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

(Summary)

June 2011

Japan International Cooperation Agency (JICA)

CHUBU Electric Power Co., Inc.

Japan Coal Energy Center (JCOAL)

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Table of Contents

List of Figures

List of Tables

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

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.

2.2 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.

2.3 Power development plans

2.3.1 Generation plans

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

Table 2.3-1 shows 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 2.3-1 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

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.

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.

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

Table 2.3-2 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 2.3-2 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)

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

Table 2.3-3 shows 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 2.3-3 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

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

2.4.1 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.

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.

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 2.4-1.

Table 2.4-1 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)	
India	2005	▲20-25% (Per unit of GDP)	

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
- AM0056: Energy efficiency improvement by boiler replacement or rehabilitation (and an optional fuel switch) in a fossil fuel-fired steam boiler system
- AM0062: Energy efficiency improvement in a power generation facility by retrofitting turbines

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, 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.

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, transportating and storing CO_2—each of which is subject to research and development.

(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.

<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.

2.4.2 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 2.4-2.

Table 2.4-2 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 2.4-3. CO_2 emissions account for more than 96% of the total GHG emissions. GHG emissions from coal combustion account for approximately 38%.

Table 2.4-3 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 2.4-1 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.
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.

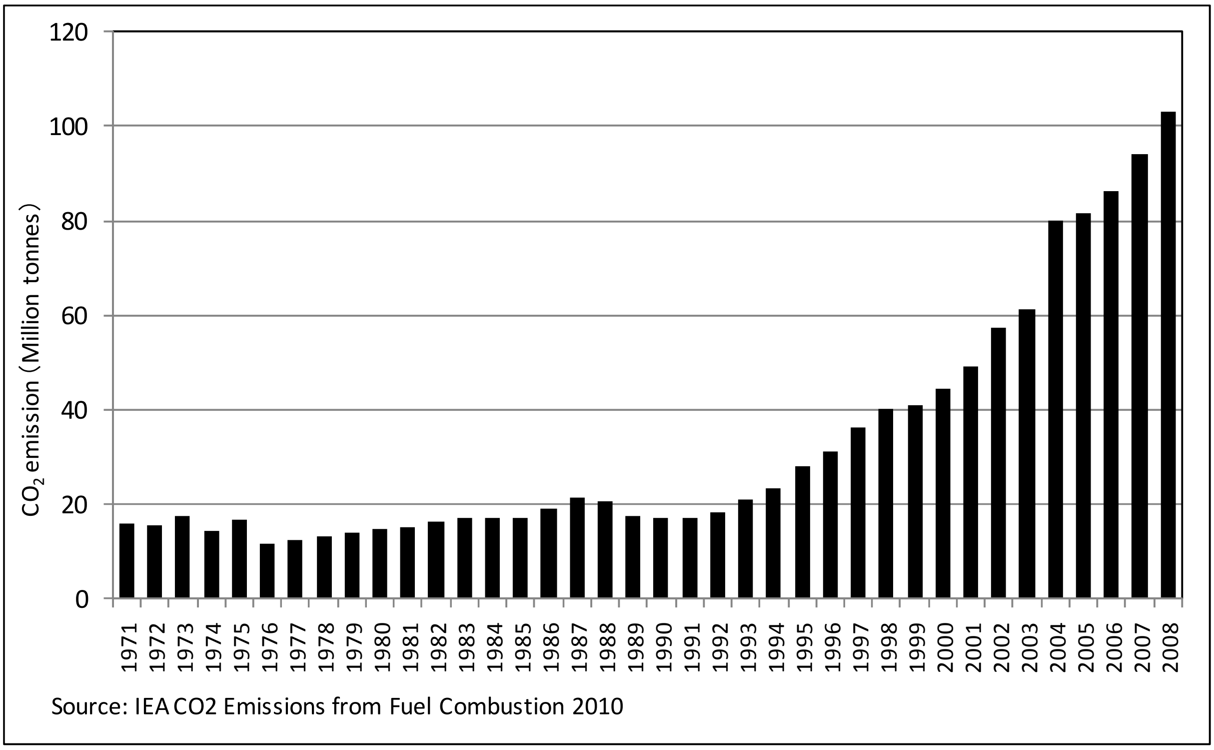

Figure 2.4-1 CO_2 emissions from Vietnam

(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. 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.

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.

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.

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.

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.

2.4.3 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.

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

3.1.1 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.

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

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 3.1-1 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 ($kg \cdot cm^2$)	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 3.1-1 Improvement of operating log sheets (example)

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

3.2.1 Boilers and environmental facilities

(1) Boilers

-Chemical cleaning of boilers

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

Figure 3.2-1 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 3.2-1 Flow of chemical washing of boilers

-Combustion simulation

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. Figure 3.2-2 shows an analysis example.

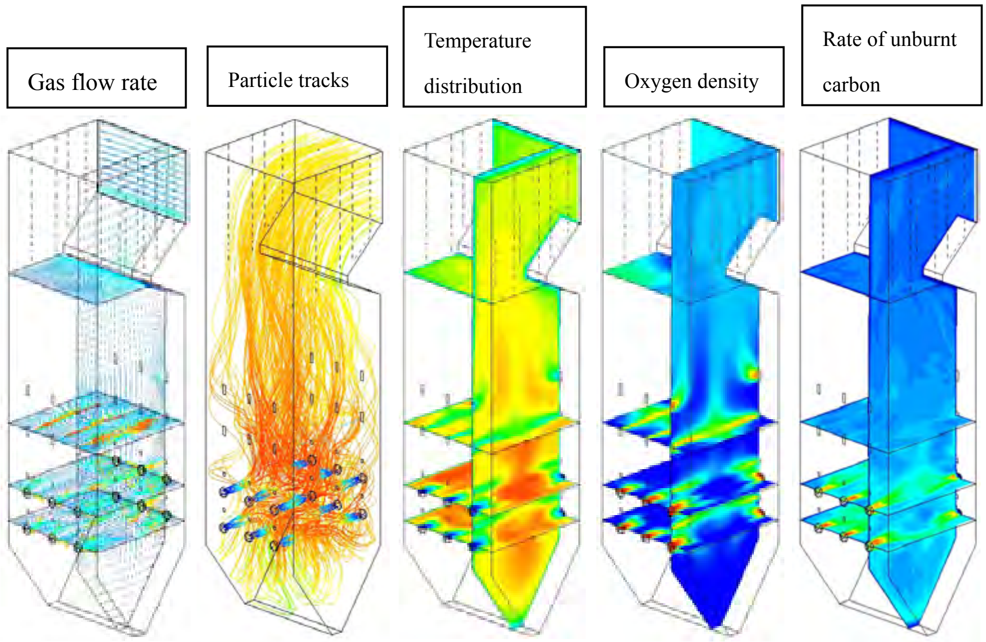

Figure 3.2-2 Combustion simulation-based boiler analysis example

-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.”

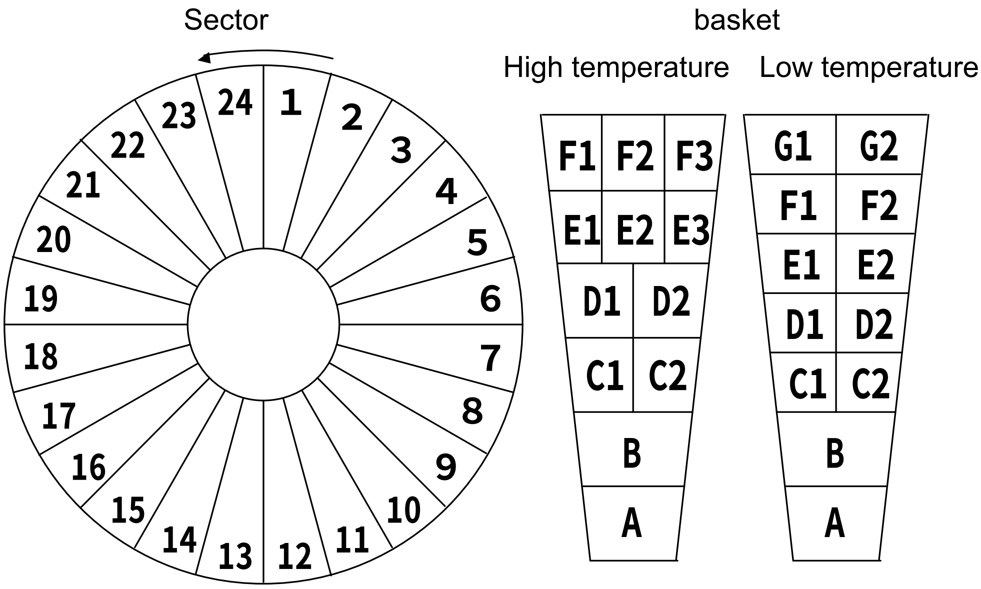

Figure 3.2-3 Element management

3.2.2 Turbines

(1) Main turbines

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.

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

(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)

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.

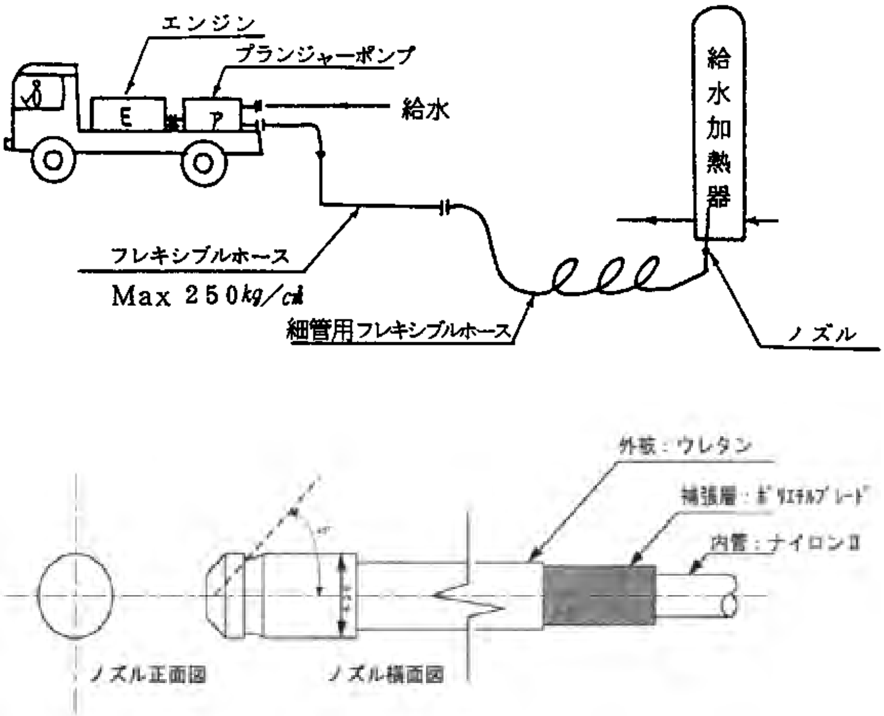

Figure 3.2-4 Outline diagram of water jet washing

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.

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.

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) Gravity separation

Table 3.3-1 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%.

Table 3.3-1 Results of separation by specific gravity

Coal Mine	Coal No. 5		Separating at Sp. Gr. 2.0	Light Product = Low Ash Coal		Heavy Product = Hi Ash Coal	
	Wt %	*Ash %*		Wt %	*Ash %*	Wt %	*Ash %*
Uong Bi area	100	*30*		66	*13*	34	*66*
Cam Pha area	100	*30*		76	*12*	24	*80*
Average	100	*30.0*		71.0	*12.5*	29.0	*71.8*

The place where the separation by specific gravity takes place is the "coal preparation plant." Specific gravity separators that are commercially in use at coal preparation plants include "jig." Figure 3.3-1 shows the principle of selection by jig.

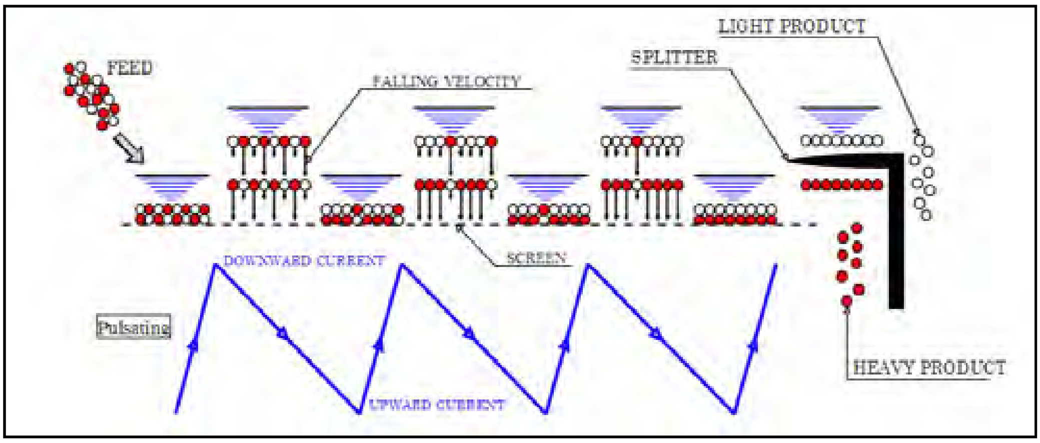

Figure 3.3-1 JIG separation principle

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.

3.3.2 Greenhouse gas reduction effects

(1) 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 3.3-2 shows the amount of coal used, quality and basic rate of energy consumption for both scenarios. This is based on the case in which the electricity of 1,000 kWh is transmitted. Based on this table, the amount of energy consumption is calculated.

Table 3.3-2 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).

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

Table 3.3-3 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 3.3-3 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

(3) 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 3.3-2 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.

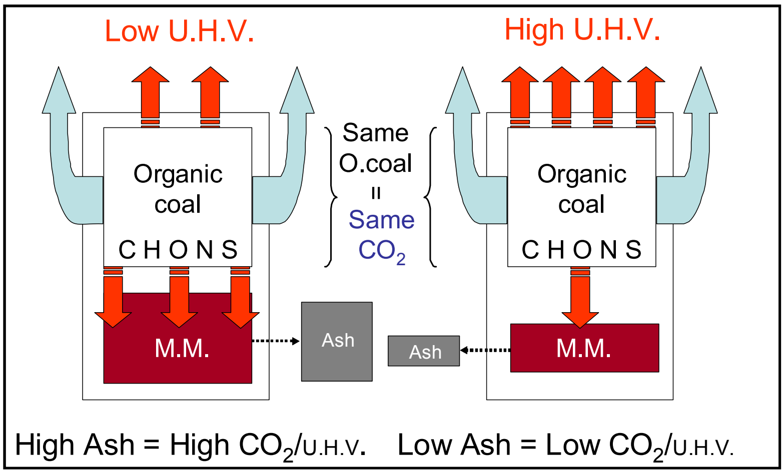

Figure 3.3-2 Mineral matter and effective calorific value

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

Table 4.1-2 shows the results for EVN's power 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

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").

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 (Table 4.1-4, 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.

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
ii. Sophisticated control because of the small heat storage capacity of the boiler
iii. Smaller tolerance to tube leaks
iv. Necessity of appropriate maintenance by the use of the remaining life evaluation method due to high-temperature and high-pressure steam

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

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

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

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 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

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.

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

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.

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

The calculation of effect was based on actual data from removal of hard scales in Japan. 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 A	B = 3600 / A / 4.1868 / 100	C = B * 0.07 / 100	D (5 Year Average)
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

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.

(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. 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.

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.

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. 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.