

Electricity Pricing for North Vietnam

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ELECTRICITY PRICING FOR NORTH VIETNAM

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ABSTRACT

The rapid economic growth in Vietnam has resulted in an increasing demand for electricity. This in turn translates to a higher rate of coal resource extraction and consequent rise in pollution of water and land resources.

This study estimated the environmental costs associated with the electricity demand requirements of the coal electricity sector, as a component of the long-run marginal opportunity cost (LR-MOC) of electricity production.

The LR-MOC has three components: Marginal Production Cost or direct cost (MPC), Marginal User Cost (MUC) and the Marginal Environmental Cost (MEC). The MEC is divided further into two components: Marginal Environmental Cost of coal mining (MEC_1) and Marginal Environmental Cost of coal burning (MEC_2). The MEC_1 consists of on-site environmental cost and off-site environmental cost while the MEC_2 is made up of control cost and off-site environmental cost.

The total production cost per tonne of clean coal was 241,050 VND in 1998 and was estimated to be 343,679.70 VND in 2010. The marginal environmental cost of coal mining (MEC_1) is 19,029.4 VND/per tonne in 2010 or 5.5% of production cost. Of the MEC_1 , on-site and off-site cost is about 3.6% and 1.93% of production cost, respectively.

The LR-MOC of coal electricity is 771.9 VND/per kWh at transmission and 975.5 VND/per kWh at distribution. The MEC ($MEC_1 + MEC_2$) accounts for 16.6% at transmission and 13.9% at distribution level. In comparison to the current tariff, the cost of the total electricity in 2010 is 1.75 times higher. The most suitable technological options for pollution control in coal-fired thermal power plants are precipitators for Group A and bag filters and limestone injection for Group B2. The least abatement and damage cost is associated with environmental technology alternative 2 (ETA_2) valued at 1,862 billion VND.

Given the worsening environmental problems in Halong Bay, which is a coal mining area, and the overall deteriorating environmental situation due to coal-fired power plants in Vietnam, the current subsidy of 25-30% to production cost and electricity tariff should gradually be removed. In fact, the environmental cost should be included in electricity and coal prices.

1.0 INTRODUCTION

1.1 Introduction and Background to the Study

The comprehensive reform of Vietnam's economic system that began in 1986 has shown impressive results. The Gross Domestic Product (GDP) has grown by an annual rate of 8.2% from 1991 to 1997 and was 5.6% in 1998 (Phan Van Khai – Prime Minister). Vietnam now not only feeds itself, but is the second largest exporter of rice in the world. Direct foreign investment has also increased significantly. Growth projections are quite optimistic.

Vietnam can learn from the experience of other countries in Asia and in the world, which shows that such accelerated economic growth imposes serious and sometimes irreversible damage on the natural environment. Already, economic growth has led to serious environmental degradation in Vietnam. The rapid growth rate (average GDP of 8.2%) has resulted in an increasing electricity demand; loss of the country's forest cover by 36% since 1943; a decrease in agricultural land per capita by almost 50% (Agricultural Environmental Conference, Agricultural Ministry 1999); an increase in contaminated surface and ground water by urban and industrial wastes; and contamination of large areas of the country from natural resource extraction such as coal mining. The air, water, ocean and land have become polluted and health has been affected by the industrial, transportation, coal mining and electricity sectors.

In 1997, Vietnam's national unified electricity system covered 61 provinces and cities (90% of districts, 50% of communes and over 50% of households). It had a total installed capacity of 4,892.4 MW (hydropower - 57.6%, gas turbines - 17.7%, coal-fired steam thermal - 13.2%, diesel - 7.5% and FO-fired steam thermal - 4%) and total electric generation of 19,095 GWh (hydropower - 61%, gas turbine - 15.3%, coal-fired steam thermal - 17.4%, Fuel-Oil fired steam thermal - 5.3% and diesel - 1%).

The rationale for long-run marginal cost (LRMC) pricing in Vietnam is as follows: a) in the context of socio-economic renovation (from 1986), the electricity sector has to reform its current electricity pricing from a subsidized electricity-pricing mechanism to an open market one; and b) in order to enlarge the different international cooperation on investment for electric power development such as through BOO (*Build-Operate-Own*), BOT (*Build-Operate-Transfer*), sharing contracts, captive power etc., it is necessary to establish a LRMC-based electricity tariff system.

However, it would be necessary to gradually change the prevailing electricity pricing by taking into account that: a) Vietnam's electric power system has been nationally unified by the 500 kV EHV (*Extra-High Voltage*) line North-South from the year 1994 with a centralized management through a subsidized electricity pricing mechanism; and b) up to now, Vietnam's current electricity pricing is still essentially

under government subsidy, especially in rural electrification, electric hydraulic pumping and in agriculture development.

What is being considered is an LRMC-based electricity pricing mechanism with two financial choices: One is to continue the current subsidized electric power pricing. In this scheme, the electricity development investment demand would be largely supported by the governmental budget. Secondly, the government will gradually reduce the current subsidy on electricity by enhancing the prevailing electricity tariff level up to the LRMC. This scheme will lead to the development of a financially self-sufficient and autonomous electricity sector that would respond to electricity development investment demand.

In the transition to a LRMC-based electricity pricing mechanism, it is necessary to take into account the current and projected electricity supply, covering up to year 2010. By that time, it was projected that there will be a shortage of electricity sources due to limited development investment in electricity. To solve the problem, Vietnam has to tap various electricity sources such as coal-fired or fuel-fired steam thermal power plants, gas turbines and hydropower plants. It would not be possible to make distinction between them in peaking or/and base-loading. However, in Vietnam, the peaking task belongs principally to gas turbines using diesel oil (DO), followed by hydropower plants (occupying a large percentage of Vietnam's electricity system). The base-loading task belongs to coal-fired steam thermal power plants, hydropower plants, and gas-based combine cycle gas turbines used at times to fuel-fired steam thermal power plants.

The present study has limited its research to the North Vietnam coal-fired steam thermal power plants. Specifically, it focused on the LRMC-based electricity pricing using coal as an electricity source.

Coal is one of Vietnam's most important sources of energy. Unfortunately, coal mining also causes environmental degradation and pollution. For example, coal mining, especially in Quangninh Province, has resulted in the following environmental damages:

- a) Ill health of coal mining workers, accidents and loss of workdays among others;
- b) Pollution of underground and surface water;
- c) Pollution of agricultural land by surface-clearing and by runoff from large piles of overburden;
- d) Destruction of forests by land-clearing for mines and timber;
- e) Air pollution in towns and cities from mining and the transport of the coal right through the residential areas;

- f) Damage to marine resources, including the heritage site of Halong Bay, because of the large discharges of mining wastes, runoff from overburden and waste piles and discharge waters from coal cleaning plants; and
- g) Noise pollution in areas surrounding the mines and processing plants.

1.2 Objectives of the Study

1. To estimate the long-run marginal opportunity cost (LR-MOC) of producing electricity using coal in North Vietnam.
2. To provide information on the marginal user cost and environmental cost of producing electricity using coal for the improvement of the present electricity pricing system in North Vietnam.
3. To identify pollution control technology options with acceptable combinations of control costs and environmental benefits.
4. To analyze the implication of improving the MOC in Vietnam and identify a set of economic and regulatory instruments for the government.

2.0 REVIEW OF LITERATURE AND METHODOLOGY

2.1 Review of Literature

Freeman (1990) showed that the economic value of resources is influenced not only by biological and economic factors, but also by institutions. In 1995, he developed an economic methodology and a computer model that calculates the external cost for new and re-licensed electricity resource options. His study in 1997 provided an overview of the issues associated with environmental costing and the effort to measure the environmental costs of electricity. It also discussed general applications of methods to estimate monetary loss due to environmental externalities.

Pearce et al. (1994) in *World Without End* concluded that the economic effects of the subsidies tend to be more dramatic than the environmental effects; they drain government revenues and thereby divert valuable resources away from productive sectors. They also tend to reduce exports of any indigenous energy, thereby adding to external debt, and encourage energy-intensive industry at the expense of more efficient industry.

During the past years, five major studies (Thayer, 1991; EC, 1994; Lee et al., 1994; Rowe et al., 1995; and Desvousges, 1995) have been completed, providing estimates of some of the external environmental costs of adding capacity to an electric generating system. All the studies used a damage function approach to estimate external costs adopting the following steps: a) estimate the emissions and other environmental stresses specific to the technology and fuel type being studied; b) estimate changes in

the relevant measurement of environmental quality; c) as functions of the emissions, estimate the physical effects of changes in environmental quality on the relevant receptors; d) apply unit values from the literature to convert physical effects to monetary damages for each end point; and finally, e) aggregate damages across all receptors and points.

Munasinghe (1982) conducted some case studies in the theory of electricity pricing. Results showed that substantial progress in reducing energy needs per unit of output, as well as controlling the level of pollution per unit of energy generated, could be achieved by combining the potential contribution of technical interventions with price reform.

Another study by Munasinghe in 1990 showed that the energy sector reform could contribute to both economic and environmental goals. In most developing countries, electricity prices have been well below the incremental cost of future supplies. Many studies showed that eliminating power subsidies by raising tariffs closer to the LRMC of power generation would encourage more efficient use of electricity. In addition, pricing reforms were found to have better economic and environmental impacts than purely technical approaches. Of course, a combination of both pricing and technical measures provided the best results.

A review of electricity tariffs in 60 developing countries by the World Bank (1993) showed that average tariffs declined over the period 1979-1988 from US\$0.052 to US\$0.0038 per kWh. This is particularly troubling as energy demands are expected to grow, and will probably double in the next 15 years.

The World Development Report for 1992 (World Bank, 1992) noted that energy subsidies exceeded US\$150 billion annually in developing countries. For electricity consumption alone, the subsidies amounted to about US\$100 billion per year, suggesting that both capital and energy sources were being wasted on a very large scale.

A study by Warford et al. (1997) indicated that raising electricity prices to the least LRMC (or as an approximation, Average Incremental Cost) is a priority. More ambitiously, it should be equal to marginal opportunity cost (MOC). Price reform will thus typically fall well into the “win-win” category. The benefits from increased electricity tariffs would be twofold. They concluded that removing all energy subsidies would produce large gains in efficiency and in fiscal balances, and would sharply reduce local pollution and cut carbon emissions by as much as 20% in some countries, and by about 7% worldwide. Consumers use about 20% more electricity than they would if they paid the true costs of supply.

Possible long-term effects discussed by Ramsay (1979) include the increased level of carbon dioxide released into the atmosphere from burning coal that may change the average temperature of the world, leading to as yet uncertain but possibly disastrous consequences. These are called health and environmental problems – the “unpaid costs of electricity because most of them do not show up in our monthly utility bills.” But

they are just as costly – in money, lives, or in a degraded environment – as any other kind of expense to society.

Most concerns on air emissions from the coal fuel cycle center on coal combustion, the emissions of which can affect natural ecosystems as well as human health and welfare over a broad region. The other portions of the fuel cycle also have important impacts but tend to be confined to a more local area (US Office of Technology Assessment, 1979).

2.2 Methodologies

Under environmental-social efficiency, Marginal Social Cost, not Marginal Private Cost should be considered. For any commodity, the social efficiency price should be achieved at P_s^* if the amount of consumption is at Q_p^* . Otherwise, if the price is P_p , the social amount should be produced at Q_s^* .

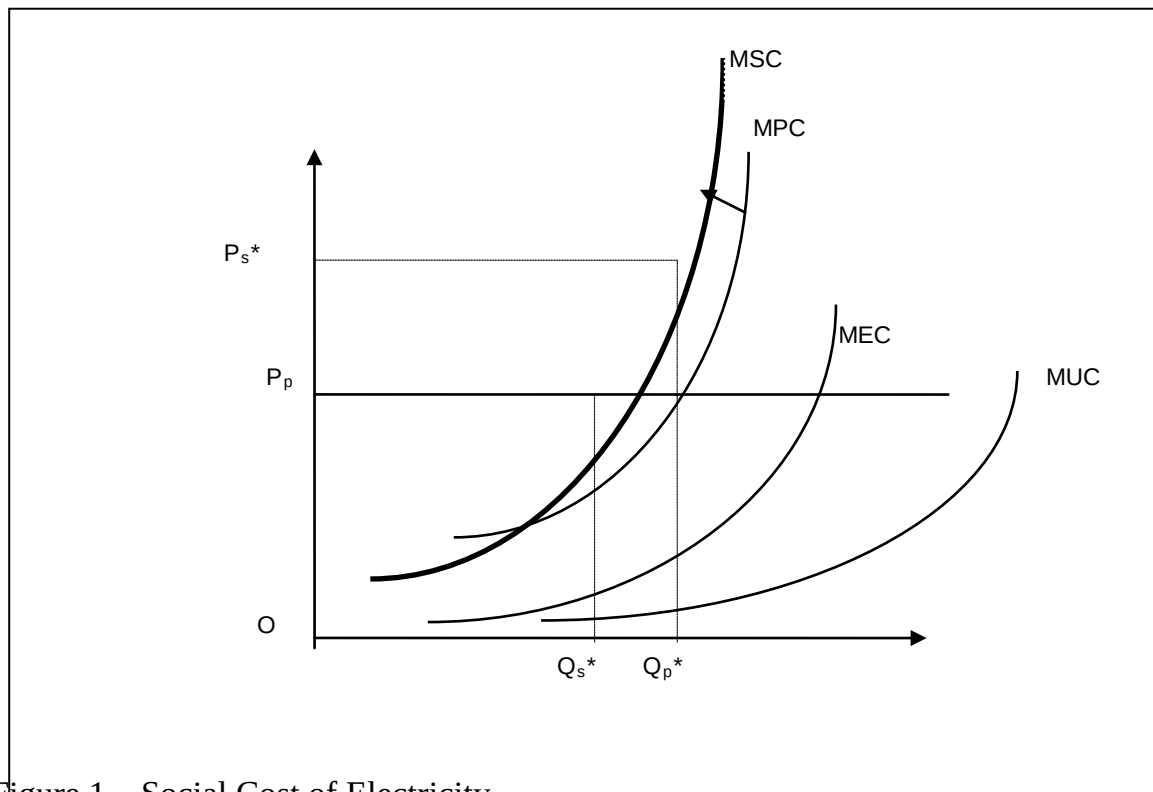


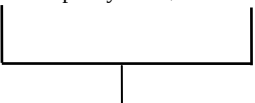
Figure 1. Social Cost of Electricity

where: MSC is marginal social cost
MPC is marginal private cost
MEC is marginal environmental (external) cost
MUC is marginal user cost

Therefore: $MSC = MC + MEC + MUC$

The components of the long-run marginal opportunity cost (LR-MOC) are as follows:

$$\begin{aligned} \text{LR-MOC} &= \text{MPC} + \text{MUC} + \text{MEC} \\ \text{or LR-MOC} &= \text{MPC}_{\text{capacity}} + (\text{MPC}_{\text{energy}} + \text{MEC}) + \text{MUC} \end{aligned}$$



Average Incremental Cost (AIC)

For the purposes of this study, the AIC is a good enough approximation to $[\text{MPC}_{\text{capacity}} + \text{MPC}_{\text{energy}}]$.

2.2.1 Estimation of the Long-run Marginal Cost

The strict long-run marginal cost (LRMC) may be defined broadly as the incremental cost of all adjustments in the system expansion plan and system operations attributable to an incremental increase in demand that is sustained into the future.

Cost Categories and Pricing Periods

Three broad categories of marginal costs may be identified for the LRMC calculations: capacity costs, energy costs, and consumer costs. Marginal capacity costs are basically the costs of investment in generation, transmission, and distribution facilities to supply additional kilowatts. Marginal energy costs are the fuel and operating costs needed to provide additional kilowatt-hours from a thermal plant, whereas in a hydroelectric system a part of the investment cost associated with storage may be related to energy. Marginal customer costs are the incremental costs directly attributable to consumers, including costs of hook-up, metering, and billing. Wherever appropriate, these elements of LRMC must be broken down by time of day, voltage level, and so on.

Suppose gas turbines are used for peaking. Then the required LRMC of generating capacity (LRMC_{Gc}) may be approximated by the cost of advancing or by the cost-saving from delaying 1 kilowatt of gas turbine. This may be estimated by the cost of a kilowatt installed, annualized over the expected lifetime, and adjusted for the reserve margin (RM) and appropriate percentage loss (L_G) typically caused by station use. Therefore:

$$\text{LRMC}_{\text{Gc}} = (\text{annualized cost per kilowatt}) + (1 + \text{RM}/100)/(1 - L_G/100)$$

Next, the LRMC of transmission and distribution is calculated. Generally, all costs of investment in transmission and distribution (T&D) –except customer costs which will be discussed later – are allocated to incremental capacity. This is because the

designs of these facilities are determined principally by the peak kilowatts they carry rather than the kilowatt-hours, particularly at the distribution level. However, the size of a given feeder may depend on the local demand peak, which may not occur within or coincide with the system's peak period. This could complicate the problem of allocating distribution capacity costs among the various pricing periods. The concept of structuring by voltage level may be introduced at this stage, considering several supply voltage categories – extra high (EHV), high (HV), medium (MV), and low (LV). Since consumers at each voltage level are charged only upstream costs, capacity costs at each voltage level must be identified.

Assume that the AIC of EHV and HV transmission has been computed and annualized over the lifetime of the plant – for example, 30 years – to yield the marginal costs $\Delta\text{LRMC}_{\text{HV}}$. Then, the total LRMC of capacity during the peak period at the HV level would be:

$$\text{LRMC}_{\text{HVC}} = \text{LRMC}_{\text{GC}} / (1 - L_{\text{HV}}/100 + \Delta\text{LRMC}_{\text{HV}})$$

where: L_{HV} is the percentage of incoming peak power that is lost in the EHV and HV network.

This procedure may be repeated at the MV and LV levels. Thus the LRMC of capacity to MV consumers is given by:

$$\text{LRMC}_{\text{MVC}} = \text{LRMC}_{\text{HVC}} / (1 - L_{\text{MV}}/100 + \Delta\text{LRMC}_{\text{MV}})$$

where: $\Delta\text{LRMC}_{\text{MV}}$ is the element of incremental MV capacity costs, for example, the AIC of distribution substation and primary feeders; and L_{MV} is the percentage of incoming peak power that is lost at the MV level.

The LRMC of transmission and distribution (T&D) calculated in this way is based on actual growth of future demand and is averaged over many consumers.

The LRMC of off-peak energy corresponding to a load increment during the off-peak period would usually be the running costs of the least efficient base-load or cycling plant used during this period. Exceptions to this generalization would occur when the marginal plant used during a pricing period was not necessarily the least efficient machine that could have been used. For example, less-efficient plants that have long start-up times and are kept running because they are required in the next pricing period may be operated earlier in the loading order than the more-efficient plants. This would correspond to minimization of operating costs over several pricing periods rather than on an hourly basis. Again, since the heat rate of the plants could vary with output level, the simple linear relation usually assumed between generation costs and kilowatt-hours may need to be replaced by a more realistic nonlinear model. The loss factors for adjusting off-peak costs will be smaller than the loss factors for the peak period. For example, resistive losses are a function of the square of the current flows and are greatest during the peak period.

The treatment of losses generally raises several important issues. Total normal technical losses, including station use, vary from system to system. If these are significantly greater than about 15% of gross generation, then reduction of the losses should have a high priority.

The LRMC analysis at the generation, transmission, and distribution levels helps to establish whether these incremental costs are excessive because of over-investment, high losses, or both.

2.2.2 The Marginal Production Cost (MPC)

According to Warford (1994), the AIC can be estimated by the following formula:

$$\text{Average Incremental Cost (AIC)} = \frac{\sum_{t=1}^T (I_t + OP_t) / (1+r)^t}{\sum_{t=1}^T (Q_t - Q_0) / (1+r)^t}$$

where: I_t is investment cost in year t , OP_t is the operating cost in year t (including fuel, labor, maintenance, etc.), $(Q_t - Q_0)$ is incremental consumption of electricity in year t , and T is the planning time horizon.

2.2.3 The Marginal User or Depletion Cost (MUC)

According to Warford (1994),

$$\text{MUC} = \frac{(P_r - C)}{(1 + r)^T}$$

where: P_r is the price of backstop replacement technology or the cost of imports, C is the price of existing technology, T is the time at which the replacement technology comes in (when coal is depleted).

However, the *user cost*, in particular, is not a relevant consideration. There is sufficient coal reserve to last for many decades. After applying a discount rate, any incremental cost associated with the introduction of the next cheapest technology will have a negligible effect on present values.

2.2.4 The Marginal Environmental or External Cost ($MEC = MEC_1 + MEC_2$)

Marginal Environmental Coal Mining Cost (MEC_1)

MEC_1 is broken down into two terms: On-site environmental protection cost (control technologies + compensation/treatment costs) and off-site residual environmental damage costs.

Despite the considerable economic contribution of the national coal industry to Vietnam, it has also resulted in great losses due to environment and health damages and a decrease in productivity of other industries like agriculture, forestry, fishing and tourism. On the other hand, the coal industry spends a large amount of money for structures to treat pollution, for ensuring work safety, for improving the environment surrounding coal mining enterprises and nearby residential areas, and for health treatment of mining staff and others.

To calculate how much money Vietnam annually spends to resolve the environmental aftermath caused by the coal industry, the following section will present the method used to account for the marginal environmental cost of the national coal industry (MEC_1) in the coming years. The general steps are:

First: total environmental cost of industries relating to pollution by the coal industry in the past several years should be established.

Second: average environmental cost per tonne of pollutant and per year should be measured based on the total cost estimate earlier.

Last, average MEC_1 in the past several years should be used as a basis to project MEC_1 for the succeeding years.

A. Health damage cost

All mine workers of the National Coal Industry are required to purchase insurance cards. They always use their insurance card to take health examinations. Hence, collecting health data from document sources on health treatment and insurance is the most important basis for calculating the health treatment cost. The health insurance card, however, covers only the treatment of common diseases while other types of occupational sickness are paid for by the workers or their mine companies. This health treatment cost is calculated using the following formula:

$$A = \sum_{i=1}^n A_i$$

where:

- i = the occupational diseases often caught by mine workers
- n = number of common and occupational diseases of the coal mining industry
- A = total health damage cost for all occupational diseases, injured workers, etc.

It is sum of A_1 - A_5 discussed below.

A_1 . The health examination and treatment cost

The health examination and treatment cost (A_1) is calculated as follows:

$$A_1 = \sum_{i=1}^n N_i P_i$$

where:

- N_i = average number of workers catching the type of disease i per year
- P_i = average treatment cost for disease i per patient

The estimated health and treatment costs in 1998 are shown in Appendix 1.

A_2 . Health treatment cost for injured workers when they are working

Injury from mining is not included in health insurance. Hence, all treatment costs for injuries associated with mining are paid for by both injured workers and their mine companies. This cost can be calculated using the following formula:

$$A_2 = \sum_{j=1}^m N_j P_j$$

where:

- j = type of injury
- m = number of types of injury
- N_j = average number of injured workers for injury type j per year in recent years
- P_j = the highest damage cost paid by an injured worker for type j to recover his health and to be able to work again (data sources based in 1997 records)

The health treatment costs for injured workers in 1997 are shown in Appendix 1.

A₃. Compensation cost for deaths on the job

This cost can be calculated using the following formula:

$$A_3 = N \times Q$$

where:

N = number of dead workers per year

Q = the highest payment for dead worker's family by mine companies in the National Coal Industry in 1997

The estimates of the compensation cost for deaths of workers on the job are shown in Appendix 1.

A₄. Lost workdays

This cost may be paid by either the injured workers' companies (which normally pay them wages when they leave their jobs) or the sick/injured workers themselves (who do not enjoy workday wage) or both the company and the worker. The worker is paid only one part of wages of lost workdays. All of these costs are charged as a loss to the National Coal Industry. The wage for one workday below is calibrated at the average level for the whole industry:

$$A_4 = W \times L$$

where:

W = number of lost workdays per year of the National Coal Industry

L = average wage/day/worker (*L in the year 1998 was 38,500 VND/workday*).

The estimates of the lost workday cost in 1998 are shown in Appendix 1.

A₅. Compensation cost for residents near mining areas

This cost can be calculated by the following formula:

$$A_5 = G \times M$$

where:

G = average number of patients per year from mine's surrounding areas

M = health treatment cost

The results of the compensation cost calculation for residents near mining areas in 1998 are shown in Appendix 1.

B. Air, water and noise pollution treatment cost

In theory, b_1 or the pollution treatment cost inside the mine is computed by:

$$b_1 = n \times P$$

where:

n = number of mine exploiting companies directly under the Vietnam National Coal Corporation.

P = the average pollution treatment cost cross all mines or enterprises

The domestic water treatment cost for the different residential areas affected by coal mining activities, b_2 is also calculated as follows:

$$b_2 = n \times Q'$$

where:

n = number of residential areas

Q' = average domestic water treatment cost per year for a residential area

The sum of b_1 and b_2 constitutes the cost of air, water and noise pollution treatment cost or B .

In practice, which considers actual situation and pollution treatment cost items, B is calculated as follows as adopted in this study:

b_1 = *Pollution treatment cost inside the mine*: The data was taken from reports on the environmental impact assessments of coal mining activities in 1997 in four representative large mines: Hatu, Naduong, Cocsau (Bm1), and Hongai coal preparing plant at Quangninh province (bp1). The drinking water treatment cost for these mines is considered part of the water pollution treatment cost. Specifically, the projected values for b_1 from 1999 to 2010, were derived from the Environmental Impact Management Report in 1997 and are shown in Appendix 2.

b_2 = *Pollution treatment cost outside the mine*: This is the cost spent on treating polluted water used for household consumption, in areas affected by mining pollution. Although mine companies do not have to pay for this cost item, it is an environmental cost that has to be accounted for as a cost to society.

The b_2 incurred by society in areas affected by the mining activities per year is calculated using the following formula:

$$b_2 = \sum_{i=1}^n S_i (Q_i - P_i) \times 365$$

where:

Q_i = average production cost per m^3 of domestic water supply after pollution from mining at region i

P_i = average price per m^3 of domestic water supply before pollution from mining at region i

$Q_i - P_i$ = increase the cost of domestic water supply due to pollution from mining

S_i = shortage in domestic water supply per day due to mining pollution at region i

n = number of regions with domestic water pollution caused by mining activities

The estimated cost of treating domestic water supply (b_2) in affected areas 1998 is shown in Appendix 3.

C. Loss of tourism and recreation benefits

Halong Bay is important to the community in many ways. Many people see Halong Bay as a place that offers a pleasant contrast to their daily routines. It also provides specific recreational activities like fishing, boating, strolling, swimming and others.

Loss of tourism (C_1), caused by mining pollution can be calculated using the following formula:

$$C_1 = f \times P \times 30\%$$

where:

f = net return per tourist per year over the last seven years (1992-1997)

P = average decrease in number of tourists over the last seven years (Data was taken from records of Quangninh Tourist Company).

There is a 30% percent decrease in number of tourist as the results of coal mining activities (source *Tourist Development Assessment Project in Halong City* of Hanoi National University, 1997)

There is also the loss of recreational benefits by local residents (C_2) that is calculated as follows:

$$C_2 = \sum C_{2i} * W$$

where:

C_{2i} is the number of hours of loss in recreational time for activity i due to mining pollution.

W is average wage rate of local resident, which was adjusted by 20% for unemployment
i refers to recreation activities (swimming, boating, fishing, etc.)

The time spent by each household for swimming, fishing, boating, and strolling was collected weekly and then estimated yearly.

The estimated loss of the tourism (C_1) and recreation (C_2) in 1998 are summed up as C and are shown in Appendices 4 and 5.

D. Forestry production, fishing and agriculture losses caused by the coal industry

D₁. Forestry production loss

Quangninh is a mountainous region of approximately 600,000 ha, which include forestlands of 280,000 ha and agricultural land of 51,000 ha. Most of the large coal reserve mines in the country are located on the highland terrain of Quangninh province. According to statistical data of 1993, mineral ore mining activities took place on 28% of the total land area, 23% of the forest area and 4% of the industrial and residential area of Quangninh province. The forest land area was reduced to 42% and 18-20% in 1969 and 1985, respectively, due to both direct mining and mining service activities in this area. For example, deforestation resulted from underground mining since the area was cleared to construct mine access. For this reason, the level of annual forest products also decreased. Hence, when mineral ore mining activities are carried out in any area within the forest land, in addition to the forest land's opportunity cost generated by the mining process, mining activities also cause the loss of other forest products such as firewood, forest and animal meat. This is shown as:

$$D_1 = D'_1 + D''_1$$

where:

D'_1 = the income foregone (opportunity cost) of forest lands used for mining

D''_1 = total losses of non-timber products (e.g., firewood)

Based on the data stated above, the opportunity cost of coal mining activities per year is

$$D'_1 = S_i \times A$$

where:

S_i = forest land area destroyed by coal mining activities

A = annualized income derived after estimating the net present value (NPV) of the income from forest land use (calculated using 10% discount rate – Appendix 6)

The estimated loss of opportunity cost of forestland use, (D_1'), is shown in Appendix 5.

Quangninh Forest is not a virgin forest; it has low hills and a shrub terrain with timber. As described above, when timber from the natural forest is exploited to supply the wood requirement of underground mining and mine construction, the forest animals move to other places that are not affected by coal exploitation. Another forest product that is often exhausted is firewood.

According to data collected, the loss of forest products can be calculated by the formula below:

$$D_1'' = S \times r \times T$$

where:

S = average forest area destroyed per year by coal mining activities

r = amount of firewood/ha forest (m^3)

T = cost of 1 m^3 firewood based on net price

The estimated loss from damage to forest resources (D_1'') is shown in Appendix 5.

D₂. Loss to the fisheries sector

The coal mining industry also affects the fisheries sector because a large amount of untreated wastewater from coal mines is directly discharged into the sea. Therefore, coastal resources are strongly affected as indicated by the considerable decrease in the annual fish catch. To meet the increasing local and foreign demand for fish products, the fishing sector is improving its catching techniques and changing its fishing locations (for example, combining offshore catching and mariculture activities). Loss of fish products is very difficult to calculate exactly. Therefore, this loss may only be estimated by the following formula:

$$D_2 = k \left[\sum_{i=1}^n (P_i + Q_i) \right] / n$$

where:

- a) Increased cost of catching fish near the shoreline – municipal fishing areas:

$$Q_i = q_i \times h_{ai}$$

With:

Q_i = annual increase in cost of catching fish near the shoreline

h_{ai} = catch near the shoreline in year i

q_i = increase in weighted average cost of catching a tonne of fish near the shoreline in year i compared to year $i-1$, due to reduced fish availability caused by pollution.

- b) Increased cost of catching fish beyond 15 km from the shoreline – commercial fishing areas.

$$P_i = p_i \times h_{bi}$$

With:

p_i = increase in cost of catching a tonne of fish caught far from the shoreline in year i .

h_{bi} = catch far from the shoreline in year i

$P_{(i)}$ = annual increase in cost due to catching fish far from the shoreline.

- c) Number of years (n) and impact level (k)

n = number of years (1994 -1997)

k = impact level of the national coal industry, according to the estimates of the Quangninh Fishing Department

The estimated loss to the fishing sector (D_2') is shown in Appendix 7.

D₃. Agriculture loss

Quangninh province does not have a large agricultural land area because it is a mountainous area. The agriculture area is about 57,124 ha or 9.6% of the total land area. The province has most of the nation's large reserve mines (95% of the total national coal production), of which underground coal mining production was 33% in 1996. The percentage of underground coal production has increased because of higher stripping rate of the in-situ and deep mining deposits.

The increased level of underground mining has led to increasing demand for mine timbers. According to mining engineers, the amount of underground mine timbers used is approximately 50 m³ for 1,000 tonnes of coal. One hectare of natural forest and half a hectare of reforested areas are needed to obtain this amount of timber. This means that for one million tonnes of coal, 50,000 m³ of mine timbers would be needed from 500 ha of 12- to 15-year-old plantation forest in Quangninh.

At present, Quangninh's forest is not able to meet the demand for mine timbers for the Quangninh coal industry because of its degradation. It provided only 10% of the demand in 1996. Obtaining additional timbers from the neighboring provinces entails a high transportation cost. As a result, the needed timber is provided from illegal logging in Quangninh province. According to reports by state-owned farms, Quangninh's forest

exploitation is six to ten times higher than the national average, with the degradation rate of Quangninh's forest being also higher than the national average.

Mining activities, especially illegal mining and mining service activities, such as forest-clearing, strongly affect the natural forest resources, the forest ecology and the areas surrounding the mines. This damage includes soil erosion, which in turn results in increasing areas of bald hills and a decreasing water level. In addition, crop productivity is also reduced due to decreasing soil fertility in the agricultural land area.

The loss in agriculture (D_3) includes: land opportunity cost (D_3') and loss in harvest (D_3'')

where:

$$D_3 = D_3' + D_3''$$

D_3' = Total agricultural land area x average productivity/agriculture land area.

D_3'' = Decrease in productivity per unit land area x total agricultural land area affected by coal mining

The estimated loss to the agricultural sector (D_3) is shown in Appendix 8.

Therefore, the total agriculture, forest and fishing losses, D , are:

$$D = D_1 + D_2 + D_3$$

where:

D_1 is loss to forest;

D_2 is loss to fishing; and

D_3 is loss to agricultural sector.

E. Impact on infrastructure by the coal industry

The estimation for this item requires identifying the areas with infrastructures that were damaged by the coal industry.

The Campha coal region is located near a local residential area and its transport routes have a lot of coal vehicles as well as coal mines near the municipality. Therefore, this coal region was used as an example to estimate the cost of damaged infrastructure caused by the coal industry:

$$E = n \sum_{i=1}^m P_i$$

where: E = loss to infrastructure

n = number of residential areas surrounding the coal mine

- i = local infrastructure to be repaired (e.g., roads, bridges and drainage system)
- m = total infrastructure items
- P_i = average repair cost per year of infrastructure item i at the sample area

The estimated loss of infrastructure (E) is shown in Appendix 9.

$$AEC_1 (1997 \& 1998) = (A + B + C + D + E) / \text{Average total coal products of the coal industry in year 1997 plus 1998}$$

where:

AEC_1 = Average environmental cost of a tonne of coal (1997 & 1998)

A = Health cost

B = Air, water, and noise pollution treatment cost

C = Loss of tourism and recreation

D = Forestry, agriculture and fishing losses caused by the coal industry

E = Cost of impacts on infrastructure by the coal industry

The Marginal Environmental Consumption Cost (MEC_2)

The U-shaped pollution cost curve (Figure 2 from Hufschmidt, et al. 1983) represents the relationship between damage costs (i.e., costs imposed by pollution – external cost) and abatement costs (i.e., costs incurred to avoid/mitigate the effects of pollution – environmental control costs or internal costs).

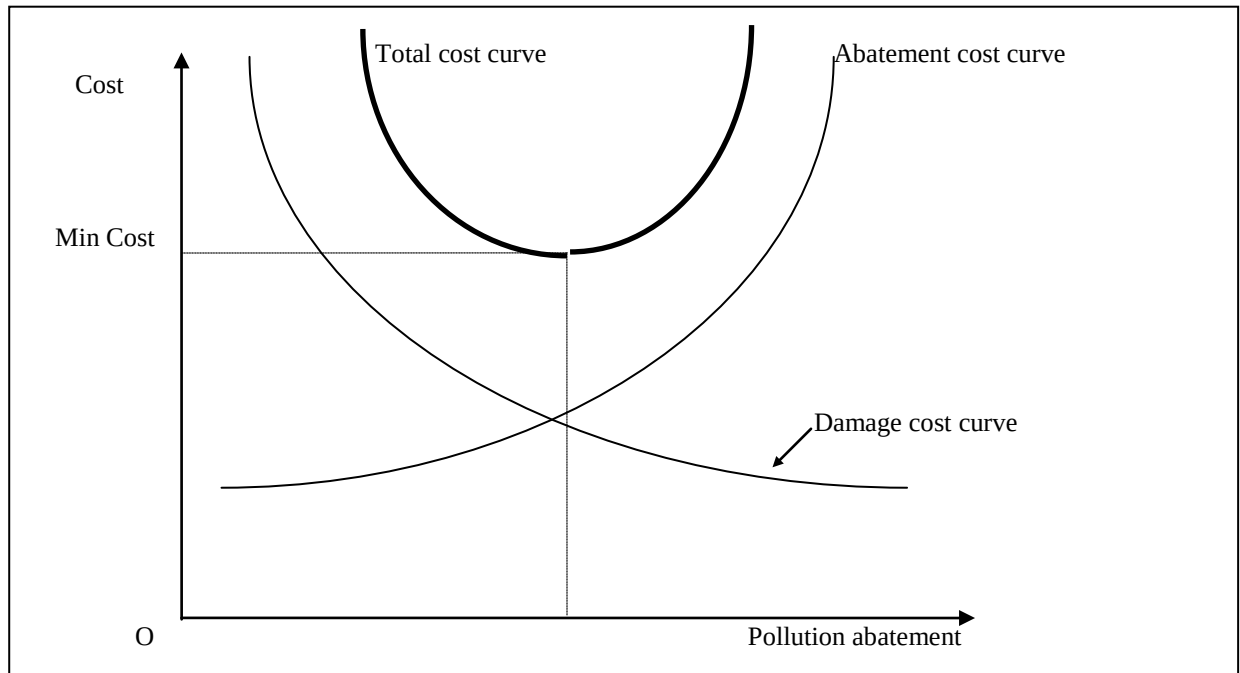


Figure 2. U-shaped Pollution Cost Curve

MEC₂ is broken into two terms. The first term is the internal environmental protection cost consisting of cost of control technologies and compensation/ treatment costs. The second term is external residual environmental damage costs.

i) Internal Environmental Protection Cost

In the study, the emission target used is the government emission standard (TCVN) set at three levels: the current standard for Vietnam; a standard 25% higher than the current standard for Vietnam; and a standard 25% lower than the current one. The three most promising control technologies with the lowest cost and those most commonly used in Vietnam were identified.

According to the definition of environmental costs in environmental impact assessment of electric projects in general, and in coal steam thermal power ones in particular, the environmental costs are defined as the costs required to restore the polluted environment to the cleaner level given in the status quo. In particular, the status quo of the air environment before it was polluted by burning coal in thermal power plants is defined as the environment that meets the national standard provided in TCVN-5937-1995 or “Air Quality – Standards on Ambient Air Quality – Critical Values Basic Parameters of Ambient Air (mg/c.m)” and TCVN-5939-1995 on “Permitted Maximal Concentration of Major Polluting Agents in Discharged Gas” relating to coal-fired thermal power sources of Group A (existing plants) and of Group B (future exploited after promulgation of the above TCVN).

In comparison with the same standards promulgated by the World Bank, the TCVNs are more strict with regards to particulate and SO_x control.

Regarding coal steam thermal power plants of Group A (existing plants), the air pollution they cause is of two types: particulate emission and toxic gas emission – (CO, NO_x, SO_x, HC)

In terms of particulate emissions, the study focused on three principal environmental technologies, namely: wet cyclones, electrostatic precipitators, and bag filters with their corresponding efficiency values.

It is necessary to emphasize that the environmental technologies to reduce the particulate emissions could not be used to reduce toxic gas emissions. Various environmental technologies to reduce the impact of toxic gas emissions of existing coal-fired thermal power plants of Group A are currently not feasible because of following reasons:

- a) The investment and O&M costs of these technologies are too high. According to data obtained from different firms, installing a scrubber to clean the discharged smoke from CO, NO_x and SO_x requires an investment of

US\$100-150 per kW installed capacity of coal-fired thermal plant and an O&M cost of US\$0.01-0.02 per kWh of coal-fired thermal power generation.

- b) The sulfur content of Quangninh's natural anthracite coal, which is used in almost all existing coal steam thermal power plants in Vietnam, is very small (under 1%, average of 0.5%).
- c) Installing a system of coal cleaning or milled limestone injecting is considered not feasible and unreasonable because of the small scale and backward technology of existing coal-fired thermal power plants under Group A.
- d) The environmental technologies to reduce toxic gas emissions are not useful for minimizing the particulate emissions of coal-fired thermal power plants.

Therefore, it is essential to identify different environmental technologies to reduce pollution due to the burning of coal in thermal power plants. The study focused on the pertinent technologies to reduce particulate emission. All existing coal-fired steam thermal power plants under Group A (Ninhbinh, Uongbi 1, Phalai 1) used the same old technology of using degraded wet cyclones to reduce coal burning emissions. These wet cyclones have a 60% efficiency and are being substituted by electrostatic precipitators.

For plants of Group B, namely: Phalai 2 (600 MW), Uongbi (300 MW), and Haiphong (600 MW), the coal burning technology injecting milled anthracite and the particulate emission-reducing technology of electrostatic precipitators were selected in forecasting control cost by the Vietnam General Electricity Company. This excludes the scrubber system that is quite an expensive pollution control measure since Vietnamese anthracite coal has a low sulfur content. It was not necessary to use supplementary environmental technologies in the Quangninh coal-fired thermal plant (600 MW) which uses fluid coal burning technology and bag filters and injected milled limestone to reduce particulate and toxic gas emissions.

In the methodology of this study, the environmental costs were included in forecasting the investment costs of the coal-fired thermal power plants of Group B to calculate LRMC. In the three selected environmental technology alternatives, their particulate and toxic gas emission quantity was considered constant. Essentially, the difference in the three environmental technology alternatives (>TCVN; = TCVN; <TCVN) was caused by particulate emission reduction technologies selected for existing coal-fired thermal power plants of Group A.

ii) External Residual Environmental Damage Costs

As presented above, the estimated costs needed to reduce environmental pollution caused by coal combustion in thermal power plants were made only for Group A plants (existing). As for Group B plants, the forecast for the period 1997-2010, corresponds to what is needed to meet the requirements specified in TCVN as reflected in the feasibility studies and designs, wherein their unit investment costs include the

environmental costs. However, the estimated damage costs caused by the emissions of TSP and toxic gas, especially of CO₂, would have to be considered not only for Group A but also for Group B.

The pollution produced by thermal power plants comes from the local firms that comprise the majority of the thermal plants. Because this was the first time that the different environmental costs caused by coal combustion in thermal power plants were estimated in the context of inadequate data relating to their environmental impacts and damages, it would be necessary to use data from other countries as basis for the estimation.

The key pollutants considered in this study were particulates and sulfur. Because Vietnamese anthracite coal has a very low sulfur content (under 1%, average of 0.5%), the TSP is considered as the most important pollutant to be the subject of the three environmental technology alternatives being compared (<25%; = 25%; >25%).

The following damage should be considered in estimating the environmental cost of coal-fired electricity generation:

- a) *Human health damage*: The consequences of TSP and toxic gas emissions are evidenced by the number of deaths and asthma attacks relating to three principal diseases associated with TSP and toxic gas emissions in urban and suburban areas located near the coal-fired thermal power plants.
- b) *Property damage* (historical, cultural, and tourism): This is caused by coal-fired thermal power plants, almost all of which are located very near important tourist areas (Halong Bay, Canhdieu Mount, Nonnuoc Pagoda, Phatdiem church, Hoalu ancient capital city, Yentu tourism areas, Kiepbac Temple, Bachdang River and Vandon Port).

The health and economic effects of air pollution were estimated using a methodology similar to that used by the US Environment Protection Agency (EPA).

To estimate the economic values associated with changes in air pollution, four factors have to be determined, as follows: a) susceptible populations; b) relevant change in air pollution; c) dose-response relationships; and d) economic valuation of health.

This report examined the change from existing levels to the proposed Vietnamese ambient standards (combined US EPA and WHO Ambient Air Quality Standards for Annual Averages (micrograms/m³)). The standards are as follows:

Unit: (microgram/m³)

<i>Pollutant</i>	<i>Proposed Vietnamese Standard</i>	<i>EPA</i>	<i>WHO</i>
Total Suspended Particles (TSP)	90	75	60-90
Lead	1.0	N/A	0.5-1.0
Nitrogen Dioxide	100	100	N/A
Sulfur Dioxide	80	80	50
Ozone	240	240	150

The Vietnamese energy planners believed that with changes below the proposed ambient air quality standards for annual averages (microgram/m³), the health effects are negligible and the slope of the dose-response function is constant. This assumes that the dose-response function is a linear one.

The estimated health impact can be measured using the following dose-response equation:

$$\Delta H_i = b_i * POP_i * \Delta A$$

where:

ΔH_i = change in population at risk of health effect i

b_i = slope of dose-response function

POP_i = population at risk of health effect i (susceptible population influenced by health effect i)

ΔA = change in air pollution under consideration

To estimate the health effects, it is necessary to do an economic valuation of the health effects given by V_i . The V_i is locally determined on the basis of Vietnamese social and health insurance conditions.

The change in total social value (ΔT) of health effects due to the change in air pollution is the summation of all effects and is valued using V_i , that is:

$$\Delta T = \sum V_i \Delta H_i$$

3.0 BACKGROUND INFORMATION: COAL MINING AND ENVIRONMENTAL IMPACTS

3.1 Coal Mining

Quangninh province has most of the largest coal mines in Vietnam. There are 93 organizations responsible for managing, protecting, exploring and exploiting various types of natural mineral ores in Quangninh province. These include 20 companies and mines directly belonging to the Vietnam National Coal Corporation and 67 partners directly participating in coal exploration and exploitation. Quangninh province accounts for 95% of Vietnam's gross coal production.

The Vietnam National Coal Corporation is authorized to manage, exploit and explore 46 mines with a total area of 458.3 m², spread over Campha, Hongai, Hoanhbo, Uongbi, Dongtrieu, Thanhung, and Yentu townships.

Coal mining, particularly opencast mining, has remarkably affected the ecology of the area. Along with coal mining, filling mined areas back in to construct new cities and carrying out other activities have caused environmental damage such as land degradation, forest destruction, change in underground and surface water regimes, road system erosion and contamination of water courses and the sea. These activities have also negatively affected famous areas, particularly the Halong Bay, which was recognized as a World Heritage Site by the UNESCO international meeting held in Bangkok in December 1994.

Compensation and treatment of the environmental damage caused by coal mining are the responsibilities of the National Coal Ministry and the community.

The electricity sector has a monopoly in pricing electricity for the whole country. This involves granting partial government subsidy, without consideration to the environmental cost of electricity production, distribution and generation. The environmental cost associated with usage of coal in electricity production must be considered in electricity pricing to correctly reflect the full cost of production electricity. This research presents an attempt to calculate the marginal environmental cost in coal mining for North Vietnam coal mining regions.

The coal sector is expected to grow by about 40% over the next ten years. This will probably be exceeded. Coal reserves are estimated at 3.52 billion tonnes, of which 88.7% are from underground mines (100-150 m). The environmental degradation and the associated costs to the economy will also grow unless changes are made in methods of mining and environmental protection of mined areas.

Energy and coal mining will have strong effects on the environment and on the economic development of other sectors. Energy pricing, therefore, is a critical policy area.

3.2 Environmental Impacts of Coal Mining

3.2.1 Environmental Pollution Problems in Halong Bay (IMST - 1997)

Halong Bay is a well-known natural area which provides value to the community in many ways. It was designated as a World Heritage Site by UNESCO in 1994. The master plan of Quangninh (1995-2000) designates Halong City as the administrative center of the province. But in recent years, Halong Bay has been polluted from several sources.

The greatest source of pollution is the waste from the household domestic water of Halong City. Thousands of cubic meters of non-treated wastewater (domestic, industrial, service) flow into Halong Bay daily. The second pollution source is the coal mining sector, followed by oil waste from ships.

The coal mining area, particularly in Quangninh province, that provides 95% of the total national coal product, has the following problems:

- a) The air in cities and communes is seriously polluted due to dust from the production, operation and transport activities of the leading industries, such as coal mining.
- b) Mine wastewater carries large amounts of pollutants. The annual amount of wastewater discharged from mines and preparation plants is 8.86 million m³. Of this, 7.16 million m³ come from the mines, having a pH content of 4-5.5; 7.65 tonnes of NH₄⁺; 8,400 tonnes of SO₄⁻; and 6,020 tonnes of settlement solids. The 1.7 million m³ from the preparation plants have 2.55 tonnes of Pb⁺²; 10.47 tonnes of Zn⁺²; 5.11 tonnes of Cu⁺²; 4.96 tonnes of SO₄²⁻ and 4,410 tonnes of slurry coal. These pollutants are discharged into the sea through the rivers and streams that run across the coal mining areas.

Table 1. Daily Waste Sources of Halong Bay Pollution

<i>Areas and Sources</i>	<i>Population</i>	<i>Domestic Wastewater (m³/per day)</i>	<i>BOD (kg/per day)</i>	<i>TSS (kg/per day)</i>	<i>N (kg/per day)</i>	<i>P (kg/per day)</i>	<i>Solid Waste (m³/per day)</i>
1. Domestic waste							
Halong City	195,440	9,640.10	9,772.00	12,703.60	1,954.40	390.88	195.44
Campha Town	118,525	5,334.00	5,926.25	7,704.13	1,185.25	237.05	10.67
2. Industrial and service waste							
Halong City	Na	177,519.58	73,365.10	719,194.88	498.59	45.23	47,599.73
Campha Town	Na	248.39	94,681.56	23,587.20	18,005.30	1,754.20	87,197.00
Uongbi Town	Na	362.21	50.24	723.45	0.18	3.55	6,866.30
Total	Na	921,493.00	348,744.00	720,114,994	664,144.00	849,754.00	533,662.00

Source: Institute of Mining Science and Technology (IMST)

*BOD = Biochemical Oxygen Demand, TSS = Total suspended solids, N = Nitrogen, P = Phosphorous.

The amount of solid waste from mines and preparation plants may soar to 900 million tonnes; the total area of barrow until 1993 was 1.200m² and will increase rapidly in the coming years. There is a large amount of radioactive substances in the type of solid waste such as U: 20.1 ppm and Th: 20.3 ppm. Besides, unplanned solid waste discharge has destroyed the land environment and the scenery of areas surrounding the Bay.

Biodiversity of sea fauna and flora systems has also decreased due to the reduction of the forest area caused by flooding with seawater. Seashore animals have become homeless and lost their abundant food supplies.

Quality and Amount of Surface Water

- An increase in the amount of suspended solids which were 500-2,500 mg/l and 6-20 times higher than the authorized standard level.
- An increase in the amount of metals and sulfates in water.
- An increase in the amount of radioactive elements (U = 1,7-2,7.10⁻¹⁵ci/l; Th = 0,4-0,7.10⁻¹⁵ ci/l; K₄₀ = 0,5-0,7⁻²%; Ra = 1-5.10⁻¹⁵ ci/l).
- The water pH content ranged from 4 to 7.5.

At present, only water for domestic and industrial use in the city meets the quality standard. Water supply at small mines, particularly the National Coal Corporation mines, comes mostly from local geological exploration wells, ponds, lakes and streams. A very little amount comes from deep wells. Results of tests of these water supplies showed that 50% of all water supplies did not meet the authorized sanitation standard for drinking and domestic water in terms of bacteria count, chemical

composition and physical aspects. These had a very low purity level (lower than 20) and a coliform organism coefficient of 10-20 (coefficients higher than 20 are not allowed according to the standard).

Seaside Water Quality

Coal mining processes increase suspended solids, heavy metal and radioactive substance contents of water, and cause its color to change. Wastewater discharged from coal mines and processing plants usually has slurry coal. This practice can be seen at the seaside from Cuaong to Hongai.

Water in these areas has the following quality:

- a) Oil content in seawater at Baichay and Cuaong, particularly Baichay, is too high compared with the standard.
- b) The pH solution of heavy metals such as Pb, Cu, Zn is three to five times higher than the authorized standard.
- c) Due to the influence by barrows, Campha-Cuaong seawater has a radioactive substance density (e.g. U, TH, K) higher than Hungthang and Baichay. However, these radioactive substances do not have an impact on the sea ecology.

The Cuaong coal processing plants discharge about 3,000 m³ of wastewater/day to Bai Tu Long Bay. Wastewater discharged from the preparing plant creates suspended solids right after the water screening process.

There are large amounts of solids and suspended solids in the discharged wastewater, which settle at the discharging gate area of the processing plants. In addition to radioactive substances, wastewater from processing plants also had characteristics that negatively affect the water environment at Cuaong Bay. Analyses of wastewater components at discharging gates of the coal processing plants and seawater components at the discharging area are shown in Tables 2 and 3.

Table 2. Analysis of Wastewater at Culvert Gates N^o 2, 3 and Seawater 200m from Gate N^o 2

Parameter	Unit	Result		
		Seawater at culvert N ^o 2	Seawater at culvert N ^o 3	Seawater
- pH	mg/l	7.8	4.7	6.5
- Solids	mg/l	1,920	2,780	2,100
- Suspended solids	mg/l	1,100	1,920	1,510
- Hardness of CaCO ₃	mg/l	470	375	390
- SO ₄ ²⁻	mg/l	19	27	28
- D0	mg/l	4.2	3.5	4.5
- COD	mg/l	175	210	178
- Color	mg/l	70	70	80
- Cu ²⁺	mg/l	1.2	3.2	2.8
- Pb ²⁺	mg/l	0.5	1.5	1.2
- Zn ⁺	mg/l	1.8	6.5	5.2

Source: Impact assessment on Cuaong coal-preparing plant environment

Table 3. Density of Heavy Metals in Seawater from Seaside

Distance from seaside	Unit	Pb ²⁺	Cu ²⁺	Zn ²⁺
20m	mg/l	0.5	1.2	1.8
200m	mg/l	0.2	0.2	0.9

Source: Impact assessment on Cuaong coal-preparing plant environment

Seawater surrounding the wastewater discharging sector of a coal processing plant is strongly affected by industrial wastewater. If most of the suspended solids settle at certain places near the seaside, metal ions exit in the seawater that decrease when mixed with seawater from the far seaside. The heavy metal ions solution process depends on the tide and hydraulic regime near the Cuaong seaside.

3.2.2 Environmental Situation in Coal Mining Areas (IMST - 1997)

General Situation

In the Hongai-Campha coal mining region, most of the coal mines are located in the valleys, in the city, and along the narrow beach downwards to Bai Tu Long Bay. The lack of a suitable buffer area between the mines and the valley and bad absorption of pollutants of Bai Tu Long Bay pollute the sea environment.

Microclimate Situation

Thousands of mine workers have been working in terrible microclimate conditions with 30°C-32.5°C temperature, 81-93% humidity and lower than a 1 m/second wind speed. According to authorized standards, the miners' working

conditions should have less than a 30°C temperature, less than 80% humidity and a 1.5 m/second wind speed.

Hence, coal mine microclimate conditions in summer do not meet the standard. Mine workers expend a lot of their energy and feel tired because of their working environment.

Quality and Flow of Underground Water

The regular pumping of water from deep pits and coal mines as well as the reduction of vegetation by coal-mining activities have decreased the underground water flow and lowered the water table. Research on the underground water quality shows that the density of heavy metals and radioactive elements has increased due to coal-mining activities.

Furthermore, polluted water also rapidly contaminates the underground water. If there are no pollution abatement methods, none of the underground water in the Hongai-Campha sectors could be used for domestic purposes. Up to now, more than 50% of underground water, which is already contaminated, is being used for domestic activities.

Coal mining decreases the underground water flow as well as the water quality; lessens the power of maintaining the water level of ponds, lakes and dams; and enables seawater to penetrate the underground water layers.

Coal mining also causes siltation (due to mud, sand and waste soil) in lakes, rivers and streams. This is especially true for the following:

- a) Lakes such as Noihoang, Kheuon 1, Kheuon 2, Tanyen, Yenduong have become more narrow. These water bodies, serving as sources of irrigation for farms of communes east of Dongtrieu. Noihoang Lake, are directly affected by Seam 8 situ, Group of Seams 1B of Mao Khe Mine, and Seam 2 of Trangbach coal mine. During the 1994-1997 period, these bodies of water were seriously polluted and became unfit for agricultural irrigation.
- b) Yen Lap Lake with its volume of 118 million m³ and the protected forest area at the head of Yen Lap lake have also been adversely impacted.

In the past, this lake provided water to irrigate 10,050 ha of agricultural land and also the domestic water requirements in Halong City and Uongbi township. Ten years later, its volume had been reduced to 60% and could only irrigate 5,500 ha of agricultural land. Impacts by the Bong Vong mine, Uongbi coal company, Hoanhbo coal enterprise, and the Quangninh company include the destruction of forest and high erosion of land area.

- c) As designed, Dienvong water dam should provide 25,000 m³ of water per day for Halong and Campha living activities. However, at present it only provides 15,000 m³ of water per day.

Halong City, which has 150,000 citizens, lacks water. In the past, the amount of water per day supplied for Halong City was 17,000 m³ but this was reduced to 3,000 m³. The drinking water supply in the Hongai-Campha sectors is also seriously polluted.

- d) Dienvong River, with its total length of 20 km, annually provides 360 million m³ of water per day for the Hoigai area. Dienvong River has become narrow because of the presence of coal opencast mining areas.

The water purifying plant stopped operating in 1989 because water supplies were seriously polluted by various types of solid waste, suspended solids and coal dust particles. Polluted water has negatively affected the water quality in the Baichay sector which used to attract many tourists. Other water bodies such as Caoson are no longer used for water supply because large amounts of coal and overburden were discharged into these bodies of water. As a result of this, Quangninh province is going to lack water for agricultural irrigation and domestic uses if pollution continues.

Expenditure on dredging up coal mine water courses accounts for the major share of the total operating cost of these enterprises. This item is considered to be one part of the environmental damage cost as coal-mining activities impact on bodies of water.

At each mine, a ditch and canal system is constructed along road transport routes or rivers and streams, through which surface running water is discharged into the sea.

In general, the water contamination is caused by opencast mining in situ, wastewater in deep pits, and surface water which is not treated and directly discharged into the sea. Up to now, no mine has been able to keep wastewater at the mines in settlement ponds before being discharged outside of the mines.

Coal-mining activities at Coc 6 mine are performed at levels lower than the underground water table, so that water from the floor of pit needs to be regularly pumped. Surface water and water in mines' deep pits directly flows to the natural water network and then is discharged into the sea.

Heavy rains and the lack of proper water management and monitoring methods cause serious environmental problems. These involve oxidization of surface water and rainfall with a pH level of 2-4, settling of sediment and raising of levels of rivers, streams and seaside areas.

The results of the chemical analysis of wastewater samples from selected Hongai-Campha coal opencast mines by the Institute of Mining Science and Technology October, 1996 are shown in Table 4.

Table 4. Chemical Analysis of Wastewater in Selected Mines

<i>Components</i>	<i>Unit</i>	<i>Nui Beo deep pit</i>	<i>Ha Tu deep pit</i>	<i>Coc Sau deep pit</i>
PH	mg/l	3.6	3.24	5.72
Mineralisation	mg@l/l	255.56	412.11	563.96
Total hardness	mg@l/l	3.75	5.75	7.5
Temporary hardness	mg@l/l	0	0	0.25
Permanent hardness	mg/l	3.75	5.75	7.5
CO ₂ free	mg/l	39.6	37.4	2.2
Ion Fe ₂ ⁺	mg/l	0.99	0.6	0.6
Ion Fe ₃ ⁺	mg/l	1.8	1.5	0.8
NH ₄	mg/l	0.8	0.4	0.6
So ₄	mg/l	180	300	400

Source: Institute of Mining Science and Technology (IMST - 1996)

The environmental problems already stated above have become more serious due to illegal coal-mining activities. The highest output from illegal coal-mining activities is approximately 500,000 tonnes. This high output, together with the lack of coal mining management and planning is the major reason for the rising level of pollution in rivers and streams.

The following coal-mining activities also pollute seaside areas:

- a) Directly discharging whole mine water, involving water from coal-preparing plants and surface water downwards from barrows, which is not handled into the sea.
- b) Eroded soil escaping from barrows.
- c) Directly discharging wastewater from coal-preparing plants into the sea.

In some reports, the affected seaside area is expected to increase to 700-800 m. There are some signs of damage caused by the polluted sea area near the city. The major causes of pollution are wastewater from household consumption, rainfall water and waste solids (Reports on Halong Bay, 1997 – National University). Impacts on sea ecology are now being assessed.

In the regulations on coal-mining activities (the Vietnam Standard N^o 5326-1), some sections on mine water management specified the need to protect water courses, establish wastewater collection areas, monitor wastewater discharged into the natural water network and adopt treatment methods. Although some maintenance and repairs are annually performed to restrain the impacts of flooding, particularly in the rainy season, little concern is given to monitoring water quality of that discharged into the natural water networks or to restraining the negative impacts on the local water balance.

Below are the elements in mine wastewater: (IMST-1997)

pH	= 2,5-5,3	NH_4^+	= 1,5 mg/s
SiO_2	= 2-4 mg/l	SO_4^{2-}	= 245-419mg/l
$\text{Fe}^{2+}; \text{Fe}^{3+}$	= 0,4-0,8 mg/l		

Wastewater quality at selected opencast mining mines is shown in Table 5. As shown in the table, wastewater acidity is characterized by a low pH content, high metal content, BOD_5 parameter (at some places higher than Vietnam's standard on grade B industrial wastewater) as well as a high SO_4^{2-} ion content.

At present, deep mine pits that were abandoned have become large lakes such as Para (Lotri), Hatu, and Trangbach with a water volume of more than 200,000 m³ and a water level of 45 m. Water reserves in abandoned and deep mine pits are expected to amount to 2,317,000m³. Water in these abandoned mines is the major cause of the eruption of water when new coal mining structures are opened near old structures. Eruption of water at some mines may be as much as 1,105 m³/hour.

Table 5. Wastewater Quality at Selected Opencast Mining Sites, September 1997

Targets	Unit	Nuibeo Deep Pit	Hatu Deep Pit	Coc 6 Deep Pit
Ph		2.25	3.60	4.28
BOD_5 (20°C)	mg/l	119.20	4.58	62
COD	mg/l	192	11.2	144
Suspended	mg/l	260	99	319
Solid	mg/l	0.0008	0.0019	0.0025
Pb	mg/l	0.940	0.391	0.031
Zn	mg/l	0.0018	0.0029	0.00004
Cadimi	mg/l	0.012	0.033	0.014
Cu	mg/l	1.445	0.005	0.002
Mn	mg/l	1.27	2.12	0.67
Fe	mg/l	3.78	3.67	2.7
Nitrate	mg/l	0	0	0
Nitrit	mg/l	1.5	0.52	0.8
Amoni Coliform	MPN (con/100ml)	2,700	1,800	3,600

Source: Institute of Mining Science and Technology

Air and noise quality (IMST-1997)

Coal-mining activities generate noxious gases such as CO₂ and CH₄, radioactive dust and noise, which pose a danger to Quangninh province.

Dust is the major factor that pollutes the mines' working and residential environment. Results showed that dust levels are 15-30 times higher than the authorized sanitary standard. In the air, the dust content is 41.6-83.3 mg/m³ air and SiSO₂ accounted for 3-12.5%. Hence, dust is the factor causing occupational dust lung disease among coal miners. According to statistics, every 1,000 tonnes of coal produce 11-12 kg of dust, which also contain SO₂, CO₂ and H₂S.

Data from the Institute of Environment and Technology Science show that the dust levels in the Hongai-Campha regions are 20-40 mg/m³. This is 60 times higher than the Vietnamese authorized health standard.

Hence, for every ten tonnes of coal/year produced, at least 7-84 tonnes of coal and overburden dust are emitted into the air.

In other examples, the dust concentration along the road from Loongtoong intersection to Bang wharf, Halong City, is 3,000-5,000 particles/cm³. The authorized standard stipulates a dust level of 200 particles/cm³ only. The dust weight is 25.5-35 mg/m², while the dust standard is 4-8mg/m². The respiration dust weight is 25-30mg/m³ while the standard is 2- 4mg/m³.

Transporting coal and overburden (inside and outside of the mine boundary) is the major source of dust. Other activities that produce dust within the coal mine involve various stages of the coal screening process. The average dust level inside the mine is 20-40 mg/m³.

Dust emission at two large coal preparing plants is generated from vehicle transportation activities, the dry coal preparing stage (transporting, crushing, screening) and coal stockpiles. The coal preparing plant is located separately from the residential area but the buffer area between these two areas is not large. Hence, dust impacts seriously on neighboring residential areas, particularly when the wind blows.

Table 6. Dust Levels at Hongai Coal Mines

<i>Activity</i>	<i>Sampling Location</i>	<i>Dust Content (mg/m³)</i>	<i>Property</i>
Drilling	Near drilling machine	4.7-23.8	Wet drilling
Detonating	1 second after detonating explosive	315	At explosives detonating field
	5 minutes after detonating explosives		At explosives detonating field
Excavating	At excavator - excavating overburden	273	
	At excavator - excavating coal	27	
Transporting	Transporting overburden by road	24	Wet road
	Transporting overburden by road	232	Dry road
	Transporting coal by road	28 - 31	Wet road
At barrow	No vehicles on road	1.9	Wet road
	When vehicles are dumping	14	Wetness
Coal screening	Mechanical screening	48	
	Semi-mechanical screening	76	
Office area	In front of yard	0.56	Wet road

Source: Institute of Mining Science and Technology, 4/1997

Outside the coal mining area, dust emission is generated by wind's barrow erosion and local residential transport activities. The result of the measurement of the dust concentration at a local residential area near the base of the Hatu waste dump for a short time on 7 October, 1996 was very low (1.5 mg/m). When the weather is windy, the dust concentration becomes high. The buffer area (200-300 m wide) between the barrow and the residential area is too narrow to reduce dust emissions towards the residential zone.

Small-scale mining activities, legal and illegal, coal-truck transport driving across the residential area to the coal wharf, coal-screening activities at coal dumping stations, as well as other transport means are dust generators. They are usually found along the road from Hongai to Campha or farther.

Spraying water to prevent dust emissions is a common method of minimizing dust used by various mines of different scales. Covering roads with reinforced cement and planting trees along the main road routes are done also to minimize dust. Efficiency of the water spray method is particularly decreased in summer because of the high evaporation. Hence, more water and spraying are required. A high-pressure foggy spraying system needs to be installed in some places within coal-preparing plants, transport systems and coal transition stations. In general, spraying activities in these places to prevent dust are not efficient because of incomplete management and security stages.

Compared with other industrial areas and cities in Vietnam, the dust problem in the Quangninh coal region is considered to be more serious because of the large-scale mining activities affecting large areas. Also, as coal production increases, so do impacts by coal mining. Up to now, in many circumstances, current dust prevention methods do not meet the national health standard.

Current Situation of Noxious and Radioactive Gas

Methane (CH_4) from the Quangninh coal mine was estimated to be 60 million m^3 at the time of the study, 100 million m^3 in the year 2000 and will increase further in future years due to coal-mining production. This greenhouse gas is not a threat to the global environment, but, accompanied by dust and the aftermath of coal burning, it will raise local mine temperatures in regions or districts. Radioactive gas at many mines is five to six times higher than at non-coal-mining activity areas.

Noise and Vibration Levels

The coal industry has many mechanical processes. Due to the backward technology processes, noise measurements at all noise monitoring places are all 68.75% higher than the authorized health standard. Noise levels at coal mines are 97-106 dB, which is almost 18-39 dB higher than the authorized health standard. The high noise level is very dangerous and easily causes occupational hearing and 'quivering' diseases. According to the latest noise measurements in 1997 from environmental impact reports for certain coal mines and preparing plants, noise levels are usually 1-2 dB and 1.5-41 dB times higher than the authorized standard, respectively. Vibration levels at coal preparing plants are 2-32 dB higher than the noise standard. The highest noise levels (15-24 dB higher than the noise standard) occur at the coal preparing assembly line, operating stations and neighboring areas of the coal-preparing plant.

Coal Mining Activities and Effects on Barrows, Local Terrain and Agricultural Land

Mining increases external impact and generates threat to areas in the form of erosion, crumbly and unstable barrows, changes to the local terrain and encroachment on agricultural land.

After 40 years of coal mining, in-situ and the left over material from mining cover a large area of the forest. The overburden dump with a volume of 540,000 m^3 not only encroaches on forest and agricultural lands, but also carries soil away, makes land crumbly, fills up streams, ravines and other water routes with mud and soil, raises the level of agricultural areas, changes the hydraulic network and creates ephemeral drained water courses. The waste soil and mud source have rapidly changed the Quangninh seaside terrain. Previously beautiful sandy beaches have turned to a muddy main land

area. This process shows the relations between digging up and filling up back to the height and area, the height of barrows and the surface of hydraulic system terrains, and the average height of the local area.

There are 30 locations that have barrows from coal mines and preparing plants along the beach from Hongai to Campha. Barrows at Deonai, Cocsau, Cuaong mines, Campha district run along the beach and measure approximately 10 km long. According to the design, barrows usually have an average height of 60-80 m and an inclination angle not higher than 36° . However, in practice, Cocsau mine is 255 m high and Caoson mine is 280 m high. Every day these barrows, situated in the Camtay and Cuaong communes, directly threaten local residents who live at their base. . After each rain, soil carried away by water flows seriously affects local residents' lives. Loose materials are carried away by water flows and raise the level of the seaside. During the 1985-1996 period, the beach expanded to an average width of 300-400 m while in some places it reached as much as 600-700 m. In the Cuaong coal-preparing plant sector, there is an alluvial deposit area of 3,980 m².

Due to coal-mining activities, the terrain of the coal mining area changes rapidly. Some mine sectors are dug up or eroded (negative change) and some are dumped or filled back up (active change).

The current method of dumping waste applied at various coal mining companies is not suitable to keep barrow beams stable, effectively monitor land erosion, reclaim post-mining land, reserve fertile land for mine reclamation stage, and use the ditch and ravine network to take water flows out of barrows. When it rains heavily, rain directly falls down to the base of a barrow through its sides. Hence, serious erosion and heavy crumbling occur. This problem is quite serious for the Deonai-Cocsau mines because these are located near the seaside and have experienced a high growth rate of agriculture, industry and urbanization. Besides, scouring road routes not only destroys, but also changes the flow direction of rivers and small streams such as the Mongduong and Dienvong Rivers. Due to construction requirements, local people and enterprises use waste soil or level mountainsides as landfill or to raise the level of the depth of the sea. In some places, the seashore has expanded to a number of kilometers. Thus, this filling-in process has affected the pressure of the tide mechanism and eroded many parts of the seaside.

Table 7. Variations in the Campha Mine Region, 1965-1978

<i>Negative change</i>			<i>Active change</i>		
<i>Fluctuation (m)</i>	<i>Total (m²)</i>	<i>Volume (m³)</i>	<i>Fluctuation (m)</i>	<i>Total area (m²)</i>	<i>Volume (m³)</i>
> 120	620,000	4,348,200	< 35	1,809,600	16,717,000
80 – 120	937,600	22,471,400	35-70	813,800	15,414,000
45 – 48	667,700	23,956,500	> 70	439,600	12,053,700
30 – 45	451,600	26,420,500			
10 – 30	233,700	23,127,600			
< 10	847,000	51,705,700			

Source: Institute of Mining Science and Technology

The current regulations on coal opencast mining (Vietnam standard N^o 5326-91) state that dumping must be suitable with the original mine plan. A section of the regulations allows dumping in compliance with the future land reclamation plan. According to the design, the barrow area has to be wide enough to contain overburden produced during mining. At the same time, the barrow incline should not be higher than the natural dumping angle. However, there are also some specific regulations on environment protection, such as prohibiting the discharge of wastewater through barrows; water and water discharge management; and reclamation of barrows to keep them stable. These regulations, however, are not seriously observed.

The current method of preventing barrows from impacting on surrounding areas is to build stone embankments and dams, and dredge bodies of water. Preventing land erosion and increasing barrow stabilization have attracted little attention at coal mining areas. Methods such as decreasing the natural incline of barrows and constructing ditch and ravine networks to take water routes and barrow water are hardly ever undertaken.

In Vietnam, there has been a lot of research on opencast mine beam stabilization. However, only few studies are on barrows, especially their stabilization in the rainy and stormy seasons. Planting of trees on a small scale is being tested at many mines. However, large-scale planting is difficult to carry out due to the expenditure on environment problems, and a lack of research experience and data on technology of post-mining land reclamation.

Changing Forest Resources

The forest resource at the Quangninh coal mining areas has decreased because it provides the large number of timbers needed at the mining sites. Extending in-situ or exploiting new mines also increases damage in the forest area in term of losses in wood and other forest products and opportunity cost of forestland.

With respect to market, coal mining activities encourage forestry's development because the annual requirement for timber is very large. In fact, forests have been

exploited at a rapid rate because of the demand by the coal industry. Although this consequence on the forest is not entirely caused by the coal industry, it has affected the whole region's economic development plan. In situ, a large amount of overburden is excavated, as well as large surface areas cleared and dredged, thus decreasing the forest area.

An impact assessment report from coal mining companies shows that there are only shrubs, bald land areas and scattered forests left at coal mines. Thus, it is very clear that coal-mining activities are major causes of decreased forest areas and the poor land quality in these areas. In Quangninh province there are a few virgin forests in remote and highland areas. Along with narrowing virgin forests, the number of valuable timber species has also been declining seriously. Secondary forests not only have a poor variety of forest plants but their quantity and quality have also declined.

Illegal private coalmining activities have recently been on the rise. Mine owners are willing to buy cheap, illegally cut trees near coal mining areas. In addition to these, hundreds of illegal coal mining places have been seriously destroying natural forests such as Yenlap, Quanghanh, Duonghuy, Khetam, Dabac, and Dichvong. The use of a product-based contract system to coal mines has led state-owned coal-mining units not to purchase wood from forestry stations but from the free market and even from illegal loggers. This has encouraged illegal timber-cutting that exploits timber and violates technology guidelines, thus seriously destroying the forest.

At present, the land area under the control of Quangninh coal ministry is only about one third of the total coal area. In the future, opencast mining activities will extend the mining area to new areas. Similarly, barrows and deep-pit areas for deep-pit mining activities will increase. These will further encroach upon the forest.

Lower Land Quality

Overburden from coal mining and processing activities mostly produces land containing chemical elements such as Fe, NH_4 and SO_4 , which lower land fertility and reduce agricultural products and plant growth. Furthermore, an increase in the coal-mining radioactive substance content decreases the land's ecological value.

Agriculture, especially modern agriculture, demands energy. The coal mining-process provides a considerable fuel source for large-scale agricultural development. However, for small-scale development, such as in mining areas, the demand for agricultural products is very high because of the high population density. The negative impacts on the environment include dust, reduced irrigation water, and lower tree productivity.

Impact of Coal Mining Activities on Cultural and Historical Vestiges

Quangninh province has a normal density of cultural and historical vestiges as compared to the whole country (0.24 vestige/km²). There are 14 vestiges compensated by the government such as the Tran family's mausoleum; the Traco communal house; Bachdang pile field islands, such as Tuanchau, Ngocvung, Quanglan, and Coto; well-known caves such as Daugo, Sungso, Trinhnu, Bonong, Tienong, and Hangluon; Yenlap, and Chucbai Son lakes; and natural sights with high mountains and rampant forest, such as Yentu and Amvap. However, coal-mining activities near these vestiges decrease the value and attraction of these famous beauty spots.

Oil pollution from ships and ferries, together with soil and rock, suspended solids, and coal dust raise sea contamination. These pollutants settle and cover the coral system and restrict its ecological development. Air pollution is recognized to be the most serious effect of the coal mining process.

Impact on Infrastructure and Other Aspects

The impact on the transport system includes the following:

- a) The encroachment of overburden on the transport system, increasing transportation intensity (for example Highway 18A – Campha commune)
- b) Air pollution of the transport system (especially from heavy freight transport facilities)
- c) The reduction in the life of transport structures, increasing free space for traveling

Analyzing the 1969-1974-1985 photography data, research No. 52D shows that the Hongai-Campha seashore had been much changed by coal-mining activities. The average extension of the Campha seashore is approximately 300-400 m; some places, such as Cocsau commune, even extended to 700 m. Particularly at Cuaong coal preparing plant, the barrow area which was 720m² in 1969 increased to 4,700 m² by 1989. With such a rate of seashore expansion, the sea transport system has also changed.

In terms of buildings and structures, impacts of coal-mining activities can be seen through the subsiding, crumbling and collapsing of houses on coal layers and dumped overburden spreading over agriculture land, gardens, houses and the irrigation ditch and ravine systems.

Many families at Khanhhoa mine previously sued the mine for using agricultural land to establish the barrow and for detonating explosives. Now, in Halong City there are a lot of complaints lodged against the mine in local authorized organizations about the threat of cracking, dust, noise pollution and the decreasing level of agricultural land. Local people at the Nam Cau Trang coal preparing plant sector also complain about

noise, dust and water pollution caused by plant activities. The Campha people's committee issued an order to the coal mining company about its dumping of waste soil, which resulted in the leveling of 23 ha of agricultural land.

Impacts on Community Health and Other Mining Activities

Coal mining activities create a demand for electricity, water and communication. An increase in coal-mining processes requires raising investment capital in order to expand the electricity wire network, and build transformer stations and residential areas.

Environmental pollution increases diseases among the local residents, staff and workers in the Quangninh coal region. An increasing number of patients have been treated for dust lung-related disease and mine staff and workers with weakening health. Requirements for investment in medical infrastructure such as patient beds, medical appliances and facilities are considered to be part of the environmental costs of coal mining.

Up to now, there have not been any reports on the biological and social effects of mining activities. These include damage to the fauna; the effect on the variety of fish and their living habits; disease incidence among local workers and residents; as well as changes in local population structures.

4.0 ELECTRICITY GENERATION AND ENVIRONMENTAL IMPACTS

4.1 Environmental Situation Related to Coal Power Plants

4.1.1 General Situation (*Ministry of Energy - 1995*)

The environmental impacts of the energy sector project in Vietnam are quite diverse. Two oil spill incidents have threatened Vietnam's waters in the past three years. It is estimated that the 50% forest cover that Vietnam had in 1940 will not be achieved again until the year 2040. The Hoabinh hydroelectric station, originally designed to have a 250-year life, may have its effective economic life considerably reduced due to siltation. Particulate pollution at the coal-fired Ninhbinh power station is three to four times higher than the norm at other stations.

4.1.2 Institutional, Legislative and Regulatory Issues

The Legal and Regulatory Framework

There are, at present, no specific enforceable environmental standards relative to the energy sector in Vietnam. Where used, environmental standards have been implemented at the design stage rather than at a stage that provides for monitoring and

enforcement. For example, most of the current power station facilities are built to Soviet environmental design standards, and some current design tenders are being released with slight ad hoc improvements to these standards. In either instance, however, there are no regulatory mechanisms in place to ensure that the standards are met or that pollution control equipment is in fact being used.

To address environmental management in a systematic fashion, governments typically proceed through a number of stages that commence with a broad formulation of environmental policy. This is followed by institutional capacity building and the promulgation of environmental legislation, which in turn leads to the enactment of more specific guidelines or regulations. Implementation, monitoring, and enforcement are the final steps. To its credit, Vietnam has rejected most ad hoc approaches and embraced the principle that environmental management must progress in an orderly fashion with well thought-out actions and programs.

Environmental Policy. On 12 June, 1991, Vietnam adopted a detailed environmental plan entitled the National Plan for Environment and Sustainable Development (NPESD): A Framework for Action. Co-author of the NPESD, and the party entrusted with its implementation, is the Vietnam State Committee for Sciences and Technology (SCST).

Environmental Legislation. The most significant broad initiative is the development of an Environmental Law, which was drafted by the Center for Resource and Environmental Studies in 1991, and which was approved by the SCST and the Council of Ministers. The law was on the agenda to be considered by the General Assembly in late 1992. Expectations are that it will pass in one of two forms: either as a “law” having a high degree of pre-emptive authority; or, as a “decree” which has less authority to pre-empt other types of legislation but which nonetheless would have similar implementation implications.

Several other legal initiatives and reforms relevant to the energy sector have been completed or are being developed. The Act of Forestry Protection and Development (enacted by the National Assembly on 18 August, 1991) entrenches the establishment of special use areas such as national parks, forests for watershed protection or coastal area protection, and production forests which must be sustainably harvested by individual, cooperative, or state interests. A key provision of the Act includes requirements for compensation if environmental disruption occurs, and requirements for designating certain areas as protection forests for hydroelectric watersheds.

A second recently promulgated regulation relates to pollution from offshore oil development (Regulation on Environmental Protection in Marine Petroleum Operation, enacted 5 September, 1990). The regulation applies only to oil exploration and production, not transportation, and sets standards for allowable levels of pollution in day-to-day operational activities. It also requires specific steps to be taken in the event

of oil spills, and provides a recourse to compensation in the event of an occurrence of environmental damage.

A Mining Law is in the process of being developed, although it has not yet reached the stage of draft preparation; its promulgation is still three to five years away. Its purpose will be to promote the efficient development of Vietnam's mineral resources (including coal). Three principles relevant to environmental management are presently foreseen:

- a) that mine limits be well-defined to contain environmental disruption of other economically productive activities;
- b) that compensation be paid for any disruption which occurs during mine operation; and
- c) that mine areas be reclaimed and rehabilitated to at least as productive a standard as they were before the mining commenced.

These principles would apply to new mining activities; there is little discussion of how existing mines will be treated.

Wastewater Guidelines and Regulations are being prepared by the Ministry of Water Resources (MWR) and a draft law was prepared by the end of 1993.

***The Power Sector (Vietnam Energy Sector Investment and Policy Review
Volume I - 1993)***

Hydroelectric Projects. Hydroelectric projects are expected to form an important component of Vietnam's generation capacity. The Hoabinh project on the River Da will have a capacity of 1,920 MW upon its completion, and the proposed Son La project, 200 km upstream would provide an additional 3,600 MW of capacity on this river system. In addition, the proposed Yali Project in central Vietnam would have a capacity of 700 MW at a strategically important location. These projects have both environmental benefits and costs associated with them. However, the detailed EIA studies being undertaken by PIDC1 and PIDC2 do not assess the potential environmental benefits (in the form of irrigation and flooding control) of hydroelectric development, but focus on identifying the cost of mitigating any negative environmental impacts. This is partly due to the difficulties in quantifying potential downstream environmental benefits, whereas upstream costs of loss of agricultural land and infrastructure are less uncertain. As a result, environmental protection costs cannot be placed in the larger context of a full cost-benefit analysis of such projects.

The potential range of benefits downstream from hydroelectric facilities can be demonstrated from some of the sporadically collected data that is available. All such dams will increase downstream water flows in the dry season and decrease flows in the

wet season. At Hoabinh, flooding prior to dam completion typically destroys 800 ha of rice, maize, and other short-term crops annually. Erosion from the flooding causes permanent losses of up to 50 ha of cropland annually, and over 3,000 households are temporarily displaced during the flooding season. However, benefits associated with reduced crop, land and infrastructure losses were evident after the completion of the Trian dam in South Vietnam. There were also notable improvements in drinking water quality as a result of changes in the hydraulic regime. For example, the saline/fresh water interface has moved approximately 20 km seaward during the dry season, providing fresh water to an area of about 100,000 ha.

A major environmental cost concern of hydroelectric projects is resettlement. At Hoabinh, for example, flooding by the reservoir resulted in the loss of about 1,800 ha of rice land, 700 ha of cash crops, 200 ha of fish ponds, 235 km of roads, 80,000 m² of buildings, and forced the relocation of over 4,000 families. Current resettlement programs suffer from a lack of money to provide land and infrastructure, and displaced families are forced to resort to slash-and-burn farming in forest areas. Typical budget allocations are about US\$500 per family, although the amount required for proper resettlement and stabilization would be about US\$500-1,000 per person. The resettlement funding issue will become important for other major projects, such as Yali (4,400 people), Thacmo (18,000 people), Dongnai 8 (10,000 people), and Sonla (112,000 people).

Another major environmental concern relates to the impacts of upstream environmental degradation on the long-term integrity of the project. Specifically, sedimentation will be a growing problem if vegetative cover in upstream watersheds is not maintained. Detailed sedimentation studies of most of the projects have commenced, and catchment basin management is an active area of study and programming.

At Hoabinh, sediment deposition into the reservoir is estimated to be about 42 million m³ annually, which would result in a rise in the reservoir floor of about 20 m, and a decline in the reservoir storage capacity of about 5%, over a ten-year period. Although this might still provide a useful reservoir life in excess of 100 years, upstream deforestation from slash-and-burn agriculture and inappropriate watershed management threatens to increase sedimentation rates and reduce the useful life of the reservoir. In fact, one of the rationales for building the Son La project upstream from HoaBinh is to decrease the sediment loads into the HoaBinh Reservoir. Removing sediment from the reservoir is not a viable solution given the large volumes involved. The technically viable long-term prospect for protecting these projects is to rely on watershed management to maintain vegetative cover to limit sediment loss.

Thermal Electric Projects. The major environmental issues associated with thermal electric generation involve particulate, NO_x and sulfur emissions, and water treatment. The priority is to limit particulate emissions from their coal-fired facilities.

Although there has been no systematic collection of emission data, the nature of some of the more serious environmental problems can be gleaned from the sporadically collected data available.

The Ninh Binh Thermal Station was built during the war to withstand aerial attacks: boilers are in constricted areas 9 m underground and the stack is in the wind shadow of a neighboring mountain; the stack height is 80 m whereas the mountain top is at 96 m. The plant is a severe environmental problem. PC1, which operates the plant, estimates a refurbishment cost of US\$6-8 million over one year, involving substantial reconstruction of the boiler units, raising the roof of the main building, adding high-powered fans, and installing an electrostatic precipitator (EPS). The only existing equipment that could likely be salvaged includes the coal loading facilities and the coal grinding units. The cost estimate for refurbishment is low by international standards. If it is determined that generation capacity is required at or near this site, serious consideration should be given to building a new plant that takes advantage of some of the existing facilities, equipment, and work force.

The Phalai Thermal Station has an ESP capable of removing 98% of particulate emissions. Due to a lack of spares, only two of its four electrolytes are currently in operation and the ESP is operating at about 91% of its design efficiency. Based on model predictions, the plant currently emits about 3 kg of fly ash/second at full capacity. Moderately small investments would reduce current emissions by a factor of about five. Some of the plant's more serious pollution problems are water-related. Oils, lubricants, and chemicals are regularly dumped into water streams and end up in the rivers; slag from the boilers and ESP also finds its way into surface water, affecting a total agricultural area of approximately 30,000 ha. Studies elsewhere suggest that such pollution can reduce agricultural productivity by as much as 25%, which would translate to an annual loss of approximately US\$7.5 million in agricultural output in the area. The investment required for effective water treatment would be approximately US\$35 million, implying a real internal rate of return for such an investment of approximately 21% over a 20-year period, even ignoring the potential health benefits from having clean water available.

Emissions from NO_x and sulfur have not been regarded as problems in Vietnam, since low sulfur fuels have been used in most thermal applications, and the number of sources of NO_x has to date been few or scattered to contribute to any ground level ozone problems. Future exceptions to this will likely arise in urban areas and in areas of heavy industrial concentration. The oil-fired facility at Thuduc on the outskirts of Ho Chi Minh City, for example, has few obvious environmental impacts; yet its location suggests that it may be required to reduce its NO_x output at some point in its remaining operating life.

A thermal power plant project is proposed for a site near Phu My, and permission has been received from local government authorities to commence survey

work. The major potential environmental problem will be the impact of water pollution on the recently rehabilitated mangrove-based fishery in the area and on the tourism potential of the downstream Vungtau area. Mitigative measures must therefore focus on proper water treatment and management. Air pollution and terrestrial impacts are less of a concern due to the proposed site. An additional thermal plant at O Mon is also being considered. The environmental impacts there are likely to be more severe than at the Phu My site. If generating capacity is required in the region, it may be environmentally more sensible to build a bigger plant at Phu My with additional distribution into the Mekong Delta, rather than to build smaller plants at both Phu My and O Mon.

4.2 Technological Options for Environmental Control

The environmental pollution provoked by burning coal in steam thermal power plants at North Vietnam is multiform and complicated. However, in the framework of this research, focus was on the different types of air pollution provoked by the coal-fired thermal plants of North Vietnam and steam coal-fired thermal power plants using domestic coal (almost all of which is anthracite) to be mined in the Quangninh coal fields.

Based on their commissioning dates, the North Vietnam steam thermal power plants are classified into two groups:

Group A: consisting of existing coal-fired thermal power plants before the promulgation of the national environment standard TCVN-5937-1995 on “Air Quality – Standards on Quality of Ambient Air – Values of Critical Basic Parameters on Quality of Ambient Air (mg/c.m)”.

This group consists of the following plants:

<i>Plant</i>		<i>Commissioning Date</i>
Ninh Binh (NB)	4 x 25 = 100 MW	1976
Uong Bi 1 (UB)	50 + 55 = 105 MW	1977
Phalai 1 (PL1)	4 x 110 = 440 MW	1978
Total	645 MW	

Group B: consisting of coal-fired thermal power plants to be operated after the promulgation of TCVN-5937-1995 and TCVN-5939-1995, namely:

Phalai 2 (PL)	2 x 300 = 600 MW
Uong Bi (UB)	1 x 300 = 300 MW
Quangninh(QN)	2 x 300 = 600 MW
Haiphong (HP)	2 x 300 = <u>600 MW</u>
Total	2,100 MW

The air-polluting agents from burning coal in coal steam thermal power plants are of two types: particulate emissions and toxic gas emissions (SO_x, NO_x, CO, HC, etc.).

In reality, particulate emission is the major type of air pollutant and provides the basis for recommending measures to reduce pollution. There are three basic technologies to reduce particulate emission, namely: wet cyclones, electric precipitators and bag filters.

As for toxic gas emissions (SO_x, NO_x, CO, etc.), using rubber is recommended. However, because of the very low sulfur content of Vietnamese anthracite coal (under 1%, average of 0.5%), the high investment and O&M costs of rubber do not make its use feasible.

4.2.1 Technological Options for Environmental Control of Coal-Fired Thermal Power Plants

To establish environmental alternatives ETA1, ETA2 and ETA3 (Environmental Technological Alternatives 1, 2, 3), the following environmental control technologies have been considered:

- a) Particulate Matter Control Technologies: Wet multicyclone collectors, electrostatic precipitators(ESP) and fabric filters (or bathhouses).
- b) Sulfur Oxides Control Technology: The flue gas desulfurization (FGD) technique used in limestone injection.

The reasons for the choice of the above environmental control technology options are as follows:

For Particulate Matter Control Technologies

- a) For small-scale coal-fired thermal power plants of Group A, like Ninh Binh thermal power plant (100 MW) and Vong Bi 1 (105 MW), the wet multicyclone is the simplest, cheapest and most-accepted particulate matter technology that could be rapidly established for old and backward coal-fired thermal power plants.
- b) For the old medium-scale thermal power plants, like Phalai 1 (440 MW), that use a variety of coal combustion sources, the electrostatic precipitation technology is the most appropriate because it could be applied to a wide range of system sizes and has no adverse effect on the combustion system's performance. At the same time, its particulate matter collection efficiency is relatively high. For instance, its fractional collection efficiencies are greater than 99% for fine (less than 0.1 micrometer) particulate matter.

- c) For new medium- and large-scale thermal power plants of Group B, such as Quangninh and Phalai 2, fabric filtration has been applied based on the BOT contract between foreign investors and the Vietnamese.

For Sulfur Oxides Control Technology

- a) Because the sulfur content of Vietnamese anthracite coal is relatively low (below 0.5%), flue gas desulfuration (FGD) is not a prime consideration of Vietnamese energy planners.
- b) For the Quangninh (QN) thermal power plant (600 MW) which has to use a coal source with a relatively high sulfur content (up to 1-1.2%) and a very low calorific value (3,900 Kcal per kg) from 2005-2010, the FGD technology with the limestone injection to the boiler burning rooms has been considered. It is the simplest, cheapest and most-appropriate FGD technology when using a coal source with very low calorific value and relatively small sulfur content.

Generally, the wet multicyclone, electrostatic precipitator, the baghouse and the limestone injection methods are the appropriate environmental control technologies to be used for coal-fired thermal power plants in Vietnam up to the year 2010.

Assumptions in Estimating Investment Costs and O&M Costs of Three ETAs

Timing of the realization of the ETAs:

- a) ETA1: Investment for new wet cyclones for Group A only (existing) is expected to be realized in the first year (1997-1998). For Group B plants, new investment for TSP-reducing technologies needs to be made because these plants are designed with good TSP emission-reducing equipment. However, the environmental damage costs of ETA1 caused by discharged smoke would have to be estimated for both groups, namely A (NB, PL1, UB1) and B (B1 + B2) (B1 - PL2, UB2, HP and B2 - QN). The environmental damage costs consist of health and property costs.
- b) ETA2: Like the ETA1, investments will be made in first year, 1997-1998, but 90% for Group A will install precipitators while Group B will have TSP-reducing technologies. The environmental damage costs of ETA2 is projected to be equal to 80% (100%/125%) of ETA1.
- c) ETA3: There will be new investment for bag filters, in combination with direct scrubbers during the first year for Group A. For Sub-group B1: There will be supplementary scrubber investment for Uongbi2 Phalai2 and Haiphong in the first year in accordance to the General Scheme V of Vietnam Electricity Development for the period 1995-2010. For Sub-group B2, there will be no

supplementary investment for new TSP-reducing technologies and scrubbers because they are designed as part of the investment during their feasibility studies.

The environmental damage cost of ETAs → is equal to 60% (75%/125%) of ETAs ←.

Developing the above ETAs does not change the installed capacity of Vietnam's electricity system. However, implementing the ETAs contributes to enhanced costs relating to the system (investment, O&M cost, damage costs, etc.). All costs relating to the ETAs are discounted by three rates: 8%, 10% and 12%. The equipment used in the ETAs has the same life span (30 years) as the coal-fired thermal power plants. Also the O&M costs of ETAs are calculated in the same way as the coal-fired thermal power plants. In order to determine MEC_2 for comparison with the LRMC calculated in Section 2.0 of this study, the calculation of the above ETAs would be done separately with environmental costs to include MEC_2 , integrated in the calculation of the LRMC.

The three environmental control technology alternatives – ETA1, ETA2 and ETA3 – have been established on the basis of the following options:

- a) Wet multicyclones for Group A (existing coal-fired thermal power plants): Ninh Binh (NB-100MW), Phalai 1 (PL1-440 MW) and Uong bi 1 (UB 1-105 MW).
- b) Electrostatic precipitators for Group B1: Phalai 2, Uongbi 2, Haiphong (PL2+UB2+HP-600MW+300MW + 600MW = 1500 MW)
- c) Bag filters, FGD with the limestone injection for Group B2: Quang Ninh (QN - 600 MW)

4.2.2 Estimating Air Environmental Impacts Caused by Burning Coal in Coal-fired Thermal Power Plants of Group A

The Characteristics of Coal Used in Existing Thermal Power Plants (Group A)

- a) Type of coal: Anthracite
- b) Average calorific value: 5,500 Kcal/kg
- c) Coal use per kWh: 0.65 kg of natural coal with a calorific value of 5500 Kcal/kg) or 0.5 kg standardized coal with 7000 Kcal/kg
- d) Chemical features of coal (%): Carbon C - 62.8; Hydrogen H - 2.2; Sulfur S - 0.4; Oxygen O - 1.5; Nitrogen N - 0.4; Volatile V - 5; Moisture W - 11; Ash A - 22.
- e) Particulate emission-reducing technology: Wet cyclones with an efficiency of 50%

- f) Emission factors of used anthracite coal (Unit: kg of pollutants per tonne of used coal tonne - kg/T). Coal burning results in the generation of the following air pollutants: TSP = 1.5 kg/tonne; SO_x = 0.08 kg/tonne; CO = 1.2 kg/tonne; HC = 0.7 kg/tonne; NO_x = 8.0 kg/tonne; CO₂ = 2,200 kg/tonne.

Estimating Emissions Before the Installation of Wet Cyclones for Group A

Total installed capacity of Group A: 440 + 105 + 100 = 645 MW

Time to use the maximal capacity of Group A: 4,000 h/year

Amount of coal used for electricity generation of Group A:

$$645 \times 10^3 \times 4,000 \times 0.65 = 1,677 \times 10^3 \text{ T/year}$$

Table 8. Estimated Emissions after Installation of Wet Cyclones for Group A

(Unit: 10⁶ kg/year)

		<i>TSP</i>	<i>SO_x</i>	<i>CO</i>	<i>HC</i>	<i>NO_x</i>	<i>CO₂</i>
Amount of emissions of Group A per year before wet cyclones		2.60	0.14	2.1	1.2	13.4	3,689
<i>Type of TSP Emission-reducing Technologies</i>	<i>Real Efficiency (%)</i>						
Wet cyclones	83	0.44	0.14	2.1	1.2	13.4	3,689
Electrostatic precipitators	90	0.26	"	"	"	"	"
Bag filters	97	0.08	"	"	"	"	"

Note: Unit of emission: 10⁶ kg/year

4.2.3 Estimating Air Pollution Caused by Burning Coal in Thermal Power Plants of Group B

Plants in Group B have been designed and constructed to fully respond to the environmental sustainability required by TCVN-5937-1995 and TCVN-5939-1995. Their emissions are thus considered as within the standards.

Characteristics of Coal Used in Coal-fired Thermal Power Plants of Group B

Phalai 2 – 600 MW and Uong Bi 2 – 300 MW

- Milled coal combustion – electrostatic precipitators
- Using the same coal as Group A
- Without “scrubbers”

Quangninh – 600 MW

- Fluidized combustion – bag filters
- Characteristics of used anthracite coal (%):
C - 44.0; H - 0.3; O - 40; N - 0.2; S - 0.6; W - 8.0; A - 42.5 V - 8.0;
Calorific Value: 3,990 Kcal/kg.
- Technology to reduce toxic gas emissions: Using milled limestone to be injected to combustion chambers of boilers at the same time as injecting the natural coal.

Estimating Emissions Before TSP Emission-reducing Equipment of Group B

Phalai 2 + Uong Bi 2: 600MW + 300MW = 900 MW

- Time to use their maximal capacity: 6000 h/year
- Amount of coal used by their electricity generation:
 $900 \times 10^3 \times 6,000 \times 0.5 = 2,700 \times 10^3 \text{ T/year}$

Amount of emissions per year

<i>TSP</i>	<i>Sox</i>	<i>CO</i>	<i>HC</i>	<i>NO_x</i>	<i>CO₂</i>
4.05	0.22	3.24	1.89	21.6	5,940

Note: Unit of emissions: 10^6 kg/year

The amount of emissions presented above is before using TSP emission-reducing equipment.

Quangninh: 600 MW

- Time to use the maximal capacity: 6000 h/year
- Natural coal consumption for electricity generation
(by feasibility study report): $1,090 \times 10^3 \text{ T/year}$

Amount of emissions before the TSP emission-reducing equipment:

<i>TSP</i>	<i>SO_x</i>	<i>CO</i>	<i>HC</i>	<i>NO_x</i>	<i>CO₂</i>
1.64	0.09	1.31	0.80	8.72	2,398

Note: Unit of emissions: 10^6 kg/year

Table 9. Emissions Before TSP Emission-reducing Equipment for Group B

<i>Name of Plants</i>	<i>TSP</i>	<i>SO_x</i>	<i>CO</i>	<i>HC</i>	<i>NO_x</i>	<i>CO₂</i>
PL2 + UB2	4.05	0.22	3.24	1.89	21.60	5,940
QN	1.64	0.09	1.31	0.80	8.72	2,398
Total	5.69	0.31	4.55	2.69	30.32	8,338

Note: Unit of emissions: 10⁶ kg/year

Table 10. Emissions After TSP Emission-reducing Equipment

<i>Name of Plant</i>	<i>Type of TSP-reducing Equipment</i>	<i>Efficiency of Equipment (%)</i>	<i>TSP</i>	<i>SO_x</i>	<i>CO</i>	<i>HC</i>	<i>NO_x</i>	<i>CO₂</i>
PL2 + UB2	El. Precipitators	90	0.405	0.22	3.24	1.89	21.60	5,940
QN	Bag filters	97	0.049	0.09	1.31	0.80	8.72	2,398
Total	-	-	0.454	0.31	4.55	2.69	30.32	8,338

Note: Unit of emissions: 10⁶ kg/year

5.0 SUMMARY OF RESULTS

5.1 Coal Mining

Coal mining in Vietnam is causing tremendous pollution in the region, and many on-site and off-site impacts. Coal production in the future will slightly increase from 11 million tonnes in 1998 to 14 million tonnes in 2010 with underground mining production increasing from 3 million tonnes in 1998 to 12.5 million tonnes in 2010. This trend will lead to great impacts on underground water, health and other environmental concerns.

Table 11 shows that the on-site and off-site environmental costs of coal mining totaled 139,649.06 million VND in 1998. The highest cost was the cost of pollution treatment inside the mines (46.42%). The total health cost is 29,413.11 million VND which accounted for 21.06% of the total environmental costs. The loss in agriculture, forestry and fishing was 14.78% of the total. Loss of tourism and recreation was 9.8% of the total environmental costs. On-site costs were 65.16% of the total, and off-site costs were 34.84%.

The summary of the estimated production cost, external cost and internal cost is as follows:

Table 11. Summary of Estimated Production and Environmental Costs of Coal Mining, 1998

<i>Production</i>	<i>Unit</i>	<i>Amount</i>	<i>Percentage (%) to total environmental cost</i>
Production cost	VND/tonne	241,050.00	
Heath examination & treatment cost (A ₁)	M. VND	2,328.53	1.67
Injured workers (A ₂)	M. VND	4,232.00	3.03
Dead workers (A ₃)	M. VND	1,000.00	0.72
Lost workdays (A ₄)	M. VND	18,603.00	13.32
Pollution treatment inside the mines (B ₁)	M. VND	64,828.00	46.42
Health treatment cost for nearby residents (A5)	M. VND	3,249.58	2.33
Pollution treatment outside the mine (B ₂)	M. VND	6,885.36	4.93
Loss of tourism & recreation (C)	M. VND	13,750.59	9.85
Loss of agriculture, forestry and fishing (D)	M. VND	20,636.51	14.78
Infrastructure (E)	M. VND	4,135.49	2.96
Total environmental cost	M. VND	139,649.06	100.00

Note: Percentage in total is the comparison between each cost in column 4 with total environmental costs (139,649.06)

Table 12. Marginal Environmental Cost of Coal Mining, 2010

<i>Year</i>	<i>Underground mining production (1,000 tonnes)</i>	<i>Opencast mining production (1,000 tonnes)</i>	<i>Total production (1,000 tonnes)</i>	<i>Total EC1 (million VND)</i>	<i>Average EC1 (VND/tonne)</i>	<i>MEC₁ (VND/tonne)</i>
1998	3,124.00	7,601.00	10,725.00	139,648.85	13,342.46	13,342.46
1999	3,456.00	8,052.00	11,508.00	150,095.71	13,042.73	13,342.09
2000	4,563.00	7,180.00	11,743.00	155,669.05	13,256.33	15,736.94
2001	5,678.00	6,322.00	12,000.00	161,532.71	13,461.06	17,163.81
2002	6,123.00	6,357.00	12,480.00	168,521.32	13,503.31	16,451.55
2003	6,324.00	6,780.00	13,104.00	176,692.91	13,483.89	15,571.27
2004	7,897.00	5,993.24	13,890.24	190,183.07	13,691.85	15,965.37
2005	8,265.00	6,396.76	14,661.76	200,575.66	13,680.19	15,476.38
2006	9,324.00	4,604.67	13,928.67	194,109.94	13,936.00	16,999.58
2007	9,678.00	4,389.96	14,067.96	196,682.11	13,980.86	17,060.71
2008	11,564.00	2,714.98	14,278.98	203,845.41	14,275.91	18,063.29
2009	12,385.00	2,179.56	14,564.56	209,349.52	14,373.90	18,153.31
2010	12,569.00	1,560.83	14,129.83	204,440.80	14,468.73	19,029.40

The results show that coal production in Vietnam in the future will increase from 11 million tonnes in 1998 to 14 million tonnes in 2010. Opencast mining production will decrease quickly because of exploited opencast mines. Otherwise, underground mining production will increase quickly, so production costs will also increase. The

total environmental costs will increase as the total production and underground mining production increase.

5.2 Power Sector

5.2.1 MPC_{capacity} of Electricity

The marginal production costs (Table 13) of electricity were divided into the capacity cost (MPC_{capacity}) and the energy cost (MPC_{energy}) under the three alternatives. The MPC_{capacity} and MPC_{energy} were also computed using two level of voltage such as transition (T_p) at greater than 110 kV and distribution (D_p) for less than 110 kV. Three discount rates were assumed.

The total MPC_{capacity} is the sum of MPC_{capacity} and MPC_{capacity control cost}. The total MPC_{capacity} increases with higher investment on environmental protection cost in the development of coal-fired thermal power plants. This increase is shown in the transition from ETA1 to ETA2 up to ETA3.

Table 13. Summary of the Results of MPC_{capacity} (Constant Million of VND)

Year	Supply Voltage	Discount Rate (%)	MPC						Total MPC capacity (10 ³ VND/KW/y)		
			MPC capacity (KW cost - 10 ³ VND/KW/y)			Capacity control cost (10 ³ VND/KW/y)					
			G,T,D Capacity Cost	O&M Cost	Total KW Cost	ETA1 (<TCVN) 125%	ETA2 (=TCVN) 100%	ETA3 (>TCVN) 75%	ETA1 (<TCVN) 125%	ETA2 (=TCVN) 100%	ETA3 (>TCVN) 75%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		8	138.480	67.415	205.895	1.309	46.154	62.159	207.204	252.049	268.054
1998	T _p	10	165.916	67.415	233.331	1.585	47.095	66.770	234.916	280.426	300.101
		12	194.470	67.415	261.885	1.872	48.069	71.542	263.757	309.954	333.427
		8	197.033	91.111	288.144	1.461	51.511	69.374	289.605	339.655	357.518
	D _p	10	235.230	91.111	326.241	1.769	52.561	74.520	328.010	378.802	400.761
		12	274.857	91.111	365.968	2.089	53.648	79.846	368.057	419.616	445.814
		8	244.511	90.848	235.359	0	0	59.689	235.359	235.359	295.048
1999	T _p	10	171.781	90.640	262.421	0	0	62.133	262.421	262.421	324.554
		12	199.834	90.430	290.264	0	0	64.742	290.264	290.264	355.006
		8	200.268	115.932	316.200	0	0	66.618	316.200	316.200	382.818
	D _p	10	237.518	115.710	353.228	0	0	69.345	353.228	353.228	422.573
		12	276.071	115.490	391.561	0	0	72.256	391.561	391.561	463.817
		8	147.200	79.320	226.520	0	0	59.312	226.520	226.520	285.832
2000	T _p	10	174.032	79.400	253.432	0	0	61.474	253.432	253.432	314.906
		12	201.311	79.450	280.766	0	0	63.720	280.766	280.766	344.486
		8	201.310	102.343	211.653	0	0	66.196	211.653	211.653	277.849
	D _p	10	237.783	102.460	340.243	0	0	68.609	340.243	340.243	408.852
		12	275.156	102.530	377.686	0	0	71.115	377.686	377.686	448.801
		8	142.312	68.434	210.746	0	0	0	210.746	210.746	210.746

Table 13. *Continued...*

2001	T _p	10	167.933	68.800	236.733	0	0	0	236.733	236.733	236.733
		12	193.880	69.130	263.010	0	0	0	263.010	263.010	263.010
		8	199.344	91.501	290.845	0	0	0	290.845	290.845	290.845
	D _p	10	234.965	91.880	326.845	0	0	0	326.845	326.845	326.845
		12	271.337	92.250	363.587	0	0	0	363.587	363.587	363.587
		8	135.773	64.353	200.126	0	0	0	200.126	200.126	200.126
2002	T _p	10	159.473	64.780	224.253	0	0	0	224.253	224.253	224.253
		12	183.294	65.200	248.494	0	0	0	248.494	248.494	248.494
		8	192.221	86.999	279.200	0	0	0	279.200	279.200	279.200
	D _p	10	225.743	87.480	313.223	0	0	0	313.223	313.223	313.223
		12	259.779	87.920	347.699	0	0	0	347.699	347.699	347.699
		8	132.424	58.229	190.653	0	0	0	190.653	190.653	190.653
2003	T _p	10	154.683	58.870	213.553	0	0	0	213.553	213.553	213.553
		12	176.869	59.480	236.349	0	0	0	236.349	236.349	236.349
		8	188.635	80.225	268.860	0	0	0	268.860	268.860	268.860
	D _p	10	220.582	80.930	301.512	0	0	0	301.512	301.512	301.512
		12	252.824	81.610	334.434	0	0	0	334.434	334.434	334.434
		8	129.603	56.827	186.430	0	0	0	186.430	186.430	186.430
2004	T _p	10	150.328	57.440	207.768	0	0	0	207.768	207.768	207.768
		12	170.754	58.050	228.804	0	0	0	228.804	228.804	228.804
		8	184.057	78.131	262.188	0	0	0	262.188	262.188	262.188
	D _p	10	214.142	78.840	292.982	0	0	0	292.982	292.982	292.982
		12	244.279	78.520	323.800	0	0	0	323.800	323.800	323.800
		8	123.143	57.209	180.352	0	0	0	180.352	180.352	180.352
2005	T _p	10	142.327	57.730	200.057	0	0	0	200.057	200.057	200.057
		12	161.161	58.240	219.401	0	0	0	219.401	219.401	219.401
		8	175.898	78.205	254.103	0	0	0	254.103	254.103	254.103
	D _p	10	204.161	78.820	282.981	0	0	0	282.981	282.981	282.981
		12	232.426	78.420	310.846	0	0	0	310.846	310.846	310.846
		8	120.236	59.010	179.246	0	0	0	179.246	179.246	179.246

Table 13. *Continued...*

2006	T _p	10	138.077	59.350	197.427	0	0	0	197.427	197.427	197.427
		12	155.492	59.700	215.192	0	0	0	215.192	215.192	215.192
		8	172.711	80.239	252.950	0	0	0	252.950	252.950	252.950
	D _p	10	199.872	80.770	280.642	0	0	0	280.642	280.642	280.642
		12	226.147	81.070	307.217	0	0	0	307.217	307.217	307.217
		8	113.904	58.424	172.328	0	0	0	172.328	172.328	172.328
2007	T _p	10	130.127	58.770	188.897	0	0	0	188.897	188.897	188.897
		12	145.896	59.130	205.026	0	0	0	205.026	205.026	205.026
		8	165.386	79.489	244.875	0	0	0	244.875	244.875	244.875
	D _p	10	190.668	80.030	270.698	0	0	0	270.698	270.698	270.698
		12	215.120	80.340	295.460	0	0	0	295.460	295.460	295.460
		8	108.487	57.368	165.855	0	0	0	165.855	165.855	165.855
2008	T _p	10	123.396	57.770	181.166	0	0	0	181.166	181.166	181.166
		12	137.849	58.200	196.049	0	0	0	196.049	196.049	196.049
		8	158.648	78.053	236.701	0	0	0	236.701	236.701	236.701
	D _p	10	182.362	78.660	261.020	0	0	0	261.022	261.022	261.022
		12	205.329	79.080	284.409	0	0	0	284.409	284.409	284.409
		8	106.172	54.085	160.257	0	0	0	160.257	160.257	160.257
2009	T _p	10	120.360	54.770	175.130	0	0	0	175.130	175.130	175.130
		12	134.088	55.450	189.540	0	0	0	189.540	189.540	189.540
		8	155.473	74.169	229.642	0	0	0	229.642	229.642	229.642
	D _p	10	178.302	75.100	253.402	0	0	0	253.402	253.402	253.402
		12	200.446	75.830	276.276	0	0	0	276.276	276.276	276.276
		8	102.243	52.913	155.256	0.062	3.177	12.980	155.318	158.433	168.236
2010	T _p	10	115.556	53.670	169.226	0.075	3.569	14.457	169.301	172.795	183.683
		12	128.325	54.420	182.743	0.089	3.976	15.969	182.832	186.719	198.712
		8	152.253	72.609	225.132	0.069	3.546	14.487	225.201	228.678	239.619
	D _p	10	172.184	73.630	245.814	0.084	3.983	16.135	245.898	249.797	261.949
		12	193.238	74.470	267.708	0.099	4.437	17.822	267.807	272.145	285.530

5.2.2 The MPC_{energy} and Environmental Cost of Electricity Sector

Table 14 shows the MPC_{energy} and the marginal environmental cost (MEC₂). The total MPC_{energy} is the summation of MPC_{energy} with the environmental cost_{energy} at three discount rates (8%, 10% and 12%)

The higher the level of environmental protection for development of coal-fired thermal power plants, the lower the damage costs caused by them. The decreasing level of environmental costs (MEC₂) during transition from ETA1 to ETA2 shows this relationship.

Table 14. Summary of the Results of Estimation of MPC_{energy} and Environmental Cost (Constant of VND)

Year	Supply Voltage	MPC Energy (Fuel Cost- USD/kWh) Base loading coal steam power plant	Environmental Cost _{energy} (MEC ₂) (USD/kWh:VND/kWh)			Total MPC Energy (USD/kWh:VND/kWh)		
			ETA1 (<TCVN) 125%	ETA2 (=TCVN) 100%	ETA3 (>TCVN) 75%	ETA1 (<TCVN) Base loading coal steam power plant	ETA2 (=TCVN) Base loading coal steam power plant	ETA3 (>TCVN) Base loading coal steam power plant
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1998	T _p	0.018	0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322
			0.0082	0.0066	0.0049	0.027	0.026	0.024
1999	D _p	0.019	114.8	92.4	68.6	378	364	336
			0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322
2000	T _p	0.018	0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322
			0.0082	0.0066	0.0049	0.027	0.026	0.024
2001	D _p	0.019	114.8	92.4	68.6	378	364	336
			0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322
2002	T _p	0.018	0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322
			0.0082	0.0066	0.0049	0.027	0.026	0.024
2002	D _p	0.019	114.8	92.4	68.6	378	364	336
			0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322
2002	T _p	0.018	0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322
			0.0082	0.0066	0.0049	0.027	0.026	0.024
2002	D _p	0.019	114.8	92.4	68.6	378	364	336
			0.0078	0.0062	0.0047	0.026	0.024	0.023
			109.2	86.8	65.8	364	336	322

Table 14. *Continued...*

2003	T _p	0.018	<u>0.0078</u> 109.2	<u>0.0062</u> 86.8	<u>0.0047</u> 65.8	<u>0.026</u> 364	<u>0.024</u> 336	<u>0.023</u> 322
	D _p	0.019	<u>0.0082</u> 114.8	<u>0.0066</u> 92.4	<u>0.0049</u> 68.6	<u>0.027</u> 378	<u>0.026</u> 364	<u>0.024</u> 336
2004	T _p	0.018	<u>0.0078</u> 109.2	<u>0.0062</u> 86.8	<u>0.0047</u> 65.8	<u>0.026</u> 364	<u>0.024</u> 336	<u>0.023</u> 322
	D _p	0.019	<u>0.0082</u> 114.8	<u>0.0066</u> 92.4	<u>0.0049</u> 68.6	<u>0.027</u> 378	<u>0.026</u> 364	<u>0.024</u> 336
2005	T _p	0.018	<u>0.0055</u> 77	<u>0.0044</u> 61.6	<u>0.0033</u> 46.2	<u>0.024</u> 336	<u>0.022</u> 308	<u>0.021</u> 294
	D _p	0.019	<u>0.0059</u> 82.6	<u>0.0047</u> 65.8	<u>0.0035</u> 49.6	<u>0.025</u> 350	<u>0.024</u> 336	<u>0.023</u> 322
2006	T _p	0.018	<u>0.0055</u> 77	<u>0.0044</u> 61.6	<u>0.0033</u> 46.2	<u>0.024</u> 336	<u>0.022</u> 308	<u>0.021</u> 294
	D _p	0.019	<u>0.0059</u> 82.6	<u>0.0047</u> 65.8	<u>0.0035</u> 49.6	<u>0.025</u> 350	<u>0.024</u> 336	<u>0.023</u> 322
2007	T _p	0.018	<u>0.0055</u> 77	<u>0.0044</u> 61.6	<u>0.0033</u> 46.2	<u>0.024</u> 336	<u>0.022</u> 308	<u>0.021</u> 294
	D _p	0.019	<u>0.0059</u> 82.6	<u>0.0047</u> 65.8	<u>0.0035</u> 49.6	<u>0.025</u> 350	<u>0.024</u> 336	<u>0.023</u> 322
2008	T _p	0.018	<u>0.0055</u> 77	<u>0.0044</u> 61.6	<u>0.0033</u> 46.2	<u>0.024</u> 336	<u>0.022</u> 308	<u>0.021</u> 294
	D _p	0.019	<u>0.0059</u> 82.6	<u>0.0047</u> 65.8	<u>0.0035</u> 49.6	<u>0.025</u> 350	<u>0.024</u> 336	<u>0.023</u> 322
2009	T _p	0.018	<u>0.0055</u> 77	<u>0.0044</u> 61.6	<u>0.0033</u> 46.2	<u>0.024</u> 336	<u>0.022</u> 308	<u>0.021</u> 294
	D _p	0.019	<u>0.0059</u> 82.6	<u>0.0047</u> 65.8	<u>0.0035</u> 49.6	<u>0.025</u> 350	<u>0.024</u> 336	<u>0.023</u> 322
2010	T _p	0.018	<u>0.0055</u> 77	<u>0.0044</u> 61.6	<u>0.0033</u> 46.2	<u>0.024</u> 336	<u>0.022</u> 308	<u>0.021</u> 294
	D _p	0.019	<u>0.0059</u> 82.6	<u>0.0047</u> 65.8	<u>0.0035</u> 49.6	<u>0.025</u> 350	<u>0.024</u> 336	<u>0.023</u> 322

Note: The results shown in Tables 14, 15 and 16 were derived from calculations not included in the report due to space limitations. Please contact the authors for further information.

Table 15. The U-shaped Pollution Cost Curve of Coal-fired Power Plants in North Vietnam

<i>Cost</i> (B. VND/year)	<i>ETA1</i> (over TCVN)	<i>ETA2</i> (=TCVN)	<i>ETA3</i> (under TCVN)
Damage cost (A)	5,208.00	1,498.00	1,008.00
Abatement cost (B)	112.00	364.00	1512.00
Total of (A) & (B)	5,320.00	1,862.00	2,520.00
Percentage	286%	100%	135%

5.2.3 The U-shaped Pollution Cost Curve of Coal-fired Power Plants

The optimal level of pollution abatement is associated with ETA2 since it gives the least total cost [damage cost (A) + abatement cost (B)] in comparison with ETA1 and ETA3 based on TCVN-5937-1995.

The environmental alternative ETA2, which has minimal costs from the environmental pollution of coal-fired thermal power plants, satisfies the Vietnamese National environmental standard TCVN. The cost of ETA2 is 1,862 billion VND/year (100%) while ETA1 and ETA3 cost 5,320 billion VND/year (286%) and 2,520 billion VND/year (135%), respectively.

In comparison with ETA1, the ETA3 has a higher economic and environmental viability. This points to the need to select environmental alternatives for the development of coal-fired thermal power plants that puts emphasis on higher pollution mitigation levels.

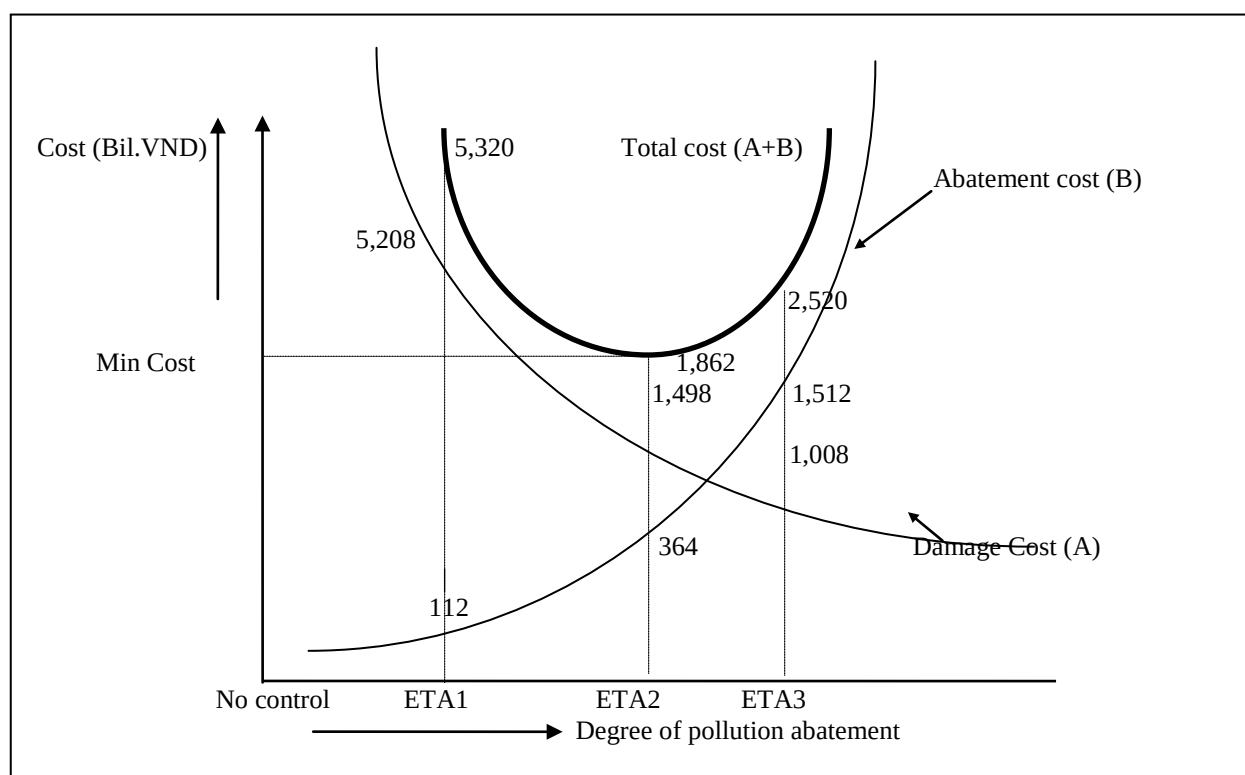


Figure 3. Cost of Abatement in Coal-fired Plants

Note, however, that the general U-shape was applied only to MEC₂ due to data limitation in the estimation of MEC₁.

Table 16 presents the summary of cost of generating electricity. This cost is composed of four components such as MPC_{capacity} , MPC_{energy} , MEC_2 and MEC_1 , all expressed on a per kWh basis.

As shown in Table 16 the following conclusions can be made:

- The percentages of environment-related costs (MEC_1 by coal mining and MEC_2 by coal-fired thermal power plants) to the total social energy costs are considerable, ranging from 14% to 19%. However, up to now, these environment-related costs are not being considered in Vietnam in electricity pricing.
- Due to the predominant role of MPC_{capacity} and MPC_{energy} in total social costs and their decreasing trend in the period 1998-2010, the total social energy costs are also decreasing.
- The electricity-related environmental costs (converted to WTP) MEC_2 are a lot higher than the coal-mining-related environmental cost, MEC_1 . The difference in magnitude is about 10-15 times, thus, it is necessary to prioritize the pollution-mitigating measures for flue gas discharged from boilers of coal-fired thermal power plants.

Table 16. Summary of the Marginal Energy Costs and the Marginal Environmental Costs per kWh ($MPC_C + MPC_E + MEC_1 + MEC_2$)

Year	MEC_1 VND/ kWh (0.86kg coal/ kWh)	$MPC_{\text{cap.}}$ (VND/ kWh) ETA2 (include control cost)		MPC_{energy}		MEC_2 (converted to WTP)		Total (social cost)		Percentage of ($MEC_1 + MEC_2$) in Total (%)	
		T	D	T	D	T	D	T	D	T	D
1998	11.20	546	756	252	266	160.6	170.9	969.8	1,204.1	17.7	15.1
1999	11.22	616	826	252	266	160.6	170.9	1,039.8	1,274.1	16.5	14.3
2000	11.29	588	798	252	266	160.6	170.9	1,011.8	1,246.1	17.0	14.6
2001	11.28	546	756	252	266	160.6	170.9	969.8	1,204.1	17.7	15.1
2002	11.27	518	728	252	266	160.6	170.9	941.8	1,176.1	18.2	15.5
2003	11.27	504	700	252	266	160.6	170.9	927.8	1,148.1	18.5	15.9
2004	11.27	490	686	252	266	111.5	170.9	864.7	1,134.1	14.2	16.1
2005	11.27	462	658	252	266	111.5	119.1	836.7	1,054.3	14.7	12.4
2006	11.27	462	658	252	266	111.5	119.1	836.7	1,054.3	14.7	12.4
2007	11.27	434	630	252	266	111.5	119.1	808.7	1,026.3	15.2	12.7
2008	11.27	420	616	252	266	111.5	119.1	794.7	1,012.3	15.4	12.9
2009	11.27	406	588	252	266	111.5	119.1	780.7	984.3	15.7	13.2
2010	11.27	392	574	252	266	111.5	119.1	766.7	970.3	16.0	13.4

Note: All above costs were discounted at 10% for each year

Unit: VND/kWh

6.0 CONCLUSIONS AND POLICY IMPLICATIONS

6.1 Costs

6.1.1 Mining Sector

The total production cost per tonne of clean coal was 241,050 VND in 1998; it was estimated to be 343,679.70 VND in 2010. The marginal environmental cost (MEC_1) of coal mining is 19,029.4 VND/per tonne in 2010 or 5.5% of production cost. The on-site cost is 65.16% of the total MEC_1 and the off-site cost accounts for 34.84%.

The MEC_1 of coal mining is 16.4 VND/per kWh at transmission. Compared to the social price of per kWh of coal electricity, MEC_1 2.1% at transmission (16.4/ 771) and 1.7% at distribution.

6.1.2 Electricity Sector

The percentage of ($MEC_1 + MEC_2$) to total kWh cost ranged from 13.9 to 16.2% at distribution level D (customer level) when converted to WTP. In comparison with the current average tariff (4 US cents/ kWh), the total average electricity cost of 7 US cents/kWh forecast for the year 2010 is 1.75 times higher, when costs are considered the charge for capacity and for the environment. Vietnam Energy (EVN) plans to remove the current subsidy on electricity production in order to be able to charge 7 US cents/kWh for the period 2000-2005. Therefore, the recommended average electricity tariff of 7 US cents/kWh is acceptable.

The average electricity tariff level of 7 US cents/kWh does not influence the role of coal-fired thermal power plants due to the following reasons:

- a) Because of the scarcity of hydropower sources and limitation of oil/gas potential, coal would become the most important domestic energy source in Vietnam for power generation.
- b) The early removal of the subsidy to take into account the charge for capacity and environmental cost is a move in the right direction. This is unavoidable to ensure financial self-sufficiency and autonomy of the electricity sector in Vietnam's economic renovation.
- c) Based on the analysis of the U-shaped total cost curve, the ETA2 is the most suitable technological option for environmental control of coal-fired thermal power plants meeting the Vietnamese standard of Ambient Air Quality TCVN-5937-1995 (precipitators for Group A and B1; bag filters and limestone injection for Group B2).

6.2 Environmental Policy Instruments

6.2.1 Environmental Policy Instruments for Coal Mining Sector

Policies

As presented above, the coal mining industry has played an important role in the national economy. To ensure sustainable development, VINACOAL and the government need to continuously take measures to minimize the environmental impact of all the mining processes. The following are techniques and technical solutions that have been implemented so far:

- a) *Toxic gas and dust prevention*: installation of inhaling equipment in underground mining, water sprays, road cover and high pressure water sprays;
- b) *Water protective solutions*: embankment systems to dam muddy flows, coal recycling, dredging of the flows and wastewater treatment;
- c) *Environmental protection for dumpsite areas*: embankments built at the base of dumpsites, tree planting on dumpsites, designing and planning for land rehabilitation of dumpsites in open-pit mining; and
- d) *Other technical solutions*: wood pillars to be replaced by metal grids and concrete bands.

Policies and Legislation

At present, Vietnam lacks the appropriate legislation to support pricing reforms in the electricity and mining sectors.

The Vietnamese Government has already issued a Law on Environment Protection and a number of legislation and legal documents and policies for mining activities. These regulations provide the basis for the existence of a legislative environmental system in Vietnam. However, they are insufficient to reduce environment-damaging activities as they have loopholes and lack uniformity. The environmental knowledge of the local environment staff is also low.

There is also an insufficient number of regulations, mechanisms and standards on the environment for mining activities, dust prevention, wastewater treatment, sorting plants and mineral processing plants.

A relevant and strict mechanism is needed for investment, technological development, equipment, and environment damage reduction and screening complexes.

Due to the specific conditions of mining, VINACOAL wants to take advantage of the capability of existing technologies to exploit open-pit mining. Waste dumping and the lack of technology have inflicted overloading pollution on the mining environment. These dumping sites extend further than accepted international standards. Thus, it is advisable to carry out research on all open-pit mines to find out methods for investment, and environment protection and prediction. Furthermore, it is necessary to reconsider the mining process and rationalize solutions, transfer technology transfer, and install advanced equipment for the deep mines.

The boundary between open-pit and underground mining activities should be identified based on the environmental protection criteria, especially on land reclamation and stabilization.

a) Regulations to Protect the Environment in Open-pit and Underground Mining

The responsibility for environmental protection among the various agencies must be clearly identified and their coordination encouraged. These should be supported by legislation creating the pre-conditions for such coordination.

To help mining units and enterprises apply environmental protection guidelines wisely in accordance with governmental regulations, rules, and standards, a legislative and regulatory system in all processes of production must also be set up. What is needed are mining implementation procedures that are feasible and scientific.

b) Energy Price Policies

A suitable price policy is needed that will help ensure three targets:

- to exploit and wisely use every kind of energy resource for the development of the national economy and livelihood of the people;
- to ensure balance and harmony in the development of every type of energy for the socio-economic development of the national economy; and
- to protect the environment.

There is a need to explore way to increase mining value in the regional and international markets so as to ensure that mining enterprises are able to invest in environmental protection measures and effective technological changes. Along with the rise of coal price, there must also be a price support mechanism in remote rural areas that commonly use coal.

c) Technical Methods to Limit Diverse Impact

Having modernized, uniform and high-tech equipment will help the mining industry improve its productivity and efficiency, as well as reduce its investment loss.

The master plan development for the mining industry includes:

- placing a limit on open pit mining in Halong city and Yentu historic heritage site;
- strengthening underground exploitation and gradually moving the coal mining and processing industry to Campha town; and
- concentrating on hi-tech equipment to minimize pollution impacts on the environment.

Water resource protection. Water resource protection includes protection of water quality and the underground water reservoir. Besides building dams to prevent muddy flows and building a master plan for the surrounding areas and water basins where wastewater and rain will fall, sedimentation should be processed so that water will runoff to the rivers. This will reduce sedimentation in rivers and increase underground water reservoirs. The bottom of the open-pit mines can be used as water reservoirs for domestic and production purposes.

Dust pollution. The general solution for dust pollution requires a combination of the following methods in all stages of exploitation: 1) wetting the coal seams; 2) water drilling; 3) air cyclones; 4) water sprays and high-pressure water sprays; 5) dust fillet and screening complexes by the high-tech equipment; 6) barges cyclones, electronic tranquillity; and 7) water spraying on haul roads.

Solid waste treatment. Waste or disposals discharged from screening complexes often contain coal or its compositions, that can be for cement production. Wise use of the solids will help save fuel for cement production and reduce areas for dumpsites.

Waste or disposals that are non-coal solids can be used for road, building land foundations and other construction purposes. In order to put these ideas into practice, the close cooperation of mining industry experts and scientists for construction, engineering, and geography is absolutely essential.

Inflammable gas withdrawal methods. Methane (CH₄) and other carbon hydro compounds are the main cause of mining explosions. To prevent gas blasting, a series of holes are drilled deeply and systematically at mines that are going to be exploited. Then gas-collecting instruments are installed and the gas is channeled to the condensing center. According to former Soviet Union experiences, the best

solution is to drill holes every 100-200 m. This way, ignitions of gas would be avoided, hence, preventing greenhouse effects and saving energy for greater economic efficiency.

Forest rehabilitation. Forest rehabilitation in dumpsite areas will cover the following activities: 1) designing and planning dumpsites; 2) clearing and construction on land; 3) stabilization during and after dumping waste; 4) planting and fertilizing trees in the dumpsites; 5) selecting the tree species and process of planting; and 6) caring for and protecting the forest.

d) Orientation on Environmental Education and Training

The activities include: 1) providing environment awareness in the curriculum at primary level and at university; 2) encouraging women and children to participate in environmental protection activities such as planting programs, energy-saving and environment sanitation; 3) updating the environmental knowledge of staff responsible for environmental protection for the mining industry; and 4) setting up a board of management and implementation to monitor and inspect the environment problems and management of VINACOAL.

A short-term training program for mining enterprises, manufacturers, workers and local environment staff responsible at the mining areas should include skills in environmental impact assessment, environmental economic assessment, and environmental management and technology.

e) Environment Tax and other Economic Instruments

There should be a regulation on legal penalties and financial compensation by enterprises or other economic entities whose operations seriously affect the natural and artificial environment. These include discharging poisonous untreated waste into rivers and of disposals that encroach on residential areas, cultivated land, and that cause frequent floods.

There is a need to build in an environment tax for processing and mining activities, which should be accounted for in the prices of coal products. There should be strict management of coal consumption, processing, and promotion for domestic consumption.

An environment fee is the contribution of individuals and organizations that operate in the mining industry to be used for environmental protection. This is different from the tax that goes straight to the state's coffers. The environment fee is only used for protecting and rehabilitating the environment damaged by mining activities. The environmental tax, tariff and fee for natural resources do not exceed the frame of financial management. Tax and fee collections are the best ways to protect the

environment. Projects that have high risks of environmental pollution should have money deposited for environmental insurance.

f) Management Solution

Management should establish and examine environmental impact assessment; natural resources; environmental auditing, monitoring, control and inspection; and environmental protection.

Environmental monitoring for the local climate, geographical conditions, specific pollutants and others, which will make management operations easier, should be undertaken.

Environmental management also involves the control and observation of mining and processing activities that may cause environmental pollution.

Environmental Solutions for Long- and Medium-term Mining Activities

The reshuffling of the VINACOAL organization to be a strong economic enterprise and the setting of management boundaries for mines in Quangninh (which accounts for 98% of the total coal deposits of Vietnam) have been considered effective environmental management methods. Illegal mining activities have been dramatically reduced; and the management mechanism for mining activities has improved. However, to strengthen environmental protection, VINACOAL should be supplemented by other solutions for management and organization as follows:

Long-term Solutions:

- An approved mining law is needed to highlight the need to integrate environmental concerns into the development of coal mining. This will serve as the basis for the governance of mining in Vietnam.
- The environment management authority among mining units with local authorities needs to be identified.
- The annual environmental impact assessment of coal mining and processing activities must be fully implemented.
- The environmental standards, specifying forming and processing activities, should be promulgated.
- The local authorities should work together to set up a monitoring system and environment control.
- Coupled with environment protection regulations, economic methods (reward, penalties, environmental fee) should also be implemented in mining activities.

Medium-term Solutions:

- All the environmental impact assessment procedures in coal producing enterprises should be implemented and the environmental protection regulations should be ratified.
- Temporary standards for the mining industry should be set up.
- A fund (specific anticipation) for the building environment staff and recovery of adverse environmental impacts should be set up.

g) Environmental Aspects and Methods to Increase the Value of the Natural Environment

The value of the natural environment is evaluated by environment quality and operation in the field. In mining areas, the quality of the air, water, land, ecology and producing operations, coal consumption, tourism and services are considered.

To improve and protect the value of the natural environment, anti-deterioration methods must focus on dumpsites, land reclamation, protection and recycling of water resources, development of the tourism sector, services and overall development for coal consumption.

The tourism sector in isolated and small areas must be designed and developed. The natural sightseeing areas of tourism complexes must also be protected as a whole.

Small-scale tourism areas and environmental protection for local areas must be encouraged and ensured.

There should be investment for the development of the local community to support sustainable tourism operation.

The advantages of the open-market economy must be used to enhance the development of the tourism sector.

h) Social Methods: Improvement of Human Resources, Community Benefits, Environment and Living Quality

People play an important role in insuring environmental quality. The individual's benefits from the environment are often linked to the local community's benefits. Therefore, to limit adverse impacts on the environment, it is necessary to make the individuals and the community aware of environmental concerns and to encourage tree planting, environment sanitation, energy-saving and other schemes.

Coupled with these activities is the need for investment and campaigns to ensure clean water, protection of the ecological and biological systems, and health care for workers and the local community.

6.2.2 Environmental Policy Instruments for Coal-fired Electricity Sector

General Environmental Protective Policies Relating to Coal-fired Thermal Power Plants

- Provide a reliable and adequate supply of electricity at a cost allowing a well-balanced economic development according to local needs.
- Give priority to the protection of the local environment. Low-cost local protection measures include using chimneys of adequate height, electrostatic precipitators and modifying burners to reduce NO_x.
- Protect as much as possible the regional and global environment by adopting catalytic DENO_x systems and flue gas desulfurization (FGD) systems.
- Reduce fuel pollutants through physical or chemical cleaning.
- Improve energy efficiency of existing and new power generation plants.

Environmental Control Technologies Option Policies

a) Relevant Technologies for Short-term Applications:

- Low-NO_x combustion technologies
- Sorbent and duct injection
- Dry scrubbers
- Advanced electrostatic precipitators
- Circulating AFBC
- Bag filters (only with sorbent/duct injection and mainly in association with AFBC technologies)

The above technologies are appropriate for Vietnam due to their low capital cost and easy transfer.

Large sub-critical pulverized-coal and life extension/rehabilitation technologies for existing power plants must also be considered for short-term applications.

b) Relevant Technologies for Long-term Applications:

- Large subcritical and supercritical pulverized coal plants
- Wet scrubbers (flue-gas desulfurization)
- Combined cycle gas turbine (CCGT)

Environmental Policy Instruments

There are two major policy instruments for the environmental management of coal-fired thermal power plants, namely tax imposed on ash and sulfur contents of coal input, and early removal of the current subsidy mechanism to account for the charge for environmental cost and capacity.

The impacts of human activities on the environment can be reduced by two means: cutting down or reducing pollutants and improving energy transformation efficiency.

As indicated above, the technologies to reduce environment impacts exist, but society must be prepared to accept their costs.

Environmental policy instruments are the legal standards and regulations enforced by legal entities. These instruments include: voluntary negotiations by producers, communities and individuals on safeguards, standards and matters of compensation; the abilities of governments to tax, subsidize or grant aid; and the influence of the public and private sectors on the values and moral restraints on matters related to the production and consumption of coal and the correct application of regulations.

Institutional Legislative and Regulatory Arrangement Policies for Environmental Protection Relating to Coal-fired thermal Power Plants

In line with the policy and legislative initiatives discussed above, a priority of Vietnam should be to define some of the key roles to be played by various institutional players. The principal issues that need to be resolved are the following:

a) *Central environmental authority:* SCST is currently responsible for coordinating and overseeing legislative activities, but there are longer-term proposals to establish a separate Environment Ministry, a composite Environment Ministry (attached to some other ministry such as Labor, or MTT), or a separate Environmental Council which effectively acts above the ministerial level. Barring a complete restructuring of all the ministries, the expectation is that the SCST will retain its responsibilities and that its position as a central authority will be reviewed in 1995.

b) *Role of line ministries.* The various line ministries have taken substantial initiatives in environmental planning and have been relied on by the SCST to draft selected guidelines relevant to their ministries. It is most likely that this role will continue to grow.

c) *Enforcement/implementation of regulations.* There is a strong intent to delegate implementation and enforcement tasks to decentralized regional or local

authorities. This will require a substantial strengthening of regional institutions to deal with environmental problems.

d) Institutional constraints. As elsewhere in the world, overcoming problems associated with inter-jurisdictional cooperation will be a key challenge in Vietnam. Unclear jurisdiction lines are already responsible for a number of cases where energy and environment issues are not being adequately addressed.

Another constraint is the conflict of interest that arises when expert guidance and advice are solicited from technical agencies that will subsequently implement the ensuing regulations.

The lack of awareness about certain types of environmental impacts also poses problems. While there is a good appreciation in Vietnam of impacts associated with obvious land degradation or human health, there is less awareness of the long-term effects of certain types of pollution, in particular those related to volatile organic compounds (VOCs) and NO_x emissions. A related constraint is the general lack of knowledge regarding the technologies available for water and waste treatment, reclamation, or atmospheric pollution control, due largely to the fact that most personnel have no experience with such equipment and have had their training in countries where such systems have not been used.

A very important problem is the historical focus on ambient standards for air and water quality as a basis for object design. This stems primarily from the fact that most Soviet standards are based on ambient levels. There has been no systematic monitoring of actual emissions, and in the rare instances where ambient concentrations were actually monitored, it was not possible to correlate them to particular industrial activities. Even if the acceptable levels are made more stringent, ambient standards form a poor basis for future regulation. The emission-based regulations and standards which are likely to be adopted in Vietnam in the future will require the establishment of monitoring and enforcement systems which currently do not exist.

A key constraint to overcoming all of the above problems has been the general lack of availability of funds for training, investment, and information gathering. Cost recovery systems (such as environment “taxes”) have not been used in Vietnam to an extensive degree. The exception is a modest charge on water usage and waste disposal for household and industrial use.

Context for Setting Priorities

Vietnam’s environmental priorities in energy depend on the perceived or actual severity of environmental damage, and the relative contribution of the energy sector to overall pollution levels. Land-use issues relating to watershed management and hydroelectric development receive a high priority because of their perceived widespread impact on human settlements, the environment, and the energy investment itself.

Similarly, particulate emissions from power plants receive a high priority because they have obvious human health impacts and are, in addition, not too difficult or costly to control. A number of other environmental problems, in contrast, are implicitly of lower priority.

Pollution from coal transportation receives a low priority because of the perception that losses are relatively small and that most of this coal is recovered either by small-holder activities or through routine dredging operations undertaken by the power companies.

Oil pollution from oil exploration and development is relatively small and therefore is low priority. Water pollution from thermal power projects also is low priority. Efforts to address water pollution from heavy industry or thermal projects would have a relatively small impact given their smaller contribution to total pollution levels (<10%).

Emissions of NO_x and sulfur from thermal power projects are also typically regarded as small in comparison to those of other projects in their immediate vicinity. Regulatory efforts or mitigation investments directed solely at the thermal plant would have little impact in the absence of similar initiatives for the entire airshed.

Vietnamese Electricity Pricing Policies

Based on the above analysis of the Vietnamese electricity pricing situation and comments on the calculation of MPC energy, MEC₁ and MEC₂, it is possible to establish recommendations on Vietnamese electricity pricing policies as follows:

- For the near future, Vietnamese electricity pricing has to be established in the LRMC-based orientation on the basis of AIC calculation.
- The current subsidy mechanism used in Vietnamese electricity pricing has to be gradually and rationally reduced in the context of the socio-economic renovation.
- Vietnamese electricity tariffs have to include the charge for energy, capacity and environment in order to reflect comprehensively and realistically the marginal cost of electricity services for all customers.
- Vietnamese electricity tariffs have to include following components: a) Energy charge based on kWh metered; b) Capacity charge based on kWh invested for responding to incremental capacity demand; and c) Environment charge based on health and property damage costs incurred by TSP and toxic gas emissions of electricity production generally, and coal-fired thermal power plants in particular.
- Vietnamese electricity tariffs have to be established incorporating the following factors: a) Regional; b) Seasonal; c) Time-of-day tariffs (peak,

valley, off-peak); and d) Escalating tariff based on excess in monthly quota by which the tariffs have to be increased.

- Being a developing country, Vietnam has to use an exception for rural electricity pricing. In this context, the financial viability of rural electrification projects is not the government's prime consideration. Hence, the government has to keep a rational subsidy mechanism in rural electricity pricing for poverty elimination.

The market-oriented instruments for environmental protection have to be included in electricity pricing policies. Environmental initiatives in Vietnam have traditionally been guided by a command and control approach. There is currently no knowledge on the use of market-based instruments (taxes, charge, tradable permits) as a means for environmental protection. Strict regulatory approaches may not be entirely appropriate if Vietnam starts to grow rapidly. Market-based mechanisms are both environmentally and economically more efficient, as the growing experience with such mechanisms in industrialized and developing countries shows. They can be particularly effective for small-scale polluters (such as coal-fired thermal power plants) which might otherwise be difficult to monitor and regulate.

To control and limit environmental damage sources, the Government should issue suitable policy instruments, including, among others, technology, education, human resource improvement, laws, management, taxes, and standards on the ash and sulfur content of coal input.

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APPENDICES

Appendix 1. Health Cost (A) for 1997 and 1998: Health Damage Costs Respectively for Mine Workers and Nearby Residents: A1 and A5

(i)	Occupational diseases among mine workers: (i)	Number of occupational disease persons affected by the coal industry/year: (Ni)	Average treatment costs for disease i /person paid by the patient: (Pi) (M.VND) (Converted WTP)	Sum of health treatment cost for disease i (M.VND): A_i
1	Tuberculosis	598	3,26	1,950,68
2	Bronchitis	250	1,10	275,00
3	Bronchial and lung cancer	25	1,65	41,25
4	Other diseases	70	0,88	61,60
	Cost A_1			2,328,53
5	Health treatment cost for nearby residents (A_5)	943	3,446	3,249,58
Total	$A_1 + A_5$	943	1,72	5,578,10
(i)	Occupational diseases among mine workers	Average health treatment person	Cost P_i (million VND)/ person (converted WTP)	Total cost (Million VND)
1	Injured workers, (A_2)_person	529	8,00	4,232,00
2	Dead workers (A_3)_person	10	100,00	1,000,00
3	Loss of workday (A_4)_day	232,540	0,08	18,603,20
	Total (A_2, A_3, A_4)	233,079	27,02	23,835,20
Cost A (million VND)				29,413,30

Note:

* Excludes illegal mining. Illegal mining estimated production is 700,000 tonnes of coal per year

* The data on the number of occupational disease-affected persons was obtained from the records of hospitals in mining areas

Appendix 2. Pollution Treatment Cost (B): Pollution Treatment Cost in Areas Inside Mine (B_1)

Calculating bm_1 (Production Scenario 1)

(i)	Description	Year					$Bm_1(i)/\text{year}$
		1997	1998	1999	2000	2001-2005	
1	HaTu	3,200,000	1,113,607	3,450,000	3,250,000	4,250,000	3,052,721,429
2	NaDuong	1,190,000	1,113,607	340,000	340,000	340,000	664,721,429
3	Coc Sau	1,032,000	1,113,607	7,162,700	5,227,800	1,687,274	3,244,676,229
	Total $Bm_{1i}tb$ (1) (1,000 VND)	Average environment treatment cost/year at 3 mines					6,962,119,086
	Annual gross coal production of mines (i) (1,000 tonnes)	3,600	1,500	1,500	1,300	5,230	1,458,889
	Assumed annual gross coal production of the coal industry according to the comprehensive development plant (1,000 tonnes)	9,388	9,260	9,538	9,418	46,657	9,362,333
	bm_1 (Production Scenario 1) (1,000 VND/year)						44,678,988,293

Calculating bm_1 (Production Scenario 2)

(i)	Description	Year					$Bm_1(i)/\text{year}$
		1997	1998(*)	1999	2000	2001-2005	
	Total $bm_{1i}tb$ (2) (VND)	Average environment treatment cost/ year at 3 mines					6,962,119,086
	Annual gross coal production of mines (i) (1,000 tonnes)	1,900	1,800	1,800	1,700	7,300	1,611,111
	Assumed annual gross coal production of the coal industry according to the comprehensive development plan (1,000 tonnes)	9,953	10,460	10,873	11,158	57,743	11,131,944
	bm_1 (Production Scenario 2) (VND/year)						48,104,641,786

Appendix 2. Continued...

Calculating bm_1 (Production Scenario 3)

(i)	Description	Year					$B_1(i)/\text{year}$
		1997	1998	1999	2000	2001-2005	
	Total $bm_{1i}tb$ (Scenario 3)	Average environment treatment cost/year at 3 mines					6,962,119,085.71
	Gross annual coal production of mines (i) (1000tonnes)	640	630	630	1,700	7,300	1,211,111
	Assumed annual coal production of the coal industry according to the comprehensive development plan (tonnes)	10,208	10,725	11,508	11,743	66,136	12,257,778
	bm_1 (Production Scenario 3) (VND/year)						70,464,309,866
	Therefore, bm_1 = the average of 3 scenarios	54,415,979,981	VND/ year = 4,984.36 VND/tonne				
	Pollution treatment cost in coal processing plant (bp_1)	10,411,615,566	VND/ year = 1,025.94 VND/tonne				
	B_1	64,827,595,548	VND/ year = 6,010.30 VND/tonne				

Note: Underlined numbers are the actual investments in the environment made by the mines

(*) The data for 1998 is the average assumed investment value for environmental treatment by the mining units

Scenarios 1, 2, 3 are coal mining development plans of VINACOAL based on 3 levels of technologies

Detailed calculation of pollution treatment cost (bp_1) in coal processing plant

Description	Unit	1997	1998
Revenue per year	1,000 VND	96,000,000	102,000,000
Total production by coal processing plant	1,000 tonnes	1,000	1,060
Total pollution treatment cost in the plant per year	1,000 VND	1,000,000	1,115,000
$bp_1(i)$	VND/tonne	1,000	1,052
Bp_1 (average)/year	VND/tonne	1,026	

Note: $bp_1(i)$ is calculated by dividing total pollution treatment cost in plant by total coal production of the coal processing plant

Appendix 3. Cost of Treating Domestic Water Sources in Areas Outside the Mines (B₂)

<i>i</i>	<i>Region</i>	<i>S_i (m³)/the amount of domestic water shortage due to mining pollution</i>	<i>(P_i) The price of 1m³ l of domestic water before pollution sets in (VND)</i>	<i>(Q_i) The price of 1 m³ of domestic water workers and residents must pay after pollution (VND)</i>	<i>b₂ = S_i × (Q_i - P_i) × 365 (VND)</i>
1	Halong City	4,000	800	1,330	773,800,000
2	Dien Vong River	1,000	800	1,300	182,500,000
	b _{2i} _Average (VND)				478,150,000
	b ₂ _(VND)				8,606,700,000

There are 18 regions where domestic water supply was polluted

$$B_2 = 478,150,000 \times 18 = 8,606,700,000$$

Appendix 4. Loss of the Tourism and Recreation Benefits (C)

Calculating C₁_ loss of tourism benefits

<i>(i)</i>	<i>Year</i>	<i>No. of Tourists (in plan) (persons/year)</i>	<i>No. of Tourists (actual) (persons/year)</i>	<i>Revenue (Million VND)</i>	<i>Rate of Net Return/ Revenue</i>	<i>Total of Net Return (million VND)</i>
1	1992	90,000	96,510	15,002.0	7.20%	1,080.1
2	1993	300,000	268,670	26,849.0	7.20%	1,933.1
3	1994	490,000	367,800	40,400.0	7.20%	2,908.8
4	1995	1,080,000	386,000	88,000.0	7.20%	6,336.0
5	1996	1,330,000	476,000	114,736.0	7.20%	8,261.0
6	1997	1,550,000	375,000	102,000.0	7.20%	7,344.0
7	1998	1,700,000	384,000	150,000.0	7.20%	10,800.0

Appendix 4. Continued...

Loss of international tourism benefits C1 (i)

(i)	Year	No. of Tourists (in plan) (persons/year)	Total of Revenue (in plan) (Million VND)	No. of Tourists (actual) (persons/year)	Total of Revenue (actual) (million VND)	Average net return/tourist (USD/person)	Increase in Number of Tourists /year	Economic loss (million VND) C1(i)
1	1992	55,000		48,500	6,000.0	178.1	6,500	1,562.8
2	1993	72,600		66,453	11,185.0	178.1	6,147	1,478.0
3	1994	90,000	15,000.0	88,760	13,400.0		1,240	1,600.0
4	1995	190,000	50,121.6	194,235	88,767.2		-4,235	-38,645.6
5	1996	319,200		324,765	81,519.8	178.1	-5,565	-1,338.0
6	1997	536,256		150,564	119,606.9	178.1	385,692	92,733.9
7	1998	900,910		155,320	(30,967.8)	178.1	745,590	179,265.9
(USD 1 = 11,350 VND exchange rate in 1995) (USD 1 = 13,500 VND exchange rate in 1998)							C ₁ (I) =	39,520.1

Source: "Tourist Development Assessment Project in Halong City" of Hanoi National University, 1997)

Loss of domestic tourism benefits C₁ (N)

(i)	Year	No. of Tourists (in plan) (person/year)	No. of Tourists (actual) (person/year)	Total of Revenue (actual) (million VND)	Rate of Net Return/Total Revenue	Average net return/tourist (Million/person)	Increase in Number of Tourists /year	Economic loss (million VND) C ₁ (N)
1	1992	35,000	67,500	9,002.0	7.40%	0.009869	-32,500	-320.7
2	1993	227,400	202,217	15,664.0	6.70%	0.005190	25,183	130.7
3	1994	400,000	279,040	27,000.0	6.80%	0.006580	120,960	795.9
4	1995	890,000	191,765	25,968.8	7.00%	0.009479	698,235	6,618.8
5	1996	1,010,800	151,235	20,480.2	6.70%	0.009073	859,565	7,798.9
6	1997	1,013,744	224,436	30,393.1	7.20%	0.009750	789,308	7,695.9
7	1998	799,090	228,680	30,967.8	7.20%	0.009750	570,410	5,561.6
							C ₁ (N) =	4,086.0

kc % = 30% C₁ (Million VND) = 13,081.82

Appendix 4. Continued...

Calculating C₂: Loss of recreation benefits

TT	Recreation Activity	HH Engaged in Recreation					Loss Economic Value (P) (million VND)	
		No/HH	Average time spent (hrs/day)	Total of HH near seaside	% HH (95)	% HH (97)	Total of loss in time spent (hrs/year)	
1	Swimming	3	6	2,784	86.00%	79.60%	55,743.6	429.23
2	Fishing	3	4	2,784	0.03%	0.34%	-1,800.1	-13.86
3	Strolling	4	6	2,784	56.00%	52.00%	34,839.8	268.27
4	Boating	2	1	2,784	0.30%	1.63%	-1,930.7	-14.87
Value of recreation time/Wage rate adjusted for unemployment						20%		
Value of average employment hour						0.038500		
						C ₂ =	668.77	

C/year (Million VND) = C₁ + C₂ = 13,750.59

Appendix 5. Damage to Forest Resources (D_1)

Accounting for forest land opportunity cost (D_1')

No	Parameters	Unit	Volume
1	Total forest land used for mining	Hectare	17,220.00
2	Annualized net benefits (discount rate 10%)	Million VND	0.27
3	D_1'	Million VND	4,563.30

Calculating D_1'' : The loss of firewood resources

(i)	Parameters	Unit	Number
1	Forest area affected by mining activities <u>but not used for mining</u> (Small and premature trees can be used as firewood to be cut down annually by coal mining activities).	Hectare	17,220.00
2	Average wood weight Rate/1 hectare of forest land (10%)	m ³	0.70
3	Firewood price in the year 1997: 250,000/m ³ (Approximately 0.02 million VND/m ³)	Million VND/m ³	0.02
	Loss in firewood income (D'')	Million VND	265.19
	Total D_1	Million VND	4,828.49

Appendix 6. NPV Calculation for Reforestation Projects – 10 years

unit (1,000 VND)

Projects	8%	10%	12%
Keo tree project	2,546.3	2,393.9	1,637.40
Pine tree project	3,639.3	2,649.5	1,831.70
Bachdan tree project	3,466.8	2,578.5	1,844.70

Appendix 7. Loss to the Fisheries Sector (D₂)

<i>Components</i>	<i>Statistic data (1997)</i>
Average sea product price (thousand/kg)	18,000.00
Average price (thousand VND/kg)	14,000.00
Estimated percent of impact caused by mining activities K= 20%	20%

<i>(i)</i>	<i>Year</i>	<i>Gross production (tonnes)</i>	<i>Percent of fishing activity far from shore</i>	<i>Fishing activity far from shore</i>		<i>Fishing activity near to shore</i>		<i>P(i) Average loss/year due to fishing activity far from shore (thousand VND)</i>	<i>Q(i) loss in fishing opportunity near to shore due to water pollution-induced loss in fisheries resources (thousand VND)</i>
				<i>Production (H_{bi}) tonnes/year</i>	<i>Production cost (thousand VND/kg)</i>	<i>Production (H_{ai}) (tonnes)/year</i>	<i>Production cost (Thousand VND/kg)</i>		
1	1994	15,000.00	0.50	7,500.00	15,000.00	7,500.00	10,000.00	37,500,000.00	
2	1995	14,239.00	0.70	9,967.30	15,500.00	4,271.70	10,500.00	49,836,500.00	2,135,850.00
3	1996	16,000.00	0.80	12,800.00	16,000.00	3,200.00	12,000.00	51,200,000.00	6,400,000.00
4	1997	14,200.00	0.80	11,360.00	16,000.00	2,840.00	12,000.00	45,440,000.00	5,680,000.00
								45,994,125.00	4,738,616.67

Note: The sea was considered not yet polluted before 1994

Data from the Halong fishing board (supported by Quangninh Department of Mining Science and Technology)

Appendix 8. Loss in Agriculture – Year 1998 (D₃)

<i>Description</i>	<i>Unit</i>	<i>No.</i>	<i>Decrease in productivity (Million VND/ha)</i>	<i>Notes</i>
Paddy price in the year 1998	Million VND/tonne	0.20		
Average paddy production/harvest at an undisturbed area by mining activities	Quintal/hectare	40.00		
Average paddy production/harvest at a disturbed area	Quintal/hectare	16.00	4.80	(1 crop)
Average sugar-cane or other fruit production of normal fertile and unpolluted heavy soil	Million VND/hectare	2.60		
Average sugar-cane or other fruit production/year on the normal fertile and polluted heavy soil or decreased production soil	Million VND/hectare	1.40	1.20	
Average harvest production/year in the unpolluted fruit-growing areas	Million VND/hectare	2.25		
Average harvest production/year in fruit-growing areas having decreased productivity nearby mine sites	Million VND/hectare	1.15	1.10	

Appendix 8. *Continued...*

<i>Description</i>	<i>Unit</i>	<i>S(i)</i>	<i>D₃'(i)</i> <i>Agriculture land</i> <i>opportunity cost</i> <i>Million VND/year</i>	<i>D₃''(i)</i> <i>Loss due to</i> <i>decreased plant</i> <i>productivity</i>
* Agriculture land (3.4%)	ha	585.48		
- Paddy 2 harvest planting area	ha	126.80	2,028.80	
- Paddy 1 harvest planting area	ha	112.35	898.80	
- Fruit-planting area	ha	123.43	277.72	
- Other crop-planting area (maize, potato and various types of vegetable)	ha	24.23	63.00	
- Abandoned land area and water field area	ha	198.67	0.00	
<i>D₃' =</i>			4,229.58	

Mining affected agriculture land at Khanh Hoa coal mine	ha	18.00		
In which:	ha			
- Abandoned land area	ha	4.21		0.00
- Paddy 2 harvest planting area	ha	5.32		51.07
- Paddy 1 harvest planting area	ha	1.23		5.90
- Fruit planting area (jackfruit, tropical fruit)	ha	5.78		6.36
- Crop planting area (potato, sugar cane, various types of vegetable)	ha	1.46		1.75
D ₃ "		(Million VND) =		1,431.89
D ₃ = (D ₃ '+D ₃ ") x Rate of influence				5,661.48
Total loss in agriculture, silviculture and fishing D (million VND) =				20,636.51

Source: According to the statistic data already described in the Appendixes and additional documents from the Department of Science, Technology and Environment in Quangninh Province – August, 1998

Directly surveyed in Halong and Campha areas in 1998

Appendix 9. Loss in Infrastructure (E)

No.	Repair Items	Pi Average repair cost/year 1996 (Million VND)	Note
I)	<i>Loss in transportation</i>		
1	Repairing highway 18	24.54	
2	Dredging drainage system along haul roads	36.70	
3	Repairing mine drainage and bridge system, and coal and overburden transport roads near residential areas	69.56	
4	Contribution to repair Cuaong coal export harbour	80.00	
5	Upgrading mine transportation system	15.00	
6	Upgrading local hospitals	17.00	Charged to the capital construction cost
	<i>Total</i>	<i>242.80</i>	
II)	<i>Repairing communication systems</i>		
1	Upgrading the office communication system	137.65	Charge to the equipment capital cost
2	Repairing broken electrical wire network	46.88	
3	Installing electrical wire network to the new workers' buildings area	150.00	Charged to the capital construction cost
	<i>Total</i>	<i>334.53</i>	
III)	<i>Loss in buildings including reimbursement of cracked buildings or houses by blasting and mining activities</i>		
1	The family of Mr. Nguyen Dinh Chien (group 3, group 1, HaTu).	12.67	
2	Mr. Nguyen Van Tinh, group 32, HaTu	4.86	
	<i>Total</i>	<i>17.53</i>	
	<i>Total of Pi</i>	<i>290.21</i>	
	E (million VND)	4,135.49	

Typical example of loss in the infrastructure caused by coal mining activities - Cam Pha mine data.

According to the document on current status of mine of the project "Coc Sau coal mine feasible mining study in 1997, 1998" from the Institute of Mining Science and Technology.