones compared with centrifugal control-type fans. For this reason, adoption of axial flow fans with movable rotor blades for large fans could be termed effective for improving plant efficiency.



Source: : ASIA-PACIFIC PARTNERSHIP on Clean Development and Climate

Figure 4.3-4 Diagram of the relationship between boiler output and fan power

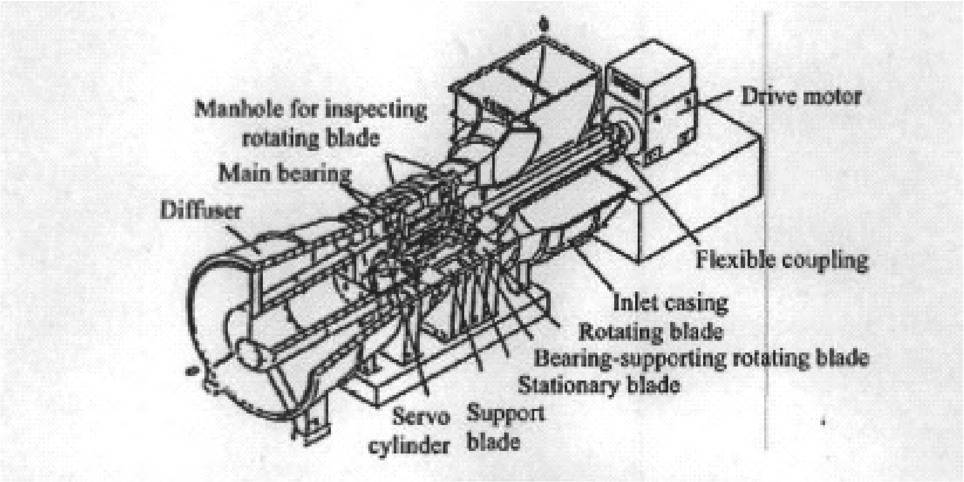


Figure 4.3-5 Axial flow fans with movable rotor blades

Appendix 1

Outline of the Power Plants

1. Features of the Ninh Binh Thermal Power Joint-stock Company

English name: Ninh Binh Thermal Power Joint-stock Company

Vietnam name: Công ty cổ phần Nhiệt điện Ninh Bình

Abbreviation: NBTPC

Establishment of a company: January 1, 2008

Location: Đường Hoàng Diệu - Phường Thanh Bình - Thành phố Ninh Bình (130km southeast of Hanoi)

Rated capacity: 100 MW (25 MW/unit)

Actual fuel: coal

Annual operating time: 7800 hours (average of all units from 2006 to 2009)

Figure 1-1 Overview of downtown in province of Ninh Binh

Ninh Binh power plant presents in center of this picture.

Figure 1-2 Overview of Ninh Binh thermal power plant

1.1 Corporate development

The construction of Ninh-binh coal-fired plant was started as an Official Development Assistance (ODA) of China from May 15 in 1971. The operation start date of the unit #1 was March 19 in 1974. Then the other units gradually started to move (unit #2 on December 1974 and unit #3 on November 1975), and the final unit (#4) was operationalized March 8 in 1976. The electricity generating capacity of Ninh-binh coal-fired plant is 100 MW which is a total of these 4 units. Major parts and equipments for the plant were made in China, and have been still supplied from a company in Shanghai to maintain or to fix.

In 1970s, this power plant had supplied the most major electricity with the other two plants. A lot of additional plant has been constructed at various regions in Vietnam, but the importance of Ninh-binh power plants is still remained even now because of the specific location. The Ninh-binh thermal power plant is sole one locating at a south point of Hanoi against major power plants assembling to the north region. This power plant was a national company as an affiliated enterprise of the Electricity of Viet Nam (EVN). Then, according to a policy of the Vietnam government, it was converted to a joint stock corporation, January 1, 2008. The shareholding ratio of EVN is ca. 54% as of December 2009.

Currently, the company has total staff strength of 900 employees, and female employees occupy almost 25%. The maximum employees in past had been almost 1400, but NBTPC has reduced the employee number by streamlining their operations. However, the further reduction of employees is difficult now because the almost equipments is manually manipulated in this plant.

1.2 Specifications of major equipments in the plant

Specifications of major equipments are described below (Table 1.2-1, Table 1.2-2 and Table 1.2-3). Features of turbines, generators and a control room are shown in Figure 1.2-1, Figure 1.2-2, Figure 1.2-3 and Figure 1.2-4.

Table 1.2-1 Boiler specifications

items	specifications
Maker	China
Type	Indoor, single drum and natural circulation
Combustion system	Corner firing type with low NOx burner
Superheater output pressure	37 kg/cm^2
Superheater output temperature	450 deg C
Steam flow	130 ton/h
Efficiency	90.1%
Mill type	Tube-type mill

There are 4 boilers in the plant.

Table 1.2-2 Turbine specifications

items	specifications
Maker	China
Type	31-25-7
Maximum output	25 MW
Vacuum of condenser	716 mmHg/cm^2
Turbine efficiency	31%

There are 4 turbines in the plant.

Table 1.2-3 Generator specifications

items	specifications
Maker	China
Type	0F-25-2TH
Rotating speed	3,000 rpm
Frequency	50 Hz
Generator efficiency	97.3%

There are 4 generators in the plant.

Figure 1.2-1 Turbine and generator

Figure 1.2-2 Generator

Figure 1.2-3 Turbine

Figure 1.2-4 Control room

1.3 Features and characteristics of systems

(1) Fuel systems

Fuel

Fuel characteristics used in this plant are described below. Fuel properties are analyzed at the same time with coal acceptances.

Type:	Anthracite coal, whose grades are 4b or 5b
Calorific value:	ca. 5,500 to 6,000 kcal/kg
Particle size:	1 to 15 mm in diameter (not including block coal, Figure 1.3-1)
Ash content:	22 to 33%
Moisture:	ca. 8%
Volatile matter -content:	ca.6 to 8%

Sulfur content: ca. 0.4 to 0.6%
Amount of consumption: ca. 1, 500 ton/day
Amount of import: 5 ships / day (ca. 300 t / ship, Figure 1.3-2)

Figure 1.3-1 Features of a coal fuel

Figure 1.3-2 Coal carriers

Coal-hoisting method

Figure 1.1-3 shows the overview of coal-hoisting facilities. Three crab bucket-type self-propelled cranes (indicated by arrows in Figure 2.1-9) are used for coal-hoisting. Then, the coals are thrown into a conveyor hopper (indicated by an arrow in Figure 2.1-10) and are directory transferred to coal bunkers. The operation is triple shift system on a round-the-clock basis.

Figure 1.3-3 Features of coal-hoisting installations
Arrows indicate crab bucket-type self-propelled cranes.

Figure 1.3-4 Belt conveyor hopper for the coal acceptance (indicated by an arrow)

Coal storage yard

A roofed yard is placed for rainy seasons (Figure 1.3-5). The stock capacity is 30,000 ton, corresponding to consumption of 20 days (Figure 1.3-6). In this plant, operators may not have to be concerned about loss of calorie by natural heat generation of coals because the stored coals contain few volatile matters. On the other hand, they have to be deeply concern about excess moisture of coals in rainy days. However, there are not operation standards for rainy days. During dry-season, coals hoisted from ships are directory transferred to coal bunkers.

Figure 1.3-5 Overview of the roofed coal storage yard

Figure 1.3-6 Inside of the roofed coal storage yard

Conveyor-belt machinery

The system is composed of two types of lines, connecting the coal-hoisting place to the coal bunker and the stock yard to the bunker. Conveyor-belts are 80 to 90 cm in width and 700 m in length, and have a canvas-like structure which does not include steel codes inside. The belt tension is adjusted by a counter weight system (Figure 1.3-7). Significant aged deteriorations and fixed marks by thermal spraying have been observed on the belts (indicated by arrows in Figure 1.3-8). Whole package of the conveyor system is covered by shields, but some chinks have been seen on the shields (Figure 1.3-9). Additionally, there are no water scrapers on conveyor-belts to remove rain water. Therefore, decrease of mill temperature has been expected by wet coals in a rain condition.

Figure 1.3-7 Conveyor-belt tensional adjuster

Figure 1.3-8 Appearance of conveyor-belt machinery

Arrows indicate failure locations on the belt.

Figure 1.3-9 Conveyor-belt lines of outdoor environments

Coal bunker

There are two coal bunkers for a unit. Additionally, a sub-bunker to accumulate coarse coal powder locates at downstream of a particle separator. Coal bunker volume and sub-bunker volume are 105 m^3 and 110 m^3, respectively. Coals of 15.6 ton are usually consumed by one unit for one hour but the coal level in bunkers is check by visual management. When the level decrease is observed, the operator manually feeds coals to bunkers.

Coal feeder

A vibrator is equipped as an outlet apparatus of each bunker (indicated by a white arrow in Figure 1.3-10). Coal flow rate is capable to adjust using an entrance gate on the vibrator (indicated by a red arrow in Figure 1.3-10), but precise adjustments of the coal flow are not done during the rated operation (Figure 1.3-11).

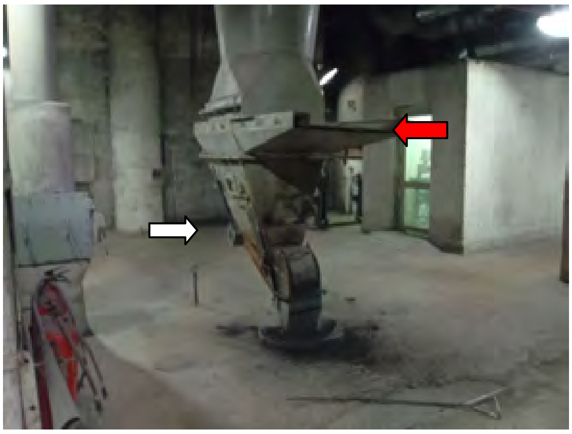


Figure 1.3-10 Coal feeder under a banker

A white arrow indicates a vibrator portion. A red arrow indicates “gate” to adjust coal supply.

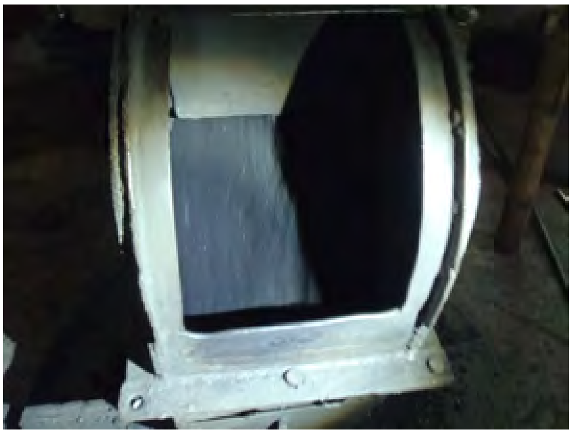


Figure 1.3-11 Affairs of Coal-feeding

Mill

The tube mill-type has been adopted for the coal pulverization (Figure 1.3-12) and 2 mills have been equipped for 1 boiler. This system is composed of wide-bodied drum containing 50,000 steel ball indenters (total 25 t, 0.5 kg/ball). It provides fine coal powder by spinning around the drum (Figure 1.3-13). The coal particle is ca. 90 µm in diameter. The actual mill temperature is ca. 90 to 100 deg C.

Figure 1.3-12 Overview of tube mill

Figure 1.3-13 Affairs of coal pulverization by a mill

Particle Separator

2 separators have been equipped for a unit. Coarse coal powder is distributed by the separator which has been placed at downstream of the fuel pipe. To confirm the distribution grade, samples are taken and checked by every 2 hours. The particle size is calculated by mesh-passing test.

(2) Draft systems

FDF (forced draft fan)

Each unit has a FDF which is a centrifugal type (Figure 1.3-14). This equipment supplies the air required for burning of fuel. PFP primary fans are not placed.

Figure 1.3-14 Forced draft fan

IDF (induced draft fan)

Each unit has two IDFs which are a centrifugal type. This equipment carries exhaust gas to a stack (Figure 1.3-15).

Figure 1.3-15 Induced draft fan

AH (air heater)

A tube-type air heating system has been installed by every unit (Figure 1.3-16). The combustion exhaust gas from a boiler passes through the inner tube and airs from FDF flow the tube outside. The inner tube-inside has been cleaned up only at every 4 years, and it has been carried out by compression air-shooting. Outside of the inner tube may have physical erosion by fly ash. However, there is no information about inner tube condition because the quantities of ash deposit and the tube thickness has not been measured on a routine basis. Therefore, they depend on only breakdown maintenances after troubles, but not preventive maintenances.

Figure 1.3-16 Air heater

(3) Circulating water systems

Water intake equipment

River water has been used. Average of water temperature is ca. 30 deg C and the maximum is from 36 to 38 deg C in summer. Four rotary screens have been equipped (Figure 1.3-17). Raw water contains a lot of pet bottle, vinyl product, can, wood chip and so on (Figure 1.3-18).

Figure 1.3-17 Rotary screen

Figure 1.3-18 Trash collected from river water

CWP (circulating water pump)

Four CWPs have been installed (Figure 1.3-19). One of these is for back-up. Chilled water has been supplied to steam condensers from here.

Figure 1.3-19 Circulating water pump

(4) Feedwater system

CP (condensate pump)

Each unit has been equipped with two CPs, which distill steam condensate from hot wells. Because all boilers are shared with single main steam pipe in this plant, it is possible to drive plural turbines using single boiler.

BFP (Boiler feed pump)

5 BFPs have been equipped in the plant (Figure 1.3-20). One is usually for backup and the others are shared by all units.

Figure 1.3-20 Boiler feed pump

1.4 Environmental efforts

(1) Chimney upgrading and expansions of low NOx burner and dry electrostatic precipitators

Early 1990's, atmospheric pollution had been serious around a region of Ninh Binh power plant because the exhaust gas from the plant had stagnated. As one of the reasons, a chimney of the plant had been 80 m in height that was 16 m lower than a small mountain adjusting to this plant. To improve this situation, Chimney height was changed to 130 m in 2000 (Figure 1.4-1). Additionally, low NOx burners produced by Mitsubishi Heavy Industries were installed instead of the old ones and dry electrostatic precipitators (EP, Figure 1.4-2) were additionally built at a same time.

Figure 1.4-1 Improved chimney

A white arrow indicates improved one (130 m). A red arrow indicates old one (80 m).

Figure 1.4-2 Dry electrostatic precipitator

(2) Plant tree

Recent year, this power plant makes an effort for greening in the establishment. Timbers and lawns have been well-pruned (Figure 1.4-3 and Figure 1.4-4).

Figure 1.4-3 Main street in the power plant

Figure 1.4-4 The front of central office building.

1.5 Organizations

An organization chart of NBTPC is shown in Figure 1.5-1, and each role is described below.

Department of general affair

- Management of quarters, dining and public facilities for stuff
- Purchase-planning of office equipments and supplies
- Custodies of corporation seal
- Carrying out administrative procedures and the other operational coordination
- Preparation of various documents directed by the president

Department of material planning

(As an assistant for the president, this department carries out affaires described below.)

- Development of business strategies
- Long or middle span-planning about production techniques and finances
- Transmittal of quarterly, semiannual and annual plans to the other section
- Procurement, supply and management of materials and of equipments
- Directions for purchase and for quality control of oils and coals

Department of labor service

- Construction of effective personnel systems
- Labor management-planning for short of long span
- Construction of labor management system according to laws and regional byelaws
- Control and readjustment of working conditions（Payroll, reword, punishment and so on）

Department of finance and account

(This department manages finances and accounts according to laws and EVN byelaws)

- Recording and understanding information of business transactions and generated electricity
- Providing financial information to the other departments
- Filing financial bulletin report to the government-affiliated organizations

Department of supervision, security and legal

- Management of affairs about supervision, security, legal, military, material appraisal and observation of fuels and equipments, to assist the president.

Department of safety techniques

- Detailed operation-planning for each boiler and each generator, according to EVN byelaws and each equipment capacity.
- Deliberation of protection measures for equipments
- Advices to the president about safety techniques, worker protections and working environment

Boiler operation block

- Safety operation of boilers and turbines, and its planning
- Observations and corrections for these equipments

Equipment-repairing block

- Heat equipment-repairing and the improvement for safety operations

Electricity and measurement device block

- Maintenance of the telecommunication network
- Operation and maintenance of electricity and measurement devices
- Maintenance of apparatuses and tools for sample analysis (coal, water and so on)

Chemicals block

- Chemical analysis of materials and wastes (water, oil, coal and ash)
- Supplying information of analysis to operation and maintenance blocks

Fuel block

- Coal acceptance
- Coal conveying

- Periodical maintenance of equipments for coal-feeding

Project coordination department

- Adviser for the president about “Thai Binh power plant construction project”

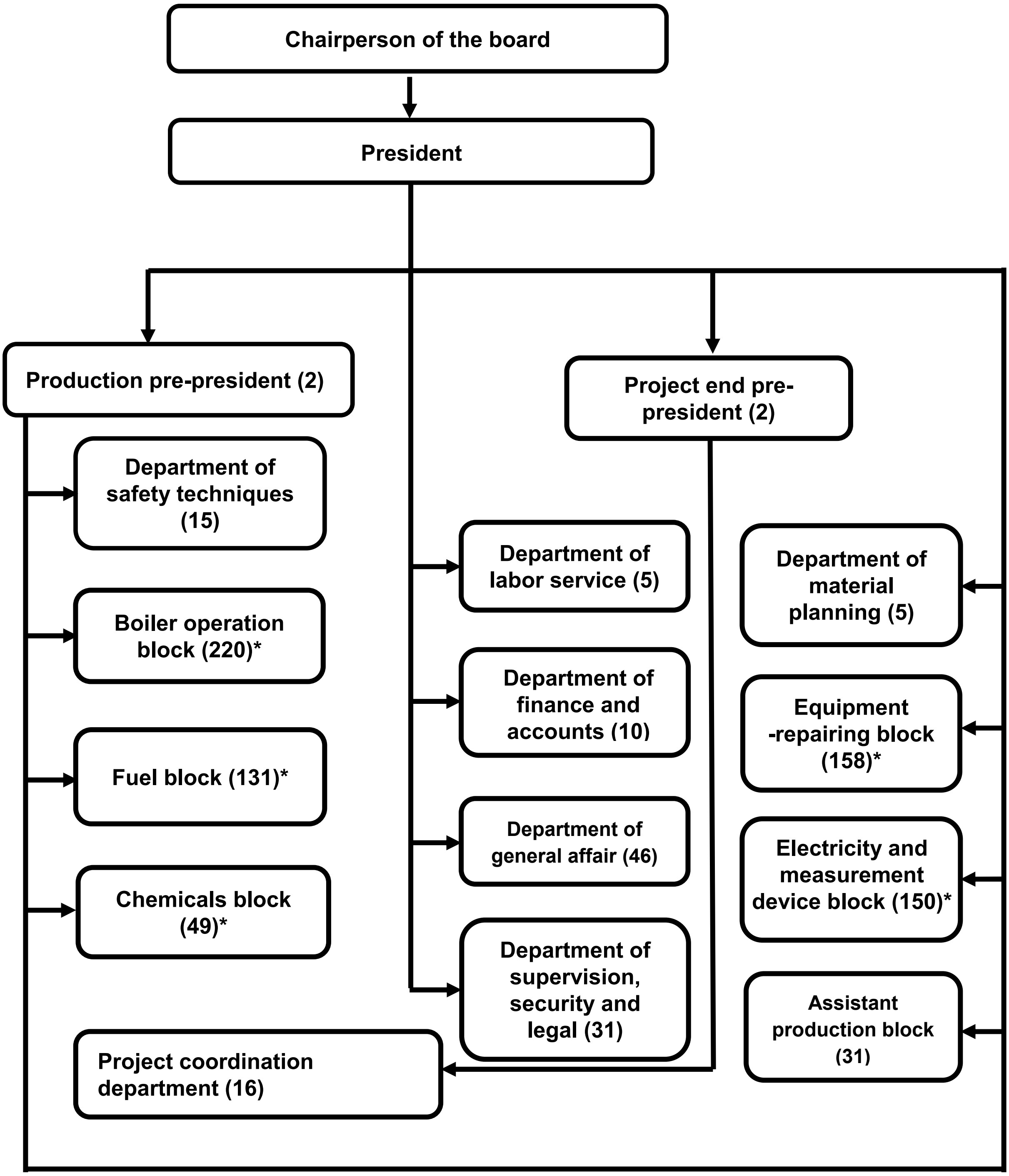


Figure 1.5-1 An organizational diagram of Ninh Binh Thermal Power Joint-stock Company.

A number shown in parentheses indicates head-count in each block or each department.
Asterisks indicate the blocks having work in three shifts.