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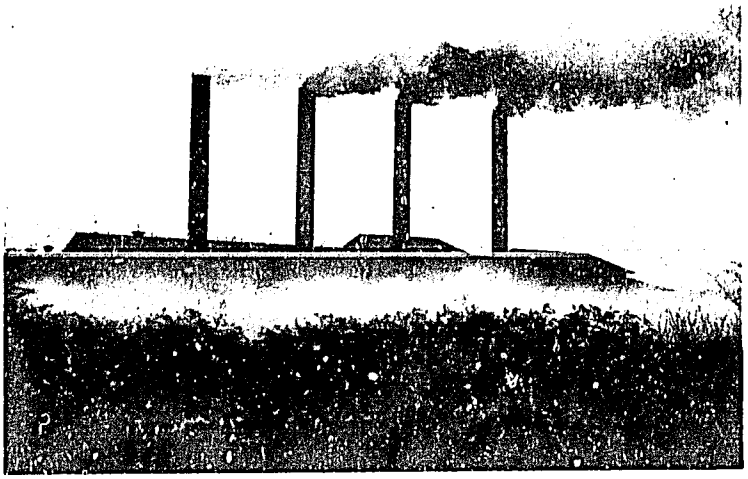
The 1990 TDRI Year-End Conference

INDUSTRIALIZING THAILAND AND ITS IMPACT ON THE ENVIRONMENT



Session: Mineral Resources Development and Its Environmental Implications

Research Report No. 4

Mineral Resource Development: Making the Best of a Limited Resource

Duangjai Intarapravich
Quanchai Leepowpanth
Theodore Panayotou
Sunt Rachadawong

December 8-9, 1990
Ambassador City Jomtien, Chon Buri

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Industrializing Thailand and Its Impact on the Environment

Policy research is a team effort. The names of researchers mobilized to undertake the various studies in preparation for the 1990 TDRI Year-End Conference and their respective topics of responsibility are listed below:

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Theme: Natural Resources for the Future

Synthesis Paper #1: Natural Resources for a Sustainable Future: Spreading the Benefits

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Synthesis Paper #3: Industrialization and Environmental Quality: Paying the Price

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Chapter 1

Introduction

BACKGROUND

Thailand's mineral industry is small sector compared to other economic sectors such as agriculture, trade, and services. The mineral industry has made substantial contributions to the Thai economy over the past several decades, but its relative importance to the economy has gradually declined as a result of Thailand's industrialization. At the same time the decline in the prices of most minerals in the world market has impeded the industry's development.

Since 1970 a maximum of 4 percent of the total GDP has been generated by the mining and quarrying sector, and approximately 5 percent to 8 percent of the total GDP has originated in the mineral-based manufacturing sector. The export of minerals and primary metals, excluding petroleum, accounts for only a small portion of the country's total exports and has been declining over time. The value of mineral exports has never exceeded 15 percent of total export value, even during periods of soaring mineral prices and extensive mineral export. Since 1986 the proportion of mineral exports to the total export of Thailand has declined to less than 2 percent. Because the mineral sector is capital-intensive and requires only a small number of workers, it does not generate employment—only 33,364 workers were employed in the mining sector in 1988, or approximately 0.12 percent of total domestic employment. The royalty payment earned from the mining sector was approximately 1,257.7 million baht in 1984, 437 million baht in 1988, and 627.2 million baht in 1989 (estimated at a 1984 constant price). The royalty payment in 1989 was only 0.04 percent of the total GDP.

However, minerals serve as the raw materials for a variety of manufacturing industries. Mining is the primary activity that can stimulate the development of other related industries including not only the mineral-based manufacturing industries, but also

related tertiary activities such as services, wholesale trade, finance, and transportation. Mineral resource activities incorporate a system of several processes; the whole range of these activities is part of mineral resources development that contributes to the Thai economy.

The contribution of the mineral-based manufacturing industries to Thailand's economy will depend on the country's ability to mobilize raw materials, open up new areas for replenishment of reserves, establish transportation facilities and services, and expand domestic and export markets. In addition to sufficient, and efficient, man power and low-cost energy and other raw materials, government participation in the management of mineral resources and related infrastructure is essential.

More than 40 minerals are produced in Thailand; however, only 21 minerals are considered economically significant. Among these minerals, some are only moderately consumed in the country (such as lead, barite, fluorite, quartz, feldspar, tin, and antimony), and the output depends mainly on the world market. Other minerals (such as anthracite, shale, glass sand, lignite, kaolin, ball clay, phosphate, rock salt, and zinc) are mostly, or totally, consumed in the country. Thailand also imports several kinds of minerals, primary metals, and intermediate mineral products—such as chemical compounds, slag, pigments, alloys, and additives—for use as raw materials in domestic downstream industries. These imported minerals (for example, asbestos, surphur, coal, iron, steel, aluminium, and copper) either have an insufficient domestic supply, cannot be produced domestically, or can be produced, but have unsatisfactory ore quality for special end uses, or excessive production costs.

The production, consumption, and export of minerals have increased over time. However, the ratio of consumption to production is increasing, whereas the ratio of export to production is declining, implying a change toward the use of more indigenous raw materials for the domestic downstream industries. The extensive expansion of the manufacturing sector has also resulted in an increase in the import demand for minerals and mineral products.

Thailand is endowed with several mineral deposits. Most of these deposits are nonmetallic minerals such as rock salt, potash, limestone, coal, diatomite, dolomite, kaolin, gypsum, and glass sand. A few metallic minerals are found in Thailand including copper, iron, zinc, lead, tin, and tungsten, and these deposits are relatively small.

STATEMENT OF PROBLEM

Local Utilization vs. Export

During the early stages of the mineral industry's development, a mineral resource was regarded as an export-earning commodity. Since the early 1970s there has been a growing awareness in Thailand of the importance of using indigenous minerals as raw materials in domestic mineral-based manufacturing. Until recently almost all of Thailand's mineral exports were raw, crude ores and concentrates which provided a small degree of value added. As a result of the high growth of the domestic downstream industries, the development of mineral resources has been directed toward more internal consumption with a smaller surplus left for export. The growth of mineral exports has thus declined, and the growth of export manufactured products and processed minerals has increased. The issue at hand is whether to support calls for an export restriction policy on domestic minerals in order to prolong the domestic reserves and to avoid the need to import minerals. It is argued that without controls for mineral exports, the existing mineral reserves might be quickly exhausted, and that because maintaining the domestic supply of minerals will guarantee a supply of mineral raw materials for domestic downstream industries, the government should restrict mineral exports to prolong domestic reserves. Moreover, it is argued, Thailand can increase the value added by exporting processed minerals rather than raw materials. But will this policy really benefit Thailand: a country that is currently a marginal mineral producer in the world market?

Environmental Factors and Land-Use Conflicts

Mining operations inevitably cause varying degrees of environmental impact, extend to tangential areas that are several times larger than the mineral deposit areas, and result in land damage and degradation as well as air and water pollution. In Thailand post-mining environmental rehabilitation and reforestation are always ignored due to the lack of environmental law enforcement. The result is the overexploitation of mineral resources and the inappropriate rehabilitation of mined-out areas for other uses, which is unacceptable for society.

The land-use conflicts between mineral resource users and other sectors have become a major source of difficulty for the mining industry. Because environmental rehabilitation and reforestation have not been effectively used, and the public is increasingly aware of the magnitude of deforestation, forest concession were revoked countrywide in 1989, and the country's forests have been reclassified to conserve more

land. It is likely that more area will be reserved as conservation forests where all development activities, including mining, are prohibited.

The government, under pressure from strong environmental advocates, the media, and the general public, has resisted repeated requests from the mining industry to allow mining at least in the economic forests and unclassified forest reserves. The mining industry has argued that minerals occur only in specific geological settings: the sites for mineral extraction cannot be freely chosen. Ninety-eight percent of the pending mining applications are in national forest reserves, and the pending area of mining concession, while large for the industry, is less than 1 percent of these national reserves and is negligibly small for the country. Environmental advocates argue, however, that while the area actually mined is small, the environmental impacts extend to areas that are several times larger. Unless the industry takes some initiative to deal with environmental impacts and land-use conflicts, its long-term future is uncertain.

Concession Rights

Another problem facing the mineral industry is concession rights. The existing Thai practice of granting mining rights has been oriented to small- to medium-scale alluvial mining operations that (1) have less capital intensive and exploration risk and (2) require lower levels of technology and expertise. This is because the current Minerals Act was drafted when tin mining dominated the industry. The development of mineral resources is sensitive to government policy, and one of the important guarantees for a flourishing mineral industry is the right to develop mineral discoveries. There are two main parties involved in the business of mineral resources development: the government and the investor. The government may wish to encourage the development of its resources for the benefit of the country, and investors have a keen interest in exploration and exploitation for maximum profit. The private investor is likely to need the security of a right to develop a mine if a commercial discovery is made, while the government may wish to maintain full control at all times by imposing various requirements at every stage from exploration to extraction and use. The mineral industry is a high-risk business combining high exploration costs with a low probability of successful commercial discoveries. In reality, exploration and mining, the upstream components of the overall mineral development system, are mutually interdependent and inseparable from the point of view of investment. Lack of security of tenure over mineral rights could discourage mineral exploration and industry diversification.

SCOPE OF THE STUDY

This report, part of an ongoing research undertaking, will be limited to three main focus areas as follows:

1. A broad picture of the mineral industry will provide an industry background.
2. A forecast for the consumption of some selected, critical minerals will provide a rough idea of Thailand's future mineral consumption trends and will facilitate the effective management of the domestic mineral supply.
3. A detailed analysis of and policy recommendations for three major issues including: (1) optimum resource extraction, competition, and trade policy; (2) environmental impacts and land-use conflicts; and (3) mineral rights and concession policy.

ORGANIZATION OF THE STUDY

The study is divided into eight chapters. **Chapter 2** reviews the national development plans to provide a historical perspective on the mining industry's development. Mining rights and concession licenses are also examined to identify how existing mining laws and regulations might be constraining the industry's development. **Chapter 3** reviews the current state of the mineral industry including mineral output, consumption, exports, imports, and reserves. **Chapter 4** presents information on current production technology and examines the feasibility of substitution for mineral raw materials as well as for metals. **Chapter 5** discusses environmental considerations and issues of land use. **Chapter 6** forecasts the consumption of 11 minerals that are classified into four groups: (1) cement raw materials (gypsum, iron ore, limestone, and shale); (2) glass and ceramic raw materials (ball clay, feldspar, glass sand, and kaolin); (3) metallic minerals (zinc and tin); and (4) energy minerals (lignite). **Chapter 7** examines the possibility of mineral shortages both locally and worldwide. It also discusses the optimal rate of domestic mineral resource extraction. Conclusions and recommendations are presented in **Chapter 8**.

Chapter 2

Historical Perspective and Legal Framework

Thailand's mineral industry has a fairly long history. Policy guidelines have been formulated to facilitate the development of mineral resources since the early 1960's under the First National Economic and Social Development Plan (1962-1966). Gradual changes in the direction of mineral resource development have been observed over time which indicate the adjustment of the government's attitude toward the exploitation of domestic mineral resources. In order to chart a proper course for mining activities, the government organizes mining legislation which governs the issuance, administration, and cancellation of mining rights. The legislation also organizes government agencies and their supervisory powers and settles disputes between competing claims. Mining legislation sometimes complicates development activities so that legislative updating is required to suit the economic and social conditions of a particular period of time. Chapter 2 analyzes the history of mineral resource development and the current mining licensing system to determine their appropriateness for the current situation.

MINERAL RESOURCES AND THE NATIONAL DEVELOPMENT PLANS

The National Economic and Social Development Board (NESDB) is the government organization responsible for the planning and implementation of policies for the economic and social development of Thailand. The mineral resource development plan is one component of the national development plan.

During the above-mentioned First Plan mineral production was aimed for export and targeted minerals included tin, lignite, gypsum, iron, lead, and tungsten (wolfram), while lignite and gypsum were locally consumed.

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The government also initiated mineral exploration and development campaigns for rock salt and iron ore, conducted mineral exploration in cooperation with the special fund of United Nations, and planned to establish a mining technical school to produce skilled technicians for mineral operations.

Most of the mineral exploration results were tentative in nature and subjective in substantive elements that required further confirmation. The idea of setting up a mining technology school did not materialize until much later than planned, and then it was through the efforts of other agencies. The private sector contributed towards mineral development and production during this period, while the government controlled and supervised the conduct of the private sector according to the provisions of the law.

Under the Second Plan (1967-1971), 22 newly discovered minerals were initially targeted for export including byproducts of tin such as tantalite, zircon, monazite, and xenotime. Industrial minerals were tried as raw materials for local use which marked the beginning of a growing interest in indigenous minerals for domestic industrial use. During this period, the mineral output accounted for 2 percent of the country's GDP, and the growth rate for the mineral industry increased by 6 percent annually.

Under the Second Plan, provisions were made for a comprehensive geological survey beginning in the North. In addition, special surveys were to be conducted for tin and iron ore in the East and Northeast; for natural fuel, base metals, and ceramic minerals in the North; and for manganese in the North and South. Physiological surveys by air were also conducted throughout the country, including the Gulf of Thailand. The plan also anticipated the establishment of mineral resources centers in the North, the South, and the Northeast to provide technical assistance to private mine operators. However, due to the lack of a follow-up assessment, the project's progress was unclear. However, mineral development was advanced by the private sector, the production of various minerals was increased, and benefits such as royalties, foreign exchange earnings, and local employment were realized.

By the end of the Second Plan, the use of some indigenous minerals, especially industrial minerals, had gained a solid base in Thailand. Limestone, gypsum, manganese, and lignite were used in the cement and gypsum board, dry cell battery, and power generation industries. Significant progress was made along these lines during the Third Plan (1972-1976) which emphasized optimum utilization of domestic minerals.

Also, a new discovery of sizable wolfram, antimony, and barite deposits resulted in higher production than the targeted figures, but depletion of higher-grade reserves and relatively low prices caused lower-than-estimated outputs of fluorite and manganese.

During the Fourth Plan (1977-1981), the worldwide commodity price boom influenced Thailand's mineral prices, which subsequently reached the highest levels of export ever recorded and spurred the production of export-oriented minerals. The local consumption-oriented-mineral industry, although viable, was overshadowed by comparison.

In order to increase mineral production to a level that would supply a stronger export demand and increase local consumption, the government urged Thai nationals to undertake small- and medium-scale mining operations that did not require sophisticated and complex technology. The discovery of large, rich deposits of tin ore off the Phang-nga coast; tungsten ores in Nakorn Si Thammarat, Chiangrai, and Prae provinces; and antimony ore in Chanburi Province stimulated a substantial increase in mineral production, and the mining sector's average growth rate reached 10.1 percent per annum.

However, the industry was hampered by illegal mining activities and encroachment on legitimate mining land in offshore tin areas in Phang-nga Province, in wolfram areas in Khao Soon, and in other rich mineral areas resulting in lost government revenue, destruction of resources, and low economic returns. Conflicts of interest among agricultural, environmental, and mining groups emerged as a significant factor affecting the progress of the mining industry and were compounded by lack of financial assistance, technical and marketing intelligence services, and basic infrastructure.

The government responded by formulating a land-use plan for the mining industry and proposing the establishment of a financial institution to develop mineral resources. At the close of the Fourth Plan, these two measures had not materialized.

The period of the Fifth Plan (1982-1986) was upset by declining and depressed prices for export minerals— especially tin. Due to a downturn in the demand and price, the production of tin, tungsten, and barite fell short of targeted production. Only lead ore made a significant gain due to sustained world demand and a firm price. Locally used minerals fared better as the prices kept steadily rising. Both the volumes and the values of domestically consumed indigenous minerals rose due to customer satisfaction with the qualities of local minerals.

The problems encountered in the Fourth Plan were more serious and included a lack of coordination among government agencies to maximize the use of natural resources. Also, a lack of basic infrastructure such as access roads and electricity forced mine operators to provide such infrastructure themselves which, in turn, increased operational costs. Industry problems included a lack of technical services and relevant data to improve production efficiency and a lack of marketing intelligence, which resulted in overproduction of minerals and price levels below production costs.

In order to attain an annual anticipated growth rate of 13.1 percent, the Fifth Plan set out several measures of concern to the mineral industry as follows:.

Mineral Resources Administration: These measures outlined plans for mineral exploration and for demarcating potential mineral areas. The economic value of minerals was compared to other land-use purposes such as forestry, water, fisheries, and tourism. Coordination among government agencies concerning the use of land for mining, control of illegal and inadequate mining activities, promotion of efficient mining methods, and protection of the environment were also included in the administration measures.

Improving Government Services: These measures included improving and expanding the basic infrastructure in cooperation with the involved agencies in the areas of high mineral potential. The Department of Mineral Resource (DMR) accelerated the compilation of geological information and mining processing techniques for miners' education.

Government Promotion of Investment: These measures sought to attract mineral investment through government promotion as stipulated in the Industrial Promotion Act. Periodic, appropriate revisions of the act were made and promotional privileges were offered to the mining firms for exploration, extraction, processing, and metallurgical projects. The government also encouraged state enterprises to carry out mineral exploration and development activities.

Marketing and Promotion of Utilization: The Ministry of Commerce, the Ministry of Industry (MOI), and the concerned private institutions set up an ad hoc committee to study and follow market trends for individual minerals, especially fluorite and barite, for the purpose of planning production targets.

Due to the depression of the worldwide market, the actual growth rate was 6.1 percent per annum rather than the projected growth of 13.1 percent.

Mineral Resources in the Current National Development Plan

During the implementation of the Sixth Plan (1987-1991), the general situation of the mineral industry has improved. The prices of the main export minerals have remained steady and relatively low. Tantalum experienced depressed prices, possibly caused by the sale of Thailand Smelting & Refining Company (THAI SARCO) slags and competiting supplies from Australia, Brazil, and China. Mineral substitution has also eroded market shares of tantalum for capacitor and carbide manufacturing. Only zinc has shown a significant price increase. Export values have fallen noticeably as the production and export of high-price minerals (such as tin, tungsten, and tantalum) have decreased, while the export of low-price commodities, like gypsum and feldspar, has increased. Minerals consumed by local industries, such as cement, glass, and ceramic raw materials, have enjoyed a steady local market with little or no risk of the price fluctuations experienced by mineral exports. Overall, the total value of local mineral consumption has been rising satisfactorily.

Thailand's government and its mineral industry analysts are well aware that rich mineral deposits are largely exhausted. New geographic areas need to be explored and developed so that mineral production can continue. Because the utilization of land for mineral extraction involves other government agencies that control the mineral-bearing land surface, conflicts among related agencies have escalated into a larger problem. Thailand's mineral exports are affected by fluctuating demand and prices in world markets. Diversification of the mining industry would help reduce this variability but only to some extent because the prices for most minerals tend to move in the same direction.

MINING RIGHTS AND CONCESSION LICENSE

The government's goal is to promote and expand the development of mineral resources to the fullest extent possible and for the country's economic well-being. Thus, mining legislation is the prime instrument for regulating the mineral industry, and it is administered by the DMR which is a department within the MOI. The DMR is empowered to enforce all the provisions of the mining laws and to issue and implement relevant ministerial regulations and rules. The DMR has two basic functions: enforcing

laws and providing technical assistance. It has the power to enforce the provision of the laws with regard to relevant legal aspects and regulatory matters and to provide guidelines of practice so that the industry can yield various benefits to the country. The DMR also gives technical assistance in exploration, mining, mineral processing, and metallurgical activities.

The major licenses involving the mining industry are: (1) the Exclusive Prospecting License (EPL) and the Special Prospecting License (SPL) (both are exploration license) and (2) the Mining Concession or Lease (the mining license).

Exclusive Prospecting License (EPL)

Before 1989 one EPL covered a maximum area of 2,500 rai and an entity was entitled to apply for EPLs covering a maximum of 5,000 rai in one province. Unless accompanied by a work plan and an expenditure statement, an entity could not apply for more than a maximum of two areas in the same province for the purpose of exploration. The holder of an EPL had to commence exploration activity within 60 days of receipt of the EPL. The first progress report had to be submitted to the DMR within 180 days from the receiving date, and the final exploration report had to be submitted within 30 days before the expiration date of the EPL could be applied and granted.

However, the MOI announced in 1989 that, from that point on, only one exploration area, or a maximum of 1,250 rai, will be issued to one entity in one province. Now, the person or firm must also submit a work plan and a description of the exploration methods as required by a ministerial regulation and these must be endorsed by a qualified geologist or mining engineer recognized by the director general of the DMR. Other areas may be granted to an applicant who is qualified under the following criteria:

1. The applicant has obtained promotional privileges for the mineral to be explored.
2. The applicant intends to use the mineral in his own metallurgical activity.
3. The applicant holds an industrial works license and intends to use the mineral in the process.

The entire process, from the application to the issuance of a license, can be time-consuming. At least 147 working days are required to complete the process, barring any obstacles encountered along the way. The time limitation was announced through a ministerial order for public services on mineral activities.

Although a provision of the law permits exploration applications for a maximum of 500,000 rai for offshore areas, the MOI's new policy states that an EPL in the offshore area can cover a maximum area of only 20,000 rai. An area larger than 20,000 rai can be applied for under the SPL category which requires that an applicant offer special benefits (such as profit sharing) to the government.

Special Prospecting License (SPL)

The SPL emphasizes binding commitments for exploration which should, by definition, not cover more than 10,000 rai. An applicant must specify an annual work plan together with expenses for each year throughout the life of the project and must also offer special benefits to the government.

The SPL has a life span of three years and can be extended for another two years. The holder of a SPL must commence exploration activities within 90 days of the receiving date of the license and submit a progress report to the DMR within 120 days from the date of receiving of the license. The processing of all documents from the application (bidding) to the granting of a SPL is also time consuming. A total of 157 working days are required according to the ministerial order issued on August 10, 1989.

A SPL is different from an EPL in three aspects: (1) the applicant for a SPL must offer the government special benefits; (2) the area licensed in the SPL has a 3-year renewal period instead of the 2-year, nonextendable period for an EPL, and (3) in applying for the renewal of a SPL, the holder may relinquish a certain part of unwanted area. Apart from these conditions, a SPL does not offer any further advantages over an EPL. The majority of applications are for an EPL. A SPL is suitable for large projects or a high-value mineral and when the applicant requires larger area and more time for exploration.

On occasion the government, through the DMR, can set aside an area of mineral potential as determined by its own tentative survey. It can then tender an invitation to public companies to submit bids for exploring and producing minerals in that area. The bidder who offers both the most sensible technologies and the healthiest benefits, including better terms and conditions, usually wins the project. In this case, exploration rights will be granted by a SPL. The bidding procedure was developed as an ad hoc policy that is used when the government considers it necessary to invite bids for the DMR's designated area to develop the deposits. In February 1987 the MOI announced its first application of this ad hoc policy. A bidding invitation was held for prospective

candidates to apply for the rights to prospect and mine for gold in designated areas. At present, this concession package will issue a SPL to the successful candidate (based both on technical considerations and on the amount of special benefits offered to the government) to explore and conduct a feasibility study. The company is entitled to obtain the right to mine gold over the area after the exploration stage. In addition, in any other areas not defined by the MOI for bidding, the exploration right for gold must only be granted by a SPL.

Mining Concession or Lease (ML)

According to the Mineral Acts of 1967 and 1979, a person cannot mine a mineral unless granted a mining lease (ML), and he can apply for a ML if he is a "qualified" person according to the law. The holder of an EPL or a SPL is assigned the first priority to apply for a ML in the areas covered by his EPL or SPL but he is not assured of obtaining a ML. Apart from dealing with various divisions of the DMR, the application for a ML involves complicated formalities with other organizations such as the Royal Forest Department (RFD), the Land Development Department, and the Office of National Environment Board (ONEB).

Each ML covers an area of not more than 300 rai, and an applicant can apply for more than one ML in an onshore area, whereas a maximum of 50,000 rai can be granted as a ML to each applicant in an offshore area.

The life of a ML can be granted for a maximum of up to 25 years. The actual operating time depends upon the deposit, the mining method, and the equipment to be used, all of which determine the ore extraction rate per annum. It is possible that the life of a mine may be calculated at less than 25 years according to the size of the deposit and other relevant information. Nonetheless, the mine operator must conduct the operation in compliance with the working scheme and the previously submitted plan. The DMR must approve any major change in the working scheme prior to the resumption of mine operation.

An applicant seeking a ML is required to submit an environmental impact assessment (EIA) report along with the working scheme in order to clarify a procedure that will protect and rehabilitate the mining area. The report will be forwarded from the DMR to the ONEB for approval within the mandatory 90 days. If no approval is obtained due to the report's deficiencies, it must be approved within 30 days after the date when the corrected report is submitted for the second time.

The EIA report is part of a prerequisite in the process of granting a ML, and it must be prepared by a competent company which has been previously registered with the ONEB. Upon approval of the report, the ONEB usually establishes a set of working conditions which the mine operator must follow. Normally, the conditions are derived from the information contained in the report. Thus, it is important that the mine operator is aware of and understands the data contained in the report.

Provisions of Interest

Royalty Payment on Minerals: Royalty payment is a matter of concern to mine operators. In Thailand, royalty payment is an ad valorem payment which is paid as a certain percentage of the officially posted prices from the DMR. The royalties for most minerals are paid as a flat rate of posted price; only tin and zinc royalties are charged on a sliding scale (see Appendix D, Table D1).

Formerly, the tin and tungsten royalty was believed to be too high, which encouraged widespread smuggling of these minerals. After the collapse of the tin market in October 1985, the tin royalty was subsequently restructured to a lower, more sensible rate, and later, the royalty rates for tungsten, lead, and zinc were amended. The new structures provide for a lower royalty with ample flexibility.

Based on the idea that the royalty rate for a local mineral should be low to provide an incentive to develop more costly mineral projects, the government set up a subcommittee in April 1990 to review and amend the entire royalty system. The objective was to reduce the rates of all minerals/metals to a low, nominal rate. Under the new system, those mines showing a profit will be subjected to a mining profit tax. However, the rate has not yet been established.

Transportation of a Mineral: The transportation of a mineral is possible only if the mineral royalty is already paid. For most minerals an official transporting license must accompany the transporting vehicle to the destination stated in the license. Some minerals including fluorite, barite, gypsum, marl, coal (lignite), gemstones, dolomite, and sodium feldspar require no transporting license after the royalty is paid.

Purchase and Sale of Minerals: Those entities having a ML for mining operations and holding a mineral-purchasing license can sell the minerals, except in some cases where special permission for the particular sale must be obtained from the director general. Normally, once the royalty is paid, a mineral may be sold by permission of the

Mineral Resources Office of the province. However, for some particular minerals, which are subject to supervision and control of movement, the mine operator must obtain special permission for a particular sale. The kinds and quantities of minerals spelled out in Ministerial Regulation No. 24 are as follows:

1. Tin Ore: quantities more than 50 kilograms
2. Gold Ore: any amount
3. Copper Ore: quantities more than 2 kilograms
4. Zinc Ore: quantities more than 2 kilograms
5. Iron Ore: quantities more than 2 kilograms
6. Ore containing columbium-tantalum, or thorium, and other radioactive materials: any amount

The minister of industry can add more minerals to the above list for control and regulatory purposes if he sees that such action is in the interest of the country.

One factor that has impeded the mining industry's development is the lack of security of tenure over mineral rights. The existing licensing system does not guarantee that the person or mining company that has conducted the exploration will obtain a mining right for the area that he/it has applied for (except for some special projects such as gold development). A mining concession is issued to any applicant, but in the prospected area covered by an EPL or a SPL, the holder is assigned first priority, but the concessions are not necessarily guaranteed by the government. This lack of a mining right guarantee for prospected land and discovered minerals may act as a deterrent to mining ventures since exploration is time consuming and expensive. A reluctance to provide assurance that concession will be granted after exploration is not only discourage investment but also wastes exploration expenditure. The government bureaucracy and the limited scope of mining laws are not the sole causes of the inability to assure a right to mine over prospected land: the conflicts and restrictions from other authorities as well as subsequent land use conflicts complicate the issuing of rights.

Chapter 3

Current State of the Mineral Industry

The mining sector is currently considered a small economic sector and generates a modest level of value added and employment compared to other economic sectors such as agriculture, industry, trade, and service. In 1989 the GDP of the mining and quarrying sectors (at 1984 constant prices) was 54,512 million baht, and that of the mineral-based manufacturing sector was 115,417 million baht. In comparison, the GDP of the agricultural and trade sectors, which was approximately 218,027 million baht and 255,529 million baht, respectively (see Appendix D, Table D2).

Minerals serve as the raw materials for a variety of domestic manufacturing industries which can stimulate the development of other related, mineral-based manufacturing industries and related tertiary activities such as services, wholesale trade, finance, and transportation.

The status of the mineral industry can be analyzed by examining its trends in output, consumption, import, and export. The mineral reserves that are actually discovered and the potential for their discovery are also important factors in determining the country's bargaining position in relation to the raw mineral supply. Chapter 3 examines the current state of the domestic mineral industry emphasizing the above-mentioned aspects that form the rudiments of mineral resources development.

MINERAL CLASSIFICATION

Of the more than 40 minerals that are produced in Thailand, only 21 are considered economically significant, while the rest are either insignificant in terms of production value, or not produced continuously. By comparing the quantities of export and consumption shown in Table 3.1, these minerals can be divided into two groups:

Export-oriented Minerals: These minerals are either consumed in small amounts domestically or are totally exported. Their output depends mainly on the world market.

Consumption-oriented Minerals: These minerals are consumed mostly, or totally, within Thailand. Export represents only a small proportion of their total production and will be made only when a domestic surplus exists.

Table 3.1 Export-to-Production Ratio of Important Minerals, 1985-1989

(%)

Minerals	1985	1986	1987	1988	1989
Export-Oriented Minerals					
Antimony	100.00	100.00	100.00	100.00	43.76
Barite	87.87	47.88	99.19	100.00	96.54
Feldspar	33.37	40.10	50.41	63.13	61.97
Fluorite	51.81	63.52	100.00	100.00	82.46
Gypsum	68.31	74.66	77.69	84.90	79.92
Lead	100.00	100.00	100.00	100.00	100.00
Quartz	91.56	92.44	36.42	85.90	73.41
Tin	75.40	82.39	69.52	70.61	54.82
Tungsten	100.00	100.00	100.00	100.00	100.00
Consumption-Oriented Minerals					
Anthracite	0.00	0.00	0.00	0.00	0.00
Ball clay	9.11	2.32	2.10	2.07	0.87
Glass sand	0.00	0.00	0.00	0.00	0.00
Iron	0.00	0.00	0.00	0.00	0.08
Kaolin	3.78	3.51	4.30	2.60	1.14
Lignite	0.00	0.00	0.00	0.00	0.00
Limestone	0.02	0.04	0.02	0.02	0.01
Manganese	0.00	0.00	0.00	6.29	0.00
Phosphate	0.00	0.00	0.00	0.00	0.00
Rock Salt	0.00	0.00	0.00	0.00	0.00
Shale	0.00	0.00	0.00	0.00	0.00
Zinc	7.73	7.39	5.61	3.00	2.97

Source: Mineral Statistics, Department of Mineral Resources

Importation is required for minerals with an insufficient domestic supply and for minerals that either cannot be produced domestically, or can be produced but whose ore quality is not satisfactory for special end uses.

The flow of minerals produced and used in Thailand is presented in Figure 3.1.

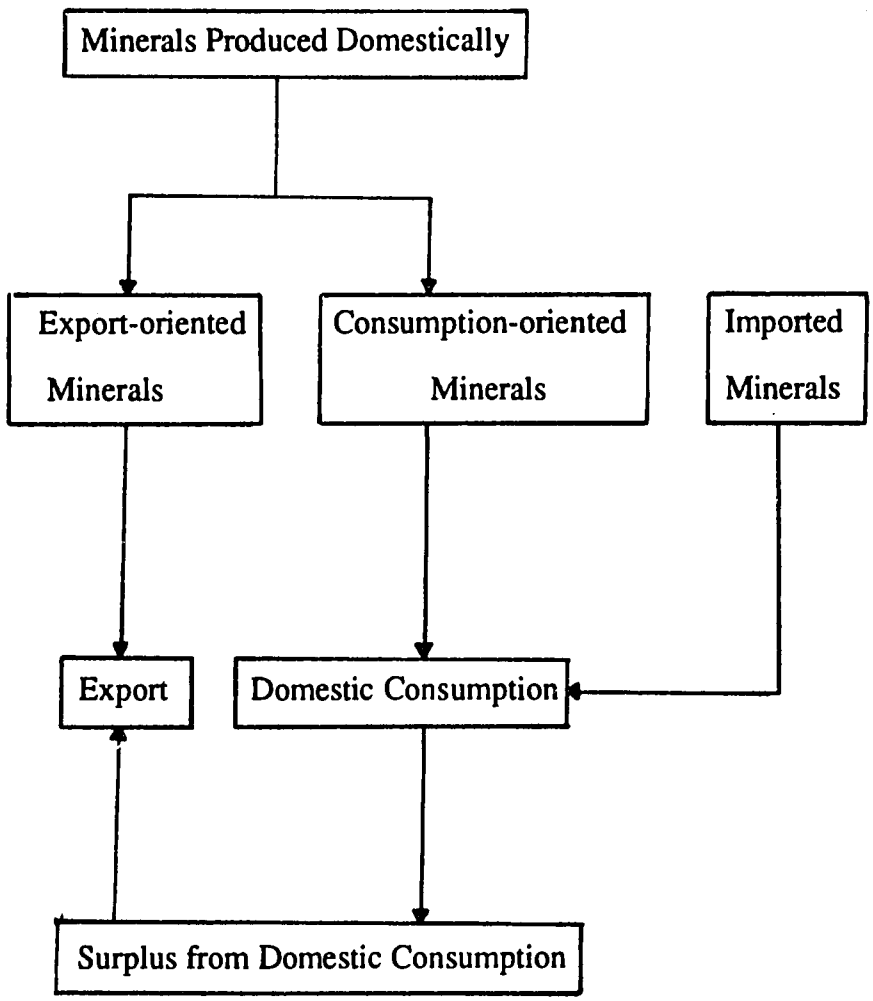

Figure 3.1 Minerals Produced and Used in Thailand

Within three groups, the minerals can be summarized as follows:

Export-oriented Minerals: Antimony, barite, feldspar, fluorite, gypsum, lead, quartz, tin, and tungsten

Consumption-oriented Minerals: Anthracite, ball clay, glass sand, iron ore, kaolin, lignite, limestone, manganese, phosphate, salt/rock salt, shale, and zinc

Imported Minerals: Asbestos, bauxite, bentonite, ceramic clay, chamotte, diatomite, graphite, high-quality coal, magnesite, natural abrasives, paper clay, rutile, steatite, sulphur, and talc

MINERAL OUTPUT

The production, consumption, and export of minerals have increased over time. However, the ratio of consumption to production is increasing, whereas the ratio of export to production is declining, implying a change toward domestic consumption (see Table 3.2 and Figure 3.2). The current demand from the manufacturing industries has required the use of more indigenous raw materials, and the domestic production of minerals is consequently oriented to consumption-oriented minerals.

Table 3.2 Trend of Consumption and Export as Compared to Production, 1970-1989

Unit: Thousand Metric Tons

Year	Production(Q)	Export(X)	Apparent Consumption	X/Q (%)	C/Q (%)
1970	1,606	428	1,178	26.65	73.35
1975	1,933	482	1,451	24.94	75.06
1980	9,710	868	8,842	8.94	91.06
1985	19,325	1,461	17,864	7.56	92.44
1989	37,173	5,223	31,950	14.05	85.95

Note: Apparent consumption = Production - Export.

Source: Mineral Statistics, Department of Mineral Resources

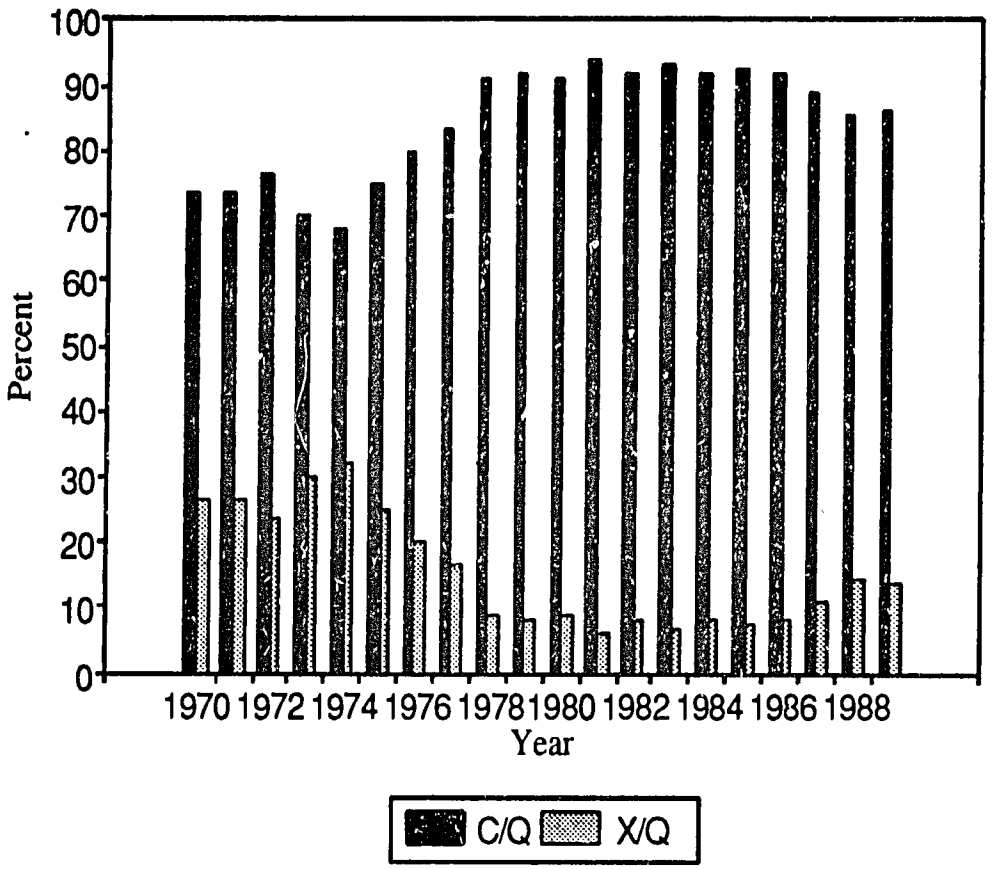

Figure 3.2 Comparison of Consumption-Production Ratio (C/Q) and Export-Production Ratio (X/Q)

The production of domestic minerals has increased in response to an increase in the production of consumption-oriented minerals (see Table 3.3). With the exception of lead, gypsum, feldspar, and quartz, the production of all export-oriented minerals has declined because of limited demand and higher competition in world markets.

Antimony production has been at a minimum level to keep the existing capacities in use since the quality of ore has become too poor for use, and the prevailing technology is inadequate to recover such low-grade deposits.

In addition, a reduction in barite and fluorite production has been duly recorded. Barite is used in oil exploration activities, and limited oil exploration activities lately have reduced its consumption and production. Fluorite production has greatly declined since 1984 due to flooding of the market with inexpensive fluorite from China.

Table 3.3 Mineral Production in Thailand, 1984-1989

Unit: Thousand Metric Tons

Mineral	1984	1985	1986	1987	1988	1989
Anthracite	-	3.0	2.5	8.4	15.3	8.7
Antimony	4.6	2.9	2.4	1.0	1.0	1.2
Ball Clay	2.5	8.0	11.2	57.7	86.9	134.9
Barite	174.9	231.0	142.2	33.4	40.6	87.1
Dolomite	10.4	16.2	13.8	50.8	140.5	257.6
Feldspar	74.4	104.6	115.2	168.9	293.7	485.8
Fluorite[a]	230.2	263.1	156.4	102.4	76.3	98.4
Glass Sand	166.8	152.1	153.6	153.5	242.4	296.1
Gypsum	110.7	1,273.5	1,665.6	3,030.9	4,549.0	5,477.2
Iron	60.7	93.8	37.3	97.0	99.3	177.4
Kaolin[b]	58.6	106.7	116.0	184.2	223.0	176.3
Lead	39.2	46.2	61.9	55.3	69.4	58.1
Lignite	2,337.2	5,146.2	5,542.2	6,929.2	7,273.6	8,899.2
Limestone	9,223.4	9,844.6	9,604.9	11,391.2	14,100.5	15,966.4
Marl	-	-	-	295.5	136.1	535.1
Phosphate	3.1	4.1	4.9	4.5	8.3	6.6
Pyrophyllite	26.9	42.0	36.2	37.7	37.3	39.8
Quartz	20.7	27.3	18.1	27.5	28.4	33.8
Rock Salt	9.9	12.8	2.0	3.3	5.7	15.4
Shale	1,563.6	1,447.6	1,013.0	1,403.0	2,283.2	2,451.6
Tin	30.0	23.0	23.3	20.5	19.4	20.4
Tungsten	1.1	0.9	0.7	0.9	0.7	0.5
Zinc	148.0	276.9	373.8	341.1	420.1	412.6

Notes: [a] Metallurgical grade fluorite
[b] Washed kaolin

Source: Department of Mineral Resources

In 1989 tungsten production was slightly less than in 1988, and no industry development has been attempted even though a slightly higher price of tungsten has prevailed.

Tin concentrate production has had a continuous downtrend since 1980, and local tin miners have been reluctant to begin any new project because of persistently unstable tin prices.

In contrast to the production of most export-oriented minerals, the production of consumption-oriented minerals continues to increase due to the high growth of the domestic downstream industries. The growth in the construction sector demands large volumes of cement and flat glass, and the beverage and food industries' growth has generated an increasing demand for container glass. Over the last few years, the ceramic industry has continuously expanded. As a result of this overall growth, the minerals used as raw materials are in great demand. Within the consumption-oriented mineral group, ball clay shows a substantial increase in production (from 2,500 metric tons in 1984 to 134,900 metric tons in 1989).

The metallic minerals such as zinc have also enjoyed an increase in production because of higher domestic consumption and the highly escalated price of zinc metal in the world market. Domestic zinc ore is processed to produce zinc metal and ingot for domestic consumption and export, while lead ore is totally exported to be refined abroad and shipped back as lead metal for domestic consumption. A portion of lead metal is available from scrap recycling, and recently, the new lead-smelting plant treating lead carbonate in Kanchanaburi Province has produced 12,000 metric tons per annum.

Lignite production has steadily increased indicating Thailand's growth in energy demand: around 8.9 million metric tons of lignite were produced in 1989 compared to 2.3 million metric tons in 1984.

MINERAL CONSUMPTION

Of the 40 domestically produced minerals, fourteen are consumed in major quantities within Thailand (see Table 3.4). The consumption of these minerals has been rising continuously, especially cement raw materials (limestone, shale, marl, gypsum, and iron ore) which is indicative of the high growth of the construction sector. Almost all of the cement raw minerals produced are used in the domestic cement industry with the

exception of gypsum: only 12 percent of total production is consumed, while the rest is exported to neighboring countries.

Table 3.4 Mineral Consumption in Thailand, 1984-1989

Unit: Thousand Metric Tons

Mineral	1984	1985	1986	1987	1988	1989
Anthracite	3.8	3.1	3.4	7.4	13.1	12.5
Ball Clay	0.01	2.8	13.0	60.8	83.5	152.9
Dolomite	4.0	16.9	13.0	22.3	34.7	87.8
Feldspar	41.6	56.4	82.7	80.9	99.5	124.1
Glass Sand	150.6	157.6	153.1	157.7	237.9	290.4
Gypsum	305.9	340.5	347.8	426.6	741.3	1,256.4
Iron	57.5	98.4	39.2	90.1	64.3	175.3
Kaolin[a]	56.5	103.1	120.6	131.4	248.0	214.4
Lignite	2,272.6	5,199.5	5,445.6	6,769.9	7,198.8	8,572.7
Limestone	9,168.5	8,700.4	8,146.1	11,131.3	13,165.7	16,376.3
Marl	-	-	-	124.8	148.8	572.7
Pyrophyllite	9.1	16.0	18.8	29.3	14.2	35.8
Shale	1,600.0	1,427.6	1,212.3	1,557.1	2,239.5	2,486.5
Zinc[b]	-	25.5	40.7	44.3	53.4	50.7

Notes: [a] Washed kaolin
[b] Zinc metal

Source: Mineral Statistics, Department of Mineral Resources

The expansion of the glass and ceramic industries has created a higher demand for the related mineral raw materials, and the consumption of feldspar, kaolin, ball clay, and glass sand has greatly increased. Interestingly, all glass sand produced is used domestically because this mineral has been banned as an export. The other minerals have been exported in small amounts with the exception of feldspar: more than 50 percent of the quantity produced is exported. Dolomite is also primarily used in glass production and in the iron and steel industries while some is exported.

Zinc is the major metallic mineral consumed domestically. Antimony, lead, and tin (in metal form only) are used to a small degree. About 66 percent of zinc production is consumed by the galvanized steel industry for products such as sheets, wire, nail, pipe, and pipe fittings. More than 60 percent of total tin consumption, in the form of tin ingot, is used in the tinplate-manufacturing industry. Antimony and lead are used mainly in battery manufacturing.

With the exception of petroleum, coal is the primary energy mineral. Coal deposits discovered in Thailand are ranked between subbituminous and lignite, and most deposits are lignite. A rapid increase in the consumption of lignite has been observed since 1984 and lignite consumption is expected to continue to grow in the future. Anthracite, a high quality coal, is also found domestically in some small amounts and is exclusively used in Thailand in the water purification process.

Pyrophyllite is also consumed domestically in some small quantities as an ingredient for cosmetic powder. The quality of domestic pyrophyllite is rather poor. It is thus always substituted by talc for high-quality products.

MINERAL EXPORT AND IMPORT

Mineral Export

Until recently, almost all of Thailand's mineral exports were raw, crude ores and concentrates which provided a small degree of value added. However, the necessity of using minerals as raw materials in domestic downstream industries has been recognized and export has been superseded by internal consumption. The value added has been increased through more domestic use of minerals in diversified industries.

A list of the major minerals exported is shown in Table 3.5. The minerals exported in large volumes include gypsum, feldspar, and dolomite. The large-value exported minerals are gypsum, lead, feldspar, and fluorite. Supplies of antimony and tungsten are entirely exported since these two minerals do not have any domestic uses. In 1989 the export of antimony was only 42 percent of the total production, not as a result of domestic consumption, but because there was a surplus of antimony in the world market resulting in an unwanted supply from Thailand.

Table 3.5 Export of Important Minerals, 1984-1989

Unit: Thousand Metric Tons

Mineral	1984	1985	1986	1987	1988	1989
Antimony	4.6	2.9	2.4	1.0	1.0	0.5
Barite	163.4	202.9	68.1	33.1	77.1	68.4
Dolomite	5.3	2.2	20.2	-	76.0	217.5
Feldspar[a]	12.4	31.6	42.7	80.2	178.6	276.6
Fluorite[b]	170.1	166.8	119.9	105.2	89.2	80.4
Gypsum	738.0	869.9	1,243.6	2,354.9	3,862.1	4,377.4
Lead (Ore)	42.0	46.4	54.1	49.0	57.1	45.0
Quartz	14.5	25.0	16.7	10.0	24.4	26.1
Tin[c]	18.31	17.4	18.6	13.4	13.4	11.1
Tungsten	1.1	0.9	0.7	0.9	0.7	0.5
Zinc[c]	-	21.4	27.6	19.1	12.6	12.2

Notes: [a] Sodium feldspar
[b] Metallurgical grade fluorite
[c] Metal

Source: Department of Mineral Resources

A continuous downward trend in export-oriented minerals has been observed over the past few years, and with the exception of feldspar, gypsum, lead, and quartz, the export volumes of tungsten, barite, fluorite, antimony, and tin have been declining. Strong competition for fluorite in the world market and a lowered requirement for fluorite in the steel industry have reduced the quantities exported and reduced exploration drilling activities in the petroleum industry have created stagnant market conditions for barite.

The export of consumption-oriented minerals like zinc has also slowed due to an increase in domestic consumption. The proportion of export to consumption has decreased as more domestic demand is apparent. Currently, all exports of zinc and tin are in metal form, while all exports of lead are in concentrate form.

Unlike other export-oriented minerals, feldspar, gypsum, lead, and quartz have increased rapidly in export volume. Over 50 percent of total feldspar production is exported to Taiwan, Singapore, and Malaysia at a relatively low price. Because good-quality Thai gypsum is inexpensive in the world market, the export volume of gypsum has increased drastically since 1983. Feldspar and dolomite follow the same trend, but to a lesser extent, and excessive amounts were exported in 1989. Dolomite export has greatly increased since 1988, and good-quality dolomite deposits have been discovered in several areas around the country. However, because the price of dolomite is low, only the sources close to ports are feasible for export.

Because Thailand is now using its own resources for industrial development and leaving some surplus for export, it is likely that the growth in mineral exports will decline while the growth in manufactured products and processed minerals exports will increase.

Mineral Import

Thailand must import several kinds of minerals, intermediate mineral products, and metals for use as raw materials in domestic downstream industries. These minerals and mineral products may not be produced in the country because (1) the reserves do not exist and/or the required technologies are not available, and (2) they may be domestically producible, but the ore qualities are poor and have limited uses. Import is necessary for the use of domestic downstream industries that require higher quality ore or metal.

Due to a recent, large expansion of the manufacturing sector, the demand for minerals and metals as raw materials for downstream industries has increased substantially, and the resulting need for minerals is filled by imports as shown in Table 3.6. The largest import volume is represented by high-quality coal which has less sulphur and high heating values. Good-quality coal and coke are in demand for use in the industrial sector; especially for cement manufacturing and large industrial boilers. Lime-burning and some metallurgical establishments also employ coke in their processing. Good-quality coal needs must be met by import since only lignite to subbituminous coal of a moderate calorific value is available from indigenous sources.

Table 3.6 Import of Important Minerals, 1984-1988

Unit: Thousand Metric Tons

Mineral	1984	1985	1986	1987	1988
Abrasive(Natural)	2.2	2.4	1.6	1.4	2.4
Asbestos(Raw)	38.7	41.4	44.2	70.9	109.1
Bauxite	11.7	7.5	11.5	21.7	n/a
Bentonite	4.2	2.9	3.2	5.4	n/a
Ceramic clay	0.8	1.2	3.0	3.3	n/a
Chamotte	9.1	9.3	5.0	5.5	n/a
Coal	190.2	282.7	219.5	254.5	n/a
Graphite(Natural)	0.5	0.7	0.8	1.1	n/a
Magnesite	11.2	10.2	14.4	22.1	n/a
Paper clay	1.4	2.9	16.3	10.4	n/a
Rutile	0.8	1.9	0.5	1.4	0.1
Steatite (Natural)	5.1	4.8	1.4	1.5	0.1
Sulphur	41.4	54.8	59.9	59.0	81.9
Talc	12.4	14.1	20.8	25.0	n/a

Source: Foreign Trade Statistics, Department of Customs

Asbestos and sulphur are two other large-volume, imported minerals. The rapid growth in the construction sector has increased the use of asbestos for insulation board, for which no commercial indigenous deposit has been discovered. Sulphur is used mainly for sulphuric acid in the zinc-refining process and for other chemical usages.

Talc, magnesite, and bauxite are imported in large amounts. Although some talc is produced in Thailand, the quality is rather poor, and imported talc is required for good-quality products. Magnesite is mainly used for refractory purposes, and bauxite is used in alum production, but no suitable source of these two minerals is available in Thailand.

The imported value of high-grade clay for ceramic production was as high as 123 million baht in 1987. At present, high-grade clay cannot be produced in the country due to a lack of technology.

Thailand also imports primary metals and other intermediate ore products such as chemical compounds, slag, pigments, alloys, and additives. These mineral products accounted for 90 percent of the total import value of minerals in 1985 and for 96 percent in 1988. The largest import volumes are of iron and steel products, and the second largest are of aluminum. Primary metals such as pig iron, ferro-manganese, aluminum, and copper are totally imported, while primary metals such as ferro-silicon, ferrosilico-manganese, and unwrought lead, tin, and zinc, can be partially produced domestically.

Mineral derivative compounds such as titanium dioxide, iron oxide, and lithopone, which are used as pigments in the paint industry, are imported in sizeable quantities. Although zinc oxide can be produced locally, it is still necessary to import a large volume due to the high level of growth of the tire-manufacturing industry. A large volume of silicon dioxide is also imported every year for use as a filler in several manufacturing industries.

MINERAL RESERVES

Thailand is endowed with moderately rich mineral deposits that are scattered throughout the country. The availability of domestic reserves is not completely known. Exploration and discovery are, more or less, continuous processes, and as a result, reserves are dynamic: the total reserve deposit is continually depleted by usage and augmented by discoveries. The preliminary and conservative compilation of existing reserves information should be updated when new discoveries are made and more geological information is available. The presently known reserves thus can only be treated as an indicative figure.

Few metallic minerals are found in Thailand, and their deposits are relatively small. In the past tin was the most important metallic mineral, but now it is less important than zinc. Tungsten deposits are found in several areas of the country, especially in the north, and sizable deposits of copper ore and iron ore are also found in Loei Province.

Specialty metallic minerals such as rare earths and tantalum-columbium groups are also important because they are essential to manufacturing in the modern electronic and communication industries. Although these minerals are not found in large deposits, they are a byproduct of tin; the amounts produced thus vary with the rate of tin production.

A larger volume of nonmetallic minerals are found in Thailand, and tonnages of these mineral reserves depend upon the type of deposit. Deposits of salt-type minerals such as rock salt and potash (carnallite) are normally extensive and occur in the Northeastern area. Nonmetallic industrial minerals such as gypsum, feldspar, kaolin, glass sand, diatomite, dolomite, and barite are present in large ore bodies as is lignite, an energy mineral with enormous reserves in several basins.

Table 3.7 presents information summarizing the known reserves of the major metallic and nonmetallic minerals. Using the United States Geological Survey's definition, the reserves are categorized into measured, indicated, and inferred reserves. These three categories are economic classifications that are based on the differing reliability of geological knowledge. Measured reserves are estimated with a margin of error of less than 20 percent and from documented geological sample sites; indicated reserves are estimated partly from sample analyses and partly from reasonable geologic projections; and inferred reserves are minerals in unexplored extensions of demonstrated resources, which are based on geological projections.

Limestone and Shale

Deposits of a limestone and shale normally occur in the same areas, and in Thailand good-quality limestone and shale, which are suitable for cement production, are distributed over several areas. However, there are few large, economically feasible deposits. The areas which contain good-quality deposits and are close to basic infrastructures with relatively inexpensive transportation costs are essential for cement plants which must keep their prices reasonably low. Therefore, most cement plants are located near these material sources.

Table 3.7 Known Mineral Reserves

Unit: Million Metric Tons

Mineral	Classification of Reserves			Total
	Measured	Indicated	Inferred	Reserves
Metallic Minerals				
Copper	-------	16.000	62.000	78.000
Iron	-------	23.100	11.700	34.800
Lead	-	0.176	1.334	1.510
Tin	-	--------	0.136 --------	0.136
Tungsten	-	-	0.002	0.002
Zinc	-	3.777	-	3.777
Nonmetallic Minerals				
Barite	---------	2.500	--------- 11.852	14.352
Coal	-	-	2,068.000	2,068.000
Diatomite	242.910	6.850	-	249.760
Dolomite			100.000	100.000
Emery	-	-	0.020	0.020
Feldspar	-	-	43.010	43.010
Fluorite	-	-	5.299	5.299
Glass sand		--------	19.194 --------	19.194
Gypsum	12.000	19.807	10.500	42.307
Kaolin	-	--------	58.675 --------	58.675
Limestone	-		-	5,474.000
Phosphate	-	0.234	-	0.234
Potash (carnallite)	-	407,000.000	-	407,000.000
Rock salt	-	18,000,000.000	-	18,000,000.000

Source: Economic Geology Division, Department of Mineral Resources

Proven reserves of limestone and shale for use in the cement industry are distributed in the provinces of Saraburi, Nakhonsawan, Petchaburi and Nakhon Si Thamarat. The total reserves of limestone are approximately 5,474 million metric tons (estimated in 1989), and there are no confirmed figures on the reserves of shale.

Over 80 percent of total limestone supplies come from the Saraburi area, especially from Amphoe Kaeng Khoi, Muak Lek, and Praputtabat, where large limestone formations are confined, and the location is fairly close to Bangkok, the main distributing market for cement. Limestone from Naknonsawan Province (at Amphoe Taklee), Petchaburi Province (at Amphoe Cha-Am), and Nakhon Si Thammarat Province (at Amphoe Thoong Song) are fed to a local cement plant. Good-quality limestone deposits also have been found at Amphoe Kahnom in Nakhon Si Thamarat Province. However, due to environmental constraints and the watershed Class 1A restrictions, development cannot take place.

Gypsum

Current gypsum reserves, approximately 42.31 million metric tons (estimated in 1988), are a very limited amount compared to the present rate of production and consumption. Gypsum reserves are located at Nakhon Sawan, Pichit, Nakhon Si Thamarat, and Surat Thani provinces. The gypsum from Nakhon Sawan and Pichit provinces is supplied to centrally located plants, vhile gypsum from Nakhon Si Thamarat and Surat Thani provinces is supplied to the cement plant in Thung Soong. Gypsum from the South (Nakhon Si Thamarat and Surat Thani provinces) represents over 60 percent of the total production.

Glass Sand

Approximately 19.19 million metric tons (estimated in 1988) of high-grade glass sand have been found along Thailand's coastline. The deposits are located in Chantaburi, Rayong, and Trarad provinces; on the eastern coast from Chumporn Province to Pattani Province; and on the western coast from Phuket Province to Trang Province.

Not all reserves of glass sand can be readily mined. Some deposits may require processing to remove iron impurities, and some are too far from downstream industries to be economically produced at current price levels. The presence of impurities such as iron oxide, rock or shell fragments, and clay, and the failure to satisfy grain-size requirements further diminishes the overall value of these reserves.

Kaolin

The total indicated reserves of kaolin are approximately 58.68 million metric tons (estimated in 1989), and are distributed in the provinces of Lampang, Uttaradit, Prachinburi, Ranong, Nakhonratsrima, and Narathiwat. The kaolin from different sources has different properties, and to prepare raw materials for ceramic production, kaolin from different sources must be mixed in appropriate proportions. Currently, kaolin used for ceramic manufacturing applications is obtained from Lampang, Ranong, and Prachinburi provinces. Kaolin from Uttaradit Province is used mainly for industrial fillers, while kaolin from Narathiwat Province is used for paper fillers.

The kaolin reserves available for ceramic use are not a major factor in the expansion of the ceramics-manufacturing industry. Rather, production technology, industry capability, and price seem to be preventing the development of raw materials that could be compatible with this fast-growing and technologically intensive industry.

Feldspar

Feldspar deposits are found in several areas in the Northern (Tak and Chiang Mai provinces), Central (Ratchaburi Province), and Southern (Nakhon Si Thammarat Province) regions of Thailand. Total inferred reserves of potash feldspar and soda feldspar are about 3 million and 40 million metric tons (estimated in 1988), respectively. Good-quality potash feldspar (high potassium), which is not easily discovered compared to soda feldspar or mixed type feldspar, is more expensive and used for more specialized purposes. Soda feldspar (high sodium), which is more common, is used in producing most ceramic products. Larger amounts of soda feldspar are consumed at prices that are relatively much lower than potash feldspar prices.

Ball Clay

Ball clay deposits are generally small and may occur as a thin layer and be exhausted in a short time. The total inferred reserves are about 0.32 million to 0.34 million metric tons, and major reserves are found in Lampang, Nakhon Sri Thamarat, Surat Thani and Prachinburi provinces. More than 90 percent of ball clay used at present comes from reserves in Lampang Province.

In general, these sources are not close to the downstream industries which are located in the Central Region, except one source in Prachinburi Province, which is unreliable. As a result the cost of transportation is a burden if the price of ball clay is too low.

Zinc

Zinc is mainly found in the form of zinc silicate, and the only known deposit in Thailand is located at Amphoe Mae Sod in Tak Province. Zinc is also found as a coproduct of lead (in the form of zinc sulphide) in some sulphide deposits around Kanchanaburi Province. No other deposits have been confirmed or discovered and total reserves are approximately 3.78 million metric tons (estimated in 1985).

Tin

Geologically, Thailand is composed of north-south granite mountain ranges of varying ages. These granites are a source of tin, and over 97 percent of Thailand's demonstrated recoverable tin is contained in placer deposits derived from tin lodes. Tin deposits contain not only cassiterite (the main economic mineral for tin), but also other valuable minerals such as columbium-tantalum and rare earth minerals. The indicated tin reserve is approximately 0.14 million metric tons (estimated in 1988).

Lignite

The probable coal reserves represented by both the public and the private sectors are approximately 2,068 million metric tons (estimated in 1988) from 53 deposits in 13 basins. The largest deposits are located in Mae Moh and Krabi and are owned and operated by the Electricity Genarating Authority of Thailand (EGAT). Of the 17 active coal mines currently producing lignite to subbitominous coal, 13 are privately owned, 2 are operated by EGAT, and the rest are contracted by the National Energy Administration (NEA).

Chapter 4

Mining Technology and Mineral Substitution

In the context of mineral exploitation, the use of technology is important for optimizing the extraction of mineral resources. In the case of most nonmetallic minerals, there are generally two stages of technology: mining and utilization. For metallic minerals, there are normally four stages: mining, processing, refining, and utilization. The application of the appropriate technologies will optimize mineral resource recovery while keeping production costs and environmental damage to a minimum.

The use of substitution in mineral markets is another factor affecting the mineral industry: substitution normally results in a change of the consumption patterns of materials, or in a shift of consumption to the cheaper and more readily available minerals. Chapter 4 provides information showing that technological changes and substitution influence mineral utilization, and these two factors must be given consideration. Mineral substitution is addressed first to put the mining industry in the right market perspective.

MINERAL SUBSTITUTION

The substitution of some metals and minerals becomes possible as engineers and technologists learn increasing amounts about the basic principles behind advanced manufacturing processes. The use of a more efficient technology in a manufacturing process could have a profound effect on the use of a mineral. Technological advancements can cause substitution among minerals. Advanced technology helps to streamline or eliminate unnecessary processing steps and thus could reduce the amount of minerals required per unit of products. By the same token, new uses for particular minerals can be realized because of an advancement in technology. Because of the development of substitute, the demand for minerals has not increased in proportion to the growth of industrial production. The demand for minerals increases at a relatively slow

rate and prices of most minerals have declined because of substitution, improved recovery, and new discoveries.

Substitution can be motivated by several factors: (1) the substituting materials are more readily available or are available at a lower price; (2) the changes in consumer preference induce substitutions; (3) the introduction of new technology results in better quality substituting materials; (4) the use of end products of some mineral are hazardous to the environment so that changes become inevitable.

The substitution of nonmetallic or industrial minerals generally takes place in processes where minerals are used as raw materials. The substitution of nonmetallic minerals, which are low price and physically bulky, is not extensive, and it is largely made to suit local conditions or particular processes. On the other hand, the substitution of metallic minerals mostly occurs in the use of semi-finished products or fabricated metal. Because the substitution of metallic minerals requires an innovation in technology, its effect is more extensive.

Mineral substitution and technology are not widespread in Thailand for three reasons. First, most domestically consumed minerals are nonmetallic and substitution is not normally used for nonmetallic minerals. Second, Thailand rarely produces metal; most domestically used metals are imported. The substitution technology for metal is thus not locally available. Finally, Thailand is a recipient, not an innovator, of new technology. Because R&D for new technology does not occur locally, the existing technology is less developed

With respect to the Thai mineral industry, some significant considerations in the substitution of minerals and metals are as follows:

Substitution for Kaolin in the Paper Industry

Although kaolin in ceramic production may not be replaced by other materials, high-quality kaolin used in the paper industry has been partially substituted. Some 32 percent of world kaolin production enters international trade, and most of this amount is destined for the paper industry for use in both fillers and in coating pigments. Calcium carbonates are the main alternatives to kaolin, but the physical and chemical differences between the two minerals prevent calcium carbonates and kaolin from being totally interchangeable in end use.

Reduction of CFC Usage

Because acid grade fluorspar is also used in the production of CFCs, the worldwide reduction in the use of CFCs will affect the demand for acid grade fluorspar to some extent. An international agreement reached in September 1987 under the so-called Montreal Protocol, which called for freeze and reduced production and consumption of CFCs over the next decade based on 1986 levels, has had an impact on the demand for acid grade fluorspar. The exploration conducted in extensive R&D programs has resulted in the identification of two compounds that show promise as potential candidates to replace CFCs in many current applications. The tests on these substitutions are close to conclusion, and these alternative compounds should be ready for introduction as the usage of CFCs is reduced. The alternatives apparently contain more fluorine, therefore an ultimate increase in acid grade fluorspar demand seems likely.

Substitution for Natural Gypsum

Gypsum is exclusively used for construction applications, principally as a retarder in cement manufacturing, or in plaster and plasterboard. On a worldwide basis, more gypsum is used as a cement retarder than in plasterboard. The chemical formula $CaSO_4 \cdot 2H_2O$ is the important property for gypsum usage, and it can be replaced by phosphogypsum, a byproduct of phosphate fertilizer manufacture, or by FGD (flue gas desulphurization) gypsum. Japan is the largest consumer of phosphogypsum, which is a byproduct of its own natural gypsum mining, but Japan lacks domestic resources, and distinctly lacks land for mining.

A considerable amount of byproduct gypsum from FGD is already used, and its usage is likely to grow, especially in Western Europe. In West Germany, the usage of byproduct gypsum has already reached approximately 14 percent of total consumption.

Substitution for Other Industrial Minerals

Feldspar can be replaced by nepheline syenite for ceramic use, and R&D are being conducted in an attempt to extract alumina from clays instead of using the more limited, typical alumina raw materials such as bauxite and gibbsite.

Substitution for Tin

The primary consumer of tin is the tinplate industry. Tinplate is used in the canning and manufacturing processes for both food and beverages. The beverage industry, which now uses cheaper, lighter aluminum in canning, has provided severe problems for the tinplate industry's competitiveness. The choice between these two metals is based on a combination of economic, environmental, and political factors. The

price of tin has been decreasing, and the significant increase in the price of aluminum in recent years retards the substitution in canning, although it is difficult for the tinplate industry to regain its lost share.

New technological progress also reduces the amount of tin solder used for joints in the electronics industry causing tin consumption in this sector to increase less than proportionally with the growth of the electronics industry.

Substitution for Zinc

The very rapid increase and long-term instability of zinc prices now threatens some of its major markets. Zinc die-castings are probably most vulnerable to substitution, particularly where direct replacement by aluminum or by plastic molding is possible. New alloys containing higher amounts of aluminum for strength can be used to produce thinner walls and more complex shapes. The casting techniques previously associated with the traditional die-casting alloys are now being extended to the higher-aluminum-content alloys.

The volume of coated steel is not likely to decrease, but the amount of zinc per unit area of coated steel may drop sharply, particularly if zinc remains at a high price. Electroplated zinc that is 12 percent nickel is a serious contender for use in automobile manufacturing instead of galvanized sheets, which have a thicker zinc coating.

Zinc that is 5 percent aluminum metal coating with about twice the corrosion resistance of conventional galvanizing for the some coating thickness is likely to cause a drop in zinc use, even though the amount of steel coated should rise.

Substitution for Other Metals

Tungsten can be substituted by titanium and new ceramic materials in the carbide industry. Also, the use of tungsten filaments for electrical lamps has been gradually replaced by the use of fluorescent type lamps, which has depressed the price of tungsten in recent years.

Tantalum is also prone to substitution in electronics applications. Aluminum and new ceramics provide strong competition for tantalum for use in capacitors, whereas silicon, germanium, and selenium are alternatives to tantalum in rectifiers: the major electronics components. Moreover, columbium carbide and columbium halfnium carbide can take the place of tantalum in some cutting tools. This potential for substitution could reduce the future consumption of tantalum metal.

MINERAL PRODUCTION TECHNOLOGY

Advanced technology could be helpful in many aspects of exploration, mining, mineral processing, and metallurgical activities. Improved exploration techniques will help uncover more economic minerals, and this, in turn, will help locate viable mineral deposits for possible exploration. Geophysical survey maps (including magnetic, radiometric, and aeroelectro-magnetic (AEM) anomaly maps) will be utilized to locate potential areas of mineral deposits in various parts of the country.

Improved beneficiation technology could introduce appropriate methods of mineral processing. For example, the new technology could transform low-grade feldspar into a high-quality product for use in making high-quality ceramic ware or for making kaolin processing economical for use in the ceramic industry.

The difficulties associated with the discovery of new, rich deposits become greater over time and a gradual trend to utilize lower-grade and less-accessible deposits is inevitable. The industry may expect to use resources more efficiently by improving recovery in mining and processing and speeding up recycling. At the same time, the industry may want to learn more about how to substitute relatively abundant minerals for minerals in short supply without sacrificing quality or increasing the cost of final products. The industry may learn how to overcome environmental problems at more acceptable costs.

The development of technology to meet industry's needs, however, requires technological resources, trained manpower, and R&D programs. Examining the capability of technological resources would be beneficial in preparation for efficient management to make the best use of mineral resources

The Status of Technology

The technologies inherent to the mineral industry are exploration, exploitation (mining, processing, smelting, and refining), utilization, and environmental protection.

Exploration is the first and the most important phase for defining a strategy to cope with the rapid change of the mining industry's prospects. Exploration costs are, in general, not small, and for most small- to medium-scale operations, exploration is usually ignored. Only large mines can afford systematic, expensive exploration programs.

Exploitation is an operational phase beginning with extracting a mineral from its ore body by an appropriate mining method (to produce concentrates) and progressing to

further processing by either pyrometallurgical or hydrometallurgical processes (to produce metals with a minimum amount of impurities).

The mining methods employed in Thailand include surface mining (open pit, open cast, gravel pumping, dredging), and underground mining. Most local mining uses the open pit method. Only one lead mine and few small-scale fluorite and tungsten mines utilize the underground excavation method. In tin-mining operations, the surface method is varied with the type of deposits: from gravel pumping and dredging for placer or alluvial deposits, to open pit for some lode or vein types. These mining methods are used on a small-to-large scale depending on the types of deposits and the capital used for production. For example, the lignite mine of Electricity Generating Authority of Thailand (EGAT) is a relatively large-scale, open pit operation, while some antimony mines are nothing more than a hole with negligible technological utilization.

In the processing stage ores from the mine are upgraded by mineral-processing methods. Simple processes with cheaper operating costs are applicable for easy-to-treat and less-stringent quality specification ores, such as most industrial minerals. The simple methods include washing, hand sorting, crushing, screening, blending, and using settling ponds, while the more sophisticated techniques include classification (hydrocyclone and spiral classification), gravity separation, magnetic separation, high-tension separation, and flotation and chemical processes which are suitable for difficult-to-treat ores and for those with high-quality product requirements.

Normally, the processing for most metallic minerals is more advanced than for nonmetallic ores. Many nonmetallic minerals can be used directly in manufacturing and little degree of processing is required, while most metallic minerals require further processing. Some high-quality nonmetallic minerals, such as kaolin for high-quality ceramics and acid grade fluorspar, need processing beyond the application of simple techniques.

Smelting and refining are the processes used to reduce metallic ore or concentrate to metal. These processes are expensive and consume high levels of energy. Mineral concentrates can be reduced by heat to molten metal or by chemical reagents to a metal-bearing solution; the techniques are specific for each metal. The technology in this area is intensive, and R&D is continuously carried out to develop better techniques that consume less energy and produce less pollution.

Utilization technology is used in the manufacturing process. High technology and capital intensive are required in the process of metal fabrication and in the production process of some products such as cement, glass, and ceramics. The more advanced the utilization technology, the more stringent the quality specifications for raw materials.

Most minerals in Thailand are found in small- and medium-size deposits. Technological utilization in the small mines is, in most cases, inadequate, causing large amount of waste and damage to the environment. While the medium-size mines could afford to employ a suitable technology, the efficiency of work still needs to be improved. Environmental rehabilitation is always ignored in both small- and medium-size mines, and results in unnecessary losses of mineral values and environmental damages. Large mines seem to experience less difficulties because the necessary measures can be used to correct any problems.

The current production capacities of most minerals are sufficient to supply the present demand. The limestone and lignite industries have large-scale and fully mechanized mining operations, while the other mineral industries have medium- to small-scale mines. The mining techniques employed at EGAT's lignite mines are considered efficient for both lignite extraction and environmental rehabilitation. The production capacity of the gypsum industry is actually in excess of the internal demand, although the unit price is relatively low. The uncontrolled, expanding production capacity of the gypsum industry may create an oversupply, and the price will be even lower. The kaolin, ball clay, and glass sand industries produce an adequate capacity for the glass and ceramic industry at present. Due to a requirement for high-quality kaolin, more sophisticated processing techniques have been developed in recent years. Currently, the barite, fluorite, and antimony producers have reduced their production capacity due to a decreased market demand. The technology for the mining and processing of these minerals is not complicated with the exception of the flotation of acid grade fluorite, but the production has been suspended for some time. Among all locally produced minerals, the technology for zinc smelting is regarded as one of the major advancements in metallurgical extraction.

The current production capacity and production technology of some selected minerals are summarized in Table 4.1.

Table 4.1 Current Production Capacity and Technology for Some Selected Minerals

Mineral	Number of Mines		Rated	Mining	Processing
	Active Mine	Suspended Mine	Capacity (Ton/Month)	Technology	Technology
Iron ore	7	2	15,400	Open pit	Hand sorting
Limestone	6	n/a	1,190,000	Open pit	Crushing, Screening
Gypsum	20	8	12,790	Open pit	Crushing, Screening
Ball clay	20	8	12,790	Open pit	Screening, Blending
Kaolin	n/a	n/a	33,132	Open pit	Settling pond
Glass sand	19	1	27,100	Open pit	Screening
Lignite[a]	17	n/a	673,700	Open pit	Crushing, Blending, Washing, Hand sorting
Barite	10	4	16,500	Open pit	Hand sorting
Barite	n/a	n/a	1,800	Open pit	Hand sorting
Manganese	6	19	1,125	Open pit	Hand sorting
Antimony	14	25	170	Open pit	Hand sorting
Lead	6 1	5 n/a	6,500 2,000	Underground Open pit	Flotation Washing
Fluorite	28	31	7,200	Open pit, Gophering, Underground	Hand sorting
Zinc	1	-	40,000	Open pit	Leaching Electrolysis
Tin	195	229	1,600 (Concentrate)	Gravel pump, Open pit, Dredging	Gravity Concentrate

Note: [a]Crushing and blending are used in electricity generation; crushing and washing are used in cement manufacturing; and hand sorting and blending are used in tobacco and industrial boiler manufacturing.

Source: Division of Mining Technology, Department of Mineral Resources.

Technological Resources

Technological improvement or innovation has always played a major role in solving productivity problems. Technological improvement is normally accomplished in two ways. First, an improvement can be obtained from imported technology. This is a quick, but expensive method, and it may not be appropriate. The use of technology transfer to sustain the local know-how can present another problem. The recipient of any imported technology must prepare trained personnel, however a special consultancy is normally required at a high cost. The consultant may neglect to explain or leave out important parts or critical factors of the technology so that technical changes or innovation are difficult for local personnel.

A technological improvement can also be obtained through R&D which can be tailored to suit the situation. Trained technical personnel with a full understanding of the highly mechanized technology and capital-intensive nature of mineral industry are, therefore, essential.

Technical training in areas from geology to utilization of material science can be accomplished in the country and can satisfy the need for skilled manpower to a certain degree. Higher levels of training in specific fields, for example exploration geophysics, mineral economics, and extractive metallurgy, still depend on foreign institutions.

The development of manpower for management in the mineral industry is also necessary. The government should promote training for middle- to high-level management in the mineral industry, while at the same time securing the adequacy of trained personnel to support the industry's development plan.

Recently, more emphasis has been placed on materials R&D. Several R&D projects have been granted by funding agencies including the Scientific and Technological Development Board, the National Metal and Metal Center, and the National Research Council of Thailand.

Before establishing any R&D direction, it is essential that any problems are identified and that the type and direction of research is ascertained. Specific R&D may be set up for a specific objective, and serious planning will probably strengthen the existing R&D facilities and framework.

Since business is the primary engine of technological application, the driving force behind R&D is the expectation of a satisfactory return to invested capital. Applied

R&D for commercial applications is generally best undertaken by the private sector, while the basic or applied research, which consumes more time, is more appropriately conducted through the government, or through government-allied organizations such as universities. The role of research activities should be clearly defined as to what extent the cooperative or contracted research should be granted to other government-financed research institutes. The government should be concerned with focusing R&D activity on long-term, high-risk and potentially feasible technology with a high payoff. The appropriate technological application for small-scale mining and processing in Thailand is another crucial point. The budget for R&D in mining and mining-related activities, including environmental rehabilitation, should receive serious consideration. The funds for expanding this budget, however, ought be contributed by the mining industry, not obtained from general taxation.

Private sector R&D should be encouraged, and the stimulation of constructive coordination between industry and government in the area of technological improvement is necessary.

Chapter 5

Environmental Impacts and Land-Use Conflicts

Land use in Thailand inevitably raises the problem of the best use for areas with multiple resources and development potential. When mining activity is specified for a given area, a number of factors enter into the actual mining process and the corresponding need for institutional mining controls including the need for an appropriate institutional framework and for pollution control.

Mining activity inevitably entails varying degrees of environmental damage—not only to the immediate land area and soil surrounding the mine, but also to the more mobile environmental media including air and water in confined areas. The environmental damage that results from reckless mining operations inevitably leads to conflict over land uses and conflict between users of other resources and users of minerals.

Chapter 5 discusses these above-mentioned land-use problems as well as providing extensive information on land productivity rates, the rehabilitation of mined-out areas, and the problem of environmental pollution.

ENVIRONMENTAL CONSIDERATIONS

Environmental Pollution

Air Pollution: The dust from mining operations such as drilling, blasting, transportation, and excavation causes pollution which can be harmful to the health and safety of the workers in the working area and to the people in the vicinity. Generally, dust pollution from surface mining is more extensive than that of underground mining which only generates dust from drilling and blasting in the tunnel and on the working stope. Surface hydraulic mines do not create any dust since water is used to excavate the ore. Dust suppression is normally done by using water spraying on transport roads or by using

a dust cover hood and/or a water spray jet attached to the drilling machines. Preventive measures such as the provision of dust masks for workers and the restriction of working hours are also practiced.

Air pollutants can also come from smelting and refining operations. Exhausted gases containing sulphur dioxide and other pollutants can be emitted, and the local concentration may be high sometimes so that treatment may be needed. These types of processing plants normally install anti-pollution equipment because they are strictly required by law.

Water Pollution: In hydraulic mines such as placer tin mines, ores are removed by water jetting instead of by other mechanical methods. After the ore is recovered by means of gravity concentration, wastewater containing suspended solids or slime is retained in one, or a series of, impoundment ponds to allow solid particles to settle, and relatively clear water is discharged. Water discharge standards were set by a ministerial regulation specifying that the mine operator shall not discharge slimy water containing more than 6 grams per liter of slime. Mine water discharge, especially from coal mines, is sometimes acidic or alkaline depending on mineral characteristics. Mine water is normally kept in a sump and neutralized before discharge.

Processing plants, like flotation plants, generate both solid tailings and water. Solid waste is impounded in a settling pond, while wastewater is treated to neutralize a change in pH, or to decompose low concentrations of chemicals before discharge.

A more serious problem occurs in extractive plants where acid or alkaline materials are used in processing. The dissolved solids present in wastewater usually require a complicated wastewater treatment system to meet standards of the Office of National Environmental Board (ONEB) and the Ministry of Industry (MOI).

Land pollution: A major pollution problem generated by mining activity is land pollution. The air and water pollution produced by mining activity are relatively temporary, and the effects can be mitigated by anti-pollution measures normally integrated into the operating process. The land pollution created by mining is more persistent. Most surface mines use both wet (hydraulic) and dry mining methods that involve the removal of the top soil and overburden which are then normally moved away from the pit. The inevitable changes in topography and land use are permanent and exist beyond the mining period. In this case, land reclamation is necessary.

In underground mining, the physical degradation of the surface ground is considered minimal. If underground openings or tunnels are plugged after mine closure, acid or alkaline mine leachate can be prevented from polluting natural water.

A major problem from mining operations affecting the communities that are located downstream is the pollution of natural water by slime discharged from hydraulic mining operations. Most hydraulic mines (especially tin mines) produce slime water, although tailing ponds are required by laws which set standards for discharged water.

Effective tailing ponds should consist of at least two stages. The first stage retains soil and gravel tailings, and the second stage settles the slime out, at which point only relatively clear water is discharged.

A problem occurs when the ponds are (1) too small to retain all the tailings, (2) too small to allow sufficient time for slime to settle, or (3) have been filled up with mine tailings due to improper maintenance.

The DMR regulates these pollution control measures by requiring that the mine have sufficient area to construct tailing ponds according to its rate of production of tailings; otherwise a mining permit cannot be issued. This is done on a case-by-case basis as the tailing ponds' area varies with type of mining, the depth of ore deposits, and the ratio of overburden (soil and gravel) to ore.

While it might be appropriate to suggest that standards should be established, the efficient mechanism to enforce the mines' compliance and to provide incentives when this measure is properly taken should be examined. The design of an efficient enforecement mechanism will be described in detail in a subsequent supplement.

Environmental Rehabilitation

Most domestic minerals are mined by the open pit method which results in land degradation and surface land destruction. The solution to the problem of land reform lies in working out and developing a new ground contour which will continue to provide the top soil with the necessary support to be useful for agriculture, forestry, and grazing and will include the creation of water reservoirs where none existed. It will, in short, be an exercise in landscaping. The least expensive way of reclaiming the mined area is by in-pit dumping of overburden. Subsequent dumping into the previously mined-out pit adjacent to the working pit is the most effective method of dump management for a

surface mine. Once in-pit dumping is completed, the last pit can be converted into a useful water reservoir or a recreational lake. The overburden, when placed back into the pits, is normally not useful for any meaningful agricultural development. Thus, the top soil is required to fertilize the overburden and the land for continued agricultural use. It is important that the top soil be removed and stored very carefully in the very first stage of mining activity. This practice must be planned in advance and costs can be included as an operational cost.

The following cases demonstrate the extent of rehabilitation costs for typical surface-mined land.

Case 1: Tin Mine in Ranong Province

A mined-out area of about 343 rai at Amphoe Bangrin in Ranong Province required an expenditure of about 9.675 million baht (in 1988) for rehabilitation and reforestation. The rehabilitation costs are 28,207 baht per rai.

Case 2: Tin Mine in Phuket Province

The rehabilitation of approximately 350 rai of expired tin mine in Phuket cost about 16.155 million baht (in 1988). The rehabilitation encompassed two-thirds of the area, and the remaining area was left untouched to become water reservoirs instead of back filling it to the original level. The rehabilitation for recreational purposes consisted of landscape architecture, garden and tree planting, and the construction of facility buildings and ponds. The rehabilitation costs are estimated at 46,157 baht per rai.

Case 3: Lignite Mine in Krabi Province

The reclamation costs of a lignite mine in Krabi Province were estimated to be 75 million baht (in 1987) for the total area of 2,135 rai according to the reclamation plan, or a cost of 35,129 baht per rai. The total lignite production expected from this area will be 15.34 million metric tons. Therefore, the rehabilitation costs are estimated to be about 4.90 baht per ton. The planned end use of the rehabilitated land is agricultural (a rubber tree plantation).

Case 4: Lignite Mine in Lampang Province

The Mae Moh reclamation plan has been designed to provide diversified post-mining land use. The waste dump and ash dump area have been reclaimed, and the overall rehabilitation project includes ground leveling, the construction of an asphaltic concrete road, and land development projects such as drainage, covering crops, reforestation and revegetation, water supply, maintenance, and nurseries. The total expenditure was estimated at 41.96 million baht (in 1988) for the reclaimed areas of 1,095 rai, and rehabilitation costs are 38,318 baht per rai.

At the Mae Moh lignite mine, a fund is generated for reclamation purposes by depositing 4.25 baht per ton of lignite produced which is equivalent to over 20 million baht in 1989 prices.

Past Environmental Management

So far, the government has not paid much attention to the environmental degradation brought about by mining activities, and only environmental damages for tin mining have been officially recognized. In 1981 the government announced a ministerial regulation to collect a special fee from tin miners that would be equal to 5 percent of the royalty the miners paid to the Department of Mineral Resources (DMR). Of that 5 percent, 50 percent was awarded to the provinces where mining is located, 25 percent was set aside for the suppression of mineral smuggling, and the remaining 25 percent was used for a rehabilitation program aimed at the protection and restoration of the environmental erosion caused by mining. The collection of the special fee was suspended in late 1985 in response to the collapse of the LME tin market, and it has not been resumed since.

The government projects that were initiated concerning the environment were as follows (all projects are for damages from tin mining):

1. From 1983 to 1985 the acquisition of mechanical services from the DMR was initiated for the rehabilitation of mined-out areas.
2. The rehabilitation of mined-out land at Bangrin Village in Ranong Province was completed in 1988. The project demonstrated that the mined-out areas caused by gravel pumping could be restored for planting different kinds of trees with satisfactory results.

3. The design and construction a device to be attached to an offshore dredge. The purpose of the device was to control and prevent the dispersion of slime during mining operations by the Asian Institute of Technology research team. The project was completed in 1988 and adopted for use on the dredge, as required by the ONEB and DMR.
4. The rehabilitation and utilization of mined-out land and the creation of a fast-growing plantation forest at Bang-muang, Takuapa District in Phangnga Province was completed in 1988. The project was supervised by the forestry faculty from Kasetsart University.
5. The rehabilitation of a large area of mined land to create a public park at Vichit Village in Phuket Province was supervised and implemented by the DMR and was also completed in 1988.
6. A project designed to expand the use of fast-growing trees and soil cover revegetation to reclaim a mined land sited at Tai-muang District in Phangnga Province is currently underway under the supervision of the Land Development Department. This project was started in 1983.

In addition, the government has mandated that suction boat dredges (when suction pipes are bigger than 14 inches) must now be equipped with slime suppression pipes for the offshore mining of tin, or else they will not be allowed in a mining area. This measure is aimed at eliminating slime water dispersion, particularly on the surface of seawater.

A rehabilitation project which is carried out by the Electricity Generating Authority of Thailand (EGAT) is the lignite mine reclamation at both the Mae Moh mine in Lampang Province and the Krabi mine in Krabi Province. Experimental rehabilitation exercises to study soil conditions were performed as part of the reclamation program. The project enables EGAT to understand, fairly well in advance, what kinds of trees and plants should be grown following mining in that area. A mine reclamation plan was prepared for both the Mae Moh and Krabi mines, and a fund was collected for every ton of lignite produced.

Apart from this EGAT project, the only other major rehabilitation project is carried out by a private company dealing with environmental problems for a lignite mine in the Li District of Lampoon Province. The Li lignite mine converts a mined-out area into a terrace-type landscape to grow trees for various purposes.

Elsewhere, the mining community pays less attention to environmental problems, even though the rehabilitation of mined-out areas has been mandated by law. In the mining scheme submitted for approval to the DMR, the mine operator usually promises to prevent environmental degradation, to protect the environment as much as possible, and to rehabilitate mined land so that it is as near to its former condition as possible. However, because of insufficient law enforcement, in practice, little or no effort has been expended to implement these promised changes, and several pits or holes have been left untouched. Some mined areas, especially the hydraulic mines, are so eroded that great efforts are needed to restore them to a useful condition.

Between 1972 and 1987 many mining concessions expired, and some parts of the remaining land areas (approximately 255,153 rai) were reserved. Most of these areas are public property, and the rest is divided between private and nontitled properties. As of the end of 1987, approximately 128,000 rai of expired mining lands are left to be rehabilitated, which will cost the government approximately 3,600 million baht based on the cost per rai of the Bangrin project in Ranong Province, which is indicative of the minimum rehabilitation costs. In normal practice the mined land must be rehabilitated for agricultural and other uses. However, some of the mined land area may have been converted to titled land through the cooperation of the concerned parties thereby depriving the government of the chance to distribute such land to needy farmers. Private land areas could be turned into orchards, plantations, or even rice fields after mining, but there is little that the government could do to improve private land that still belongs to the owners. Thus, land rehabilitation efforts will become a major factor for inducing support from other agencies for the development of mineral resources in reserved or restricted areas of Thailand.

Institutional Arrangements

The ONEB and the DMR are the two government agencies responsible for the implementation of mineral-activity-related environmental measures. These measures are designed to protect and rehabilitate the environment. The agencies' functions are as follows:

The Office of the National Environment Board (ONEB): According to the Improvement and Conservation of National Environmental Quality Act (which was amended in 1975 and 1978), a proposed mining project of any size must submit an environmental impact assessment (EIA) report to the ONEB for approval before

commencement of their respective activity. The impact assessment must fully address any aspects relevant to the surrounding environment as well as the possible future implications. Upon approval, the ONEB usually stipulates a set of conditions to be followed by the operator for work operation to ensure the safety of personnel and minimize the danger to the public. The ONEB then asks the DMR to occasionally inspect the mining activity and to determine whether all the conditions are being met. The ONEB may dispatch officials to observe and to periodically check the performance of the operation, but it does not have any legal power to issue orders to the operator.

The Department of Mineral Resources (DMR): To acquire a mining lease (ML), a private individual, or concern, must submit a work scheme and plan with attached necessary diagrams along with an application. In addition to specifying technical details concerned with mining and beneficiation operations, the applicant must also state clearly how he plans to protect or rehabilitate the environment in the mining area. Such commitments are mandatory, and although the operator is well aware of this fact, little is actually done to fulfill the alleged commitments. Although a mine inspector, usually a mining engineer, performs inspections regularly, the mine operators always ignore the warnings since the DMR officials are lenient. As a result of this leniency, harm is gradually being done to the environment. The mine inspectors are legally empowered to rectify any wrongdoing in a mineral activity, but their failure to enforce the law and the commitments of mine operators leads to an unhealthy relationship with the mineral industry as a whole.

LAND-USE ISSUES

While other land-use activities such as agriculture, forestry, and construction can be performed in a wide range of locations, the sites for mineral extraction cannot be freely chosen because minerals deposits are found in specific geological environments. Normally, sites for mining are relatively small, but they are the most concentrated accumulations of essential resources. With some possible exceptions, the production of mineral resources should, therefore, receive high priority in areas with high levels of mineral potential.

Land-Use Problems in Mining

The availability of mineral resources is roughly proportional to the areas in which mineral operations are possible, and a reduction of the quantity of land which has

potential for mineral development can result in a reduction of the mineral resource base. Thailand may not have a shortage of mineral resources, but it may, instead, run out of areas where the resources can be developed. Of the total land area in Thailand (320,697,000 rai), less than 1 percent has been allocated for mining activity, and the proportion has been declining. Approximately 393,000 rai were allocated for mining areas in 1978, and 321,000 rai in 1989—a decline from 0.12 percent in 1978 to 0.10 percent in 1989, as shown in Table 5.1. Approximately 42 percent of the total mining concession area (or 136,210 rai out of 320,880 rai) is in the Southern part of Thailand where tin mining in dominant (see Table 5.2).

Table 5.1 Onshore Mining Concession Area in Thailand, 1978-1989

Unit: Thousand Rai

Year	Concession Area	% of Total Country Area
1978	393.18	0.1226
1980	433.27	0.1351
1982	434.55	0.1355
1984	419.16	0.1307
1986	404.40	0.1261
1988	348.28	0.1086
1989	320.88	0.1001

Source: Mapping Section, Department of Mineral Resources.

Table 5.2 Mining Concession Areas Classified by Region, 1989

Region	No. of Concessions	Total Area ('000 Rai)	Conc.Area ('000 Rai)	%of Total
Country	2206	321,544.10	320.88	0.10
Northern	530	85,073.08	68.61	0.08
Central	629	159,290.39	105.17	0.07
Eastern	78	10,669.00	7.10	0.07
Northeastern	38	21,466.43	3.79	0.02
Southern	931	45,045.21	136.21	0.30
Total	**2,206**	**320,697.00**	**320.88**	**0.10**

Source: Mapping Section, Division of Survey and Division of Planning, Department of Mineral Resources.

The operating concession areas classified by type of minerals for the years 1981, 1983, and 1989 shown in Table 5.3, have not increased much during the last decade, and for some minerals such as gypsum and iron, the areas are even lower. Tin mining accounts for most of the concession area (over 50 percent), while limestone and lignite occupied a much smaller, but still substantial, area of land.

In an effort to preserve the country's forests, a government resolution for watershed classification in May 1985 declared that: (1) with no exception, all development activity would be prohibited in the forest areas designated as Category 1A, (2) Watershed Category 1B was subject to government approval on a case-by-case basis, and (3) mining was allowed to operate in reserved forest areas from categories 2-5.[1] Currently, it has become even more complicated and more difficult to obtain permission to operate a mine in any category of reserved forest because of the revocation of forest concessions countrywide in January 1989. The revocation of forest concessions results in a re-classification of the country's forests which are now pending classification as national parks, wildlife reserves, economic forests, and land reform zones.

Table 5.3 Operating Concession Area Classified by Type of Minerals

Unit: Thousand Rai

Mineral	Operating Concession Area		
	1981	1983	1989
Total Operating Concession Area	189.98	231.92	264.38
Tin	96.21(50.6)	121.69(52.5)	136.50(51.6)
Lignite	2.60(1.4)	4.94(2.1)	12.56(4.8)
Limestone	5.38(2.8)	12.80(5.5)	16.24(6.1)
Gypsum	3.75(2.0)	3.61(1.6)	2.93(1.1)
Feldspar	2.14(1.1)	3.43(1.4)	8.14(3.1)
Kaolin	2.80(1.5)	2.11(0.9)	7.01(2.7)
Shale	1.34(0.7)	3.28(1.4)	3.56(1.3)
Glass sand	0.60(0.3)	0.71(0.3)	0.69(0.3)
Ball clay	0.09(0.1)	0.14(0.1)	1.23(0.5)
Iron ore	3.14(1.7)	0.95(0.4)	1.49(0.6)
Zinc	—	—	0.25(0.1)
Others	71.93(37.8)	78.26(33.8)	87.8(27.8)

Notes: Figures in parentheses are percentages of the total.

[a] Onshore Tin

Source: Mapping Section, Division of Survey and Division of Planning, Department of Mineral Resources

Because the process of land reclassification is ongoing, all mining applications are now pending. A total of 75 applications—both new applications and license renewals—are still pending in 27 provinces, and approximately 95 percent of the areas of these pending cases are located in the national forest reserves as shown in Table 5.4.

Table 5.4 Pending Mining Applications

Watershed Classification Area	No. of Applications	Area			% of Total
		Rai	Ngan	Wah	
1A	2	104	1	83	1.0
1B	2	194	1	72	1.8
2	12	1,337	0	99	12.7
3	11	1,890	3	25	17.9
4	7	665	2	24	6.3
5	21	2,770	1	24	26.3
Unclassified National Forest Reserve	16	3,367	1	52	31.9
Outside of National Forest Reserve	4	225	2	15	2.1
Total	**75**	**10,555**	**2**	**94**	**100**
National Forest Reserve	71	10,330	0	79	97.9
Outside of National Forest Reserve	4	225	2	15	2.1

Sources: Department of Mineral Resources and Mining Industry Council of Thailand

The current land area classification system for Thailand is shown in Table 5.5. Forty percent of the total area is forest reserve, of which 15 percent is conservation forest, and 25 percent is economic forest. Any activities, including mining, in conservation forest areas are strictly prohibited, and several restrictions apply to mining activities in economic forest areas. Because the other areas in the country are classified as urban areas, water bodies, and areas for settlement programs, only small, site-specific areas are available for mining activity. The policy to reclassify the country's forest area, if approved by the government, will increase the total area of conservation forest to 20 percent of the total country area and reduce the total area of economic forest to 20

percent of the total country area. An increase in conservation forest will further reduce the area for mining concessions and limit the possibility of discovering new deposits.

Table 5.5 Land Classification, 1990

Unit: Thousand Rai

Area Classification	Quantity	% of Total Country Area
Forest reserve areas	128,279	40
Conservation forest	48,105	15
Economic forest	80,174	25
Urban area	2,737	1
Water body	3,059	1
Land allocated by major settlement program	102,046	32
Others	84,576	26
Total Country	**320,697**	**100**

Sources: Thailand Development Research Institute (1987), and the combined meeting report from the National Economic and Social Development Board and the U.S. Agency for International Development (1990, in Thai).

Efficiency of Land Use

The efficiency of land use in mining can be assessed from the level of productivity generated from a unit area of land. The productivity rate may be determined by the production of a mineral per rai of the corresponding operating concession area. Table 5.6 presents comparative information on the efficiency of land use for selected minerals.

Table 5.6 Efficiency of Land Use for Selected Minerals

Unit: Tons/Rai

Mineral	Productivity			Intensity of Land Use in 1989 (Rai/1,000
	1981	1983	1989	
Tons)				
Tin[a]	0.223(73)	0.112(31)	0.084(10.7)	11,905
Lignite	649(65)	375(50.8)	708(261.3)	1.4
Limestone	1,020	699	983	1.0
Gypsum	144(39.2)	308(53)	1,870(187.2)	0.5
Feldspar	11	14	61	16.4
Kaolin	5	17	47	21.3
Shale	841	366	689	1.5
Glass sand	129	164	430	2.3
Ball clay	20	35	106	9.4
Iron	20(1.2)	42(2.2)	119(20)	8.4
Zinc	-	-	1,650	0.6 (3.0 for Zinc metal)

Notes: Figures in parentheses are the GDP per rai in thousand baht.
[a] Onshore tin

Source: Compiled from Mineral Statistics of Thailand and Table 5.2.

The productivity of tin mining has been declining; it decreased from 0.223 metric tons per rai in 1981 to 0.084 metric tons per rai in 1989 indicating less efficiency of land use in tin mining over time. This is probably due to the fact that the grade of tin ore mined has become lower and more difficult to recover during the past few years. The amount of lignite produced per rai has fallen from 649 metric tons per rai in 1981 to 375 metric tons per rai in 1983, mainly because new discoveries added more operation area, while the annual production did not increase much. Limestone and shale followed the same trend when larger areas were put into operation, while production capacities did not improve proportionately. Other minerals show an increasing trend in productivity per rai of their operating concession area, especially gypsum, which has markedly increased from 144 metric tons per rai in 1981 to 1,870 metric tons per rai in 1989. The use of land for zinc mining has proven very efficient; a high level of productivity has been generated from a small area.

Intensity of land use, expressed in rai per 1,000 metric tons of mineral produced in 1989, shows that the production of 1,000 metric tons of tin required 11,905 rai of land, while zinc required only 0.6 rai. Limestone, gypsum, shale, glass sand, and lignite utilized land areas ranging from 0.5 rai to 2.3 rai per 1,000 metric tons of production. Ball clay and iron ore used more extensive land areas—between 8.4 rai to 9.4 rai per 1,000 tons—and even larger areas were needed for kaolin and feldspar. The intensity of land use reflects the quantity of areas needed in producing the specific minerals and the reclamation costs to be borne to rehabilitate these areas.

Factors determining land-use efficiency in mining are not only the intensity of technology applied, which can increase mineral recovery from the same area of land, but also the physically constraining geological factors, which can limit the recoverable amount of mineral extracted. For minerals with low productivity such as tin, kaolin, and feldspar—whose returns per rai are also relatively low (see Table 5.7)—recovery activities should be improved, otherwise, any occupied, nonproductive area should be released for other uses. Issuing new concession areas for the five minerals for which production value per rai is relatively low—including tin, kaolin, feldspar, ball clay, and iron ore—should be made only if all costs are taken into account and the amount of minerals in the areas is known to be substantial. Although other minerals have high production values per unit area which are due partly to good prices, it is also necessary to optimize the use of the present land available by applying more intensive extraction technology and by improving reliable reserve estimates so that mineral-bearing land that is worth exploiting, is not overlooked.

Table 5.7 Production Value per Rai of Operating Concession Area for Selected Minerals, 1989

Unit: Baht/Rai

Mineral	Production Value/Rai
Tin[a]	16,400
Lignite	354,200
Limestone	83,600
Gypsum	463,600
Feldspar	41,900
Kaolin	17,500
Shale	62,100
Glass sand	150,900
Ball clay	36,800
Iron ore	35,600
Zinc	18,472,000

Note: [a] Onshore tin

Sources: Compiled from Mineral Statistics of Thailand and Table 5.2

End Note

[1] Watershed Class 1 refers to protected forest (conservation forest). Both Class 1A and 1B are areas of protected forest and headwater source areas, but the areas in Class 1A still remain under permanent forest cover, while for Class 1B, portions of the area have already been cleared for agricultural use or are occupied by villages.

Watershed Class 2 refers to commercial forest.

Watershed Class 3 refers to fruit tree plantation.

Watershed Class 4 refers to upland farming.

Watershed Class 5 refers to lowland farming.

Chapter 6

Forecast for Mineral Consumption

The domestic demand for indigenous minerals has been continuously growing as a result of the high growth of both the energy sector and the domestic downstream industries—especially the cement, glass, and ceramic industries. The major end-use sectors of these downstream industries are fast becoming more important to the Thai economy as they contribute substantially to the GDP. The products manufactured by the downstream industries generate export revenues or save the country's foreign exchanges as they produce import-substitute products (as long as the foreign exchange expended on imported inputs and forgone foreign exchange for non-exported raw materials amount is less than the foreign exchange earned or saved.) The continued development of the high-growth sectors requires a secure mineral supply, either from domestic sources or from imports, and for the effective management of the domestic mineral supply, it is useful to have a rough idea of Thailand's future mineral consumption trends. The goal of Chapter 5 is to forecast the consumption of some selected, critical minerals.

Among the main minerals produced in Thailand (as discussed in Chapter 3), 11 minerals will be studied in more detail: ball clay, feldspar, glass sand, gypsum, iron ore, kaolin, lignite, limestone, shale, tin, and zinc. The minerals are selected with respect to their importance to the economy. Except for feldspar, gypsum, and tin, all selected minerals are classified as consumption-oriented minerals. More attention is paid to this group since their importance to the economy is expected to continuously increase in proportion to related domestic downstream industry growth. Tin, gypsum, and feldspar are also chosen for the study due to the fact that tin is the most-exported mineral in Thailand, and gypsum and feldspar are crucial raw materials for the booming downstream cement and glass industries. The selected minerals represent as much as 93 percent of the total quantity of mineral consumption, or 98 percent of the total values of consumption.[1]

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The selected minerals can be divided into four categories:

1. **Cement Manufacturing Raw Materials:** Gypsum, iron ore, limestone, and shale
2. **Glass and Ceramic Raw Materials:** Ball clay, feldspar, glass sand, and kaolin
3. **Metallic Minerals:** Zinc and tin
4. **Energy Minerals:** Lignite

The consumption of cement, glass, ceramic raw materials, and tin will be forecasted based on available information and using an end-use approach. In the production processes of cement, glass, and ceramics, fixed combinations of the mineral raw materials are required, and substitutions are rarely made. Sixty percent of domestic tin consumption is by the tinplate industry, and tin is used in an approximately fixed proportion to tons of tinplate produced. By knowing the future consumption of cement, glass, ceramics, and tinplate, we can more easily predict the future consumption of the related minerals.

The planned capacities of the ceramics and flat glass industries are reported by the producer, and a forecast of mineral consumption will be made from these reports. The capacity reflects the quantities of the products that can be produced and the usage of raw materials (based on the assumption that the production capacity is always fully utilized). The actual consumption of the minerals will be less than the forecast given an unused capacity. Therefore, the forecast will present the maximum annual consumption of the minerals.

For the minerals and products for which planned capacities are not reported—cement, glass bottles, glass tableware and kitchenware, tinplate, and zinc—the forecast will be made using econometric models.

The future domestic consumption of lignite is discussed, based on the study conducted by the World Bank (1989).

In general, *consumption*, not production, of the final products will be forecasted to determine the total quantities of the minerals needed to serve domestic demand. However, glass bottle production seems to better indicate mineral usage than consumption because there is high annual rate of glass bottle recycling. Using the quantities of glass bottles consumed at any period to estimate the quantities of the minerals used will constitute overestimation. Production is also forecasted for glass

tableware and kitchenware due to the unavailability of consumption data. In this case, production is a good representation of consumption because most glass tableware and kitchenware produced in Thailand are used domestically. The exported and imported quantities are small compared to the quantities produced.

The forecasts are made for the following time periods (also see Appendix A for details of the study):

1990-2010 — limestone, shale, iron ore, gypsum, zinc, and tin
1990-1994 — glass sand, feldspar, kaolin, and ball clay
1990-2000 — lignite

THE CEMENT INDUSTRY

During recent years (1978-1989), the construction sector has expanded more rapidly than other manufacturing sectors such as mining and quarrying, electricity, and water supply. In 1988, 5.1 percent of the GDP originated from the construction sector which has subsequently increased its consumption of construction materials, most notably cement. Thailand's cement production increases over time along with domestic cement consumption which creates a high demand for raw materials.

Domestic Cement Market

The domestic cement market is an oligopolistic market. Competition among producers is not strong because domestic supply is always less than domestic demand. In addition, the producers usually do not have definite power to determine prices because cement is one of the government-controlled commodities.

A variety of different qualities of cement are produced for varying end uses: mixed cement, portland cement, white cement, fonder cement, and hydraulic cement, for example. In this study, the term cement includes mixed cement and portland cement, since these two cements are mostly used by the construction sector and are mostly produced in Thailand.

Cement is a construction material that is important for the economy: it is used for housing construction, commercial building, and infrastructure development. It can also be used to produce products such as cellocrete cell and high-pressed concrete. The basic factor determining cement consumption is economic growth, which will reflect the construction demand of both the private and public sectors. The price of cement is also

expected to have some effect on consumption, although it will be less than the effect of economic growth.

Cement consumption has increased with the growth of the construction sector because there are no efficient substitute materials. The consumption increased from 2.5 million metric tons in 1970 to 11.5 million metric tons in 1988 (see Appendix D, Table D3).

Presently, the domestic cement industry is operating with a total production capacity of approximately 15.15 million metric tons (increased from 3.5 million metric tons in 1970).[2] A large expansion of the cement industry is expected in the near future, and in addition to the expanded capacity of the existing companies, five new companies are entering the industry.[3] The total capacity of the domestic cement industry is expected to be approximately 36.61 million metric tons by 1994.

Before 1974 domestic cement prices moved freely depending on supply and demand. Because of an increase in domestic cement prices during the first oil crisis in 1973, the government implemented the Anti-Profiteering Act in February 1974 to determine the ceiling for cement retail prices. This act, and other similar attempts at regulation, were subsequently adjusted and cancelled throughout the 1970s and early 1980s. At present, cement prices are again determined by the market system. The current retail price of portland cement is about 1,800 baht per ton.

Export & Import Cement Markets

The domestic cement industry targets satisfying domestic consumption, and only a surplus or a shortage will be traded internationally. Export or import cannot be conducted freely; the government has control of the volume of cement traded. During the period from 1970-1977, local production outpaced domestic consumption, but after 1977, domestic consumption increased dramatically causing domestic shortages and import requirements—especially from 1978-1980. Cement importation was reduced when production capacity in the country was expanded (see Appendix D, Table D4).

The markets for Thai exports include Indonesia, Singapore, Hong Kong, and the Lao People's Democratic Republic, and Thailand purchases cement from Australia, Taiwan, and Japan.

Forecast for Cement Consumption

The future of cement consumption is based on projections of: (1) future cement prices and (2) the GDP from the construction sector. The forecast is made for two different scenarios.

Case 1 assumes that the future real price of cement will have the same pattern as that during the sample period.

Case 2 assumes that the future nominal price will rise at the same rate as inflation (see Appendix A, Table A4).

The nominal and real prices of cement in Case 1 will fluctuate, while the nominal prices in Case 2 have a smoothly increasing trend, and the real price is relatively constant (see Appendix A, Figure A1).

The results of the forecast clearly show that, although production is at full capacity, some shortage still can be expected from 1990 to 1993. If the capacity is expanded to 36.6 million metric tons in 1994, as reported by the Federation of Industry of Thailand, and capacity is fully utilized, the shortage will disappear. Further expansion is also required by the year 1996, or the cement shortage can be expected again (see Appendix B, Table B1).

Forecast for Cement Raw Materials

The major raw materials used for cement production are limestone, gypsum, shale, and iron ore. As reported by the Siam City Cement Company and Thai Petrochemical Industry Company, every 1 kilogram of cement clinker requires the following combination of raw materials:

Limestone	1.200	kg
Shale	0.392	kg
Iron ore	0.008	kg

In addition, 95 percent of cement clinker will be mixed with 5 percent of gypsum to produce portland cement.

Using this information, consumption of cement raw materials can be predicted (see Appendix B, Table B2).

THE GLASS AND CERAMIC INDUSTRIES

The glass- and ceramic-manufacturing industries are increasingly more important to the Thai economy. Originally, glass and ceramics were produced for import substitution, but products now generate considerable export revenues for the country. Most of the main raw materials used in the glass and ceramic manufacturing industries are low priced and come from domestic sources.

Domestic Glass Market

Glass products can be divided into three groups: (1) flat glass, (2) glass bottles, and (3) glass tableware and kitchenware. Local production of glass generally serves domestic demand, and a small amount is exported. The domestic glass market is an oligopoly; there are only a few dominant producers in the business.[4]

Flat glass products include sheet glass, float glass, figured glass, polished plate glass, and tinted (or heat absorbing) glass. Flat glass is mostly used in the construction sector and demand mainly depends on construction sector growth. The demand has increased moderately in the past, but it has had a high growth rate over the last two years due to construction sector expansion. The consumption of flat glass was 124,730 metric tons in 1988, compared with 87,866 metric tons in 1986 (see Appendix D, Table D5).

Consumption data is difficult to collect for glass bottles and glass tableware and kitchenware. Because glass bottles (mostly used in the beverage industry) have high annual recycling rates, the actual consumption will be greater than the amounts produced annually. The consumption of glass bottles is expected to grow with the expansion of the beverage industry. The consumption was 351,715 metric tons in 1988 (see Appendix D, Table D6).

The quantities of glass tableware and kitchenware produced, as well as the growth rate of production each year, are small relative to other glass products manufactured. The consumption is not expected to increase greatly because close substitutions can be found easily including ceramic, plastic, aluminum, and stainless steel tableware and kitchenware. The consumption of glass tableware and kitchenware was 26,667 metric tons in 1988, compared with 28,463 metric tons in 1987 (see Appendix D, Table D6).

The current production capacity of flat glass is 250,000 metric tons, and that capacity is expected to be 512,000 metric tons by 1993 when two new entrants come into the business.[5]

The total production capacity of glass bottles is approximately 360,000 metric tons,[6] and of glass tableware and kitchenware is 28,000 metric tons per annum.[7]

The prices of glass products are determined by market supply and demand. Prices have increased over time, but at rates less than the inflation rate, so they have shown a declining trend in real terms over the past twenty years.

Export & Import Glass Markets

The export values of glass products in 1987 were around 874 million baht at constant 1984 prices, increasing substantially from 1980. Flat glass represents the largest amount of glass export and import.

The flat glass industry has and will receive promotional privileges from the government (from 1989-1998), and therefore, the products must be exported at some certain percentages.[8] Japan, Hong Kong, Singapore, and Australia are the major export markets for glass products, while the major import markets are the United States, West Germany, Japan, and France.

Forecast for Glass Production

The consumption of glass raw materials is forecasted from the projected quantities of glass production. The flat glass production is assumed to be equal to the planned capacity, thereby reflecting full capacity utilization of the glass-manufacturing companies. The planned capacity is further estimated based on the assumptions that new plants operate at only 80 percent of capacity for the first year of operation and at 90 percent of capacity for the second year. Plants can run at full capacity during and after the third year of operation (with time allotted for repair and maintenance).

The production of glass bottles, tableware, and kitchenware is forecasted by using econometric models. Glass bottle production is specified as a function of (1) its price during a previous period, (2) the GDP, and (3) the value added of the beverage industry, while glass tableware and kitchenware production is determined as a function of (1) its price at a previous period, (2) the GDP, and (3) the production of ceramic tableware and kitchenware lagged two periods. The forecasts are then made according to the expected values of the explanatory variables and are separated into two scenarios as follows:

Case 1 assumes the future nominal prices increase at an average growth rate during the sample periods (6.0 percent per annum for glass bottles and 6.5 percent per annum for glass tableware and kitchenware).

Case 2 assumes the future nominal prices will rise at the same rate as the forecasted inflation rate (see Appendix A, Table A4).

Therefore, the growth rates of future nominal prices of both glass bottles and glass tableware and kitchenware in Case 1 will be higher than those in Case 2, causing the real prices in Case 1 to increase moderately, while real prices in Case 2 remain constant (see Appendix A, Figures A2-A3). Glass production forecasts are shown in Appendix B, Table B3.

Forecast for Glass Raw Materials

Most of the raw materials used in the glass industry come from domestic sources, and a major raw material is glass sand. Although more than 60 percent of raw materials are found in Thailand, the cost of domestic raw materials is less than that of imported materials. In the flat glass industry, for instance, 80 percent of raw materials used come from domestic sources. However, these domestic raw materials cost only 23 percent of total raw material expenditure because soda ash (which is approximately 12 percent of the total weight of raw materials) has to be imported and is expensive. (Soda ash's price is 4,600 baht per ton while glass sand's price is only 355 baht per ton in 1989.) Therefore, the production costs for the glass industry will depend on prices of soda ash and fuel oil. (Fuel oil is used at a rate of approximately 200 liters to 400 liters per one ton of burning glass, depending on the type of burning stove).

The proportions of raw materials contained in one kilogram of flat glass are as follows:

Glass sand	0.457 kg
Soda ash	0.162 kg
Feldspar	0.068 kg
Dolomite	0.150 kg
Sodium sulphate(or salt cake)	0.010 kg
Cullets	0.153 kg

In the production process, however, there are weight losses of some raw materials due to chemical decomposition. The actual quantities of raw materials required to produce 1 ton of flat glass are thus greater than the above ratios. According to the producer's information from 1989, glass sand and feldspar were consumed at a rate of approximately 103,704 and 15,456 metric tons, respectively, and total production of flat

glass was 167,722 metric tons. That is, approximately 0.62 metric tons of glass sand and 0.09 metric tons of feldspar are contained in 1 metric ton of flat glass. These ratios will be used to calculate the consumption of glass sand and feldspar in flat glass production.

The composition of raw materials for glass bottles and glass tableware and kitchenware are the same, and the combination ratio of the raw materials per kilogram of product is as follows:

Glass sand	0.50	kg
Limestone	0.15	kg
Dolomite	0.05	kg
Soda ash	0.20	kg
Cullets	0.10	kg

With this ratio, the consumption of glass raw materials from 1990-2010 can be predicted, as shown in Appendix B, Table B4.

Domestic Ceramic Market

The domestic ceramic market has expanded greatly due to the government's protective tariff and import control policies. The government has also promoted investment in the ceramic industry, especially for producers who primarily export.

The ceramic-manufacturing industry is composed of five product groups: (1) tiles, (2) sanitary ware, (3) tableware and kitchenware, (4) articles of furniture and adornment, and (5) other ceramic products. The study will focus on three types of ceramic products that are quantifiable: tiles, sanitary ware, and tableware and kitchenware.

Ceramic tiles, the major ceramic products, account for more than 70 percent of total domestic consumption. Consumption of ceramic tiles as well as sanitary ware is mostly from domestic supply, and import is only a small proportion of total domestic consumption.

The ceramic tile industry's production has increased over time from 55,214 metric tons in 1977 to 221,200 metric tons in 1988 (see Appendix D, Table D7). Production will most likely continue to increase due to an expansion of both the export and domestic

markets. At present, there are 14 companies in the ceramic tile industry with a total production capacity of approximately of 647,000 metric tons per annum.

The domestic production of sanitary ware was started in 1970, with the goal of replacing imports. The industry has grown extensively since 1978 when the government initiated a policy to protect the domestic market by forbidding imports. Currently, there are six companies in the sanitary ware industry with total capacity of 67,000 metric tons.

About 60 manufacturers are producing ceramic tableware and kitchenware, and most of them are small-scale manufacturers or household manufacturers. The total current capacity is 69,000 metric tons per annum. (The statistics on production, export, import, and consumption of ceramic sanitary ware, and tableware and kitchenware are shown in Appendix D, Tables D8-D9.)

The prices of ceramic products are determined by supply and demand. The nominal prices of ceramic tiles and tableware and kitchenware have a declining trend, whereas sanitary ware is rather constant. The current nominal price of ceramic tiles is approximately 11,000 baht per ton, while the nominal price in 1980 was 39,000 baht per ton. The current nominal prices of sanitary ware, and tableware and kitchenware range between 35,000-40,000 baht per ton.

Export & Import Ceramic Markets

The export of ceramic products has increased over time as a result of cheaper labor costs and the availability of domestic raw materials. Ceramic tiles are the major ceramic products exported. The quantities of export have been increased, especially during the past three years. The export markets (which earned about 686.5 million baht from export in 1986 and increased to 2,015 million baht or 193.5 percent in 1988) are the United States, Australia, West Germany, and Singapore. The potential export markets are Japan, Hong Kong, the Netherlands, and the Middle East.

Sanitary ware is the second largest ceramic product exported. Hong Kong and the United States are the major customers, and other markets include Japan, the Republic of Korea, and Singapore. The United States is a major market for export ceramic tableware and kitchenware, while other export markets include Belgium, the Netherlands, West Germany, and Japan.

Since 1978, the importation of ceramic products can be made only in some special cases, and the import markets include Japan, Italy, the United States, Hong Kong, and Britain.

Forecast for Ceramic Production

The forecast for the future consumption of ceramic raw materials is made from the amounts of capacity planned by the producers presented in Appendix B, Table B5.

Forecast for Ceramic Raw Materials

The proportions of raw materials consumed in the production process of ceramics are varied depending upon the techniques of production. The approximate ratios are as shown below.

For 1 square foot of ceramic tiles, which weighs approximately 1 kilogram, the materials are used in the following proportions:

Kaolin	0.37	kg
Feldspar	0.28	kg
Ball clay	0.23	kg
Glass sand	0.12	kg

The materials used per kilogram of sanitary ware are as follows:

Ball clay	0.35	kg
Kaolin	0.30	kg
Feldspar	0.25	kg
Glass sand	0.10	kg

The production per kilogram of tableware and kitchenware includes the following approximate proportions of the raw materials:

Kaolin	0.20-0.40	(average 0.30)	kg
Ball clay	0.10-0.30	(average 0.20)	kg
Feldspar	0.15-0.35	(average 0.25)	kg
Glass sand or quartz	0.20-0.35	(average 0.25)	kg

The consumption from 1990-1994 of all ceramic minerals, except glass sand, is predicted based on the above requirement ratios. The actual quantities of glass sand required in the production process will be less than the ratios presented above because silica dioxide (SiO_2), which is a component in glass sand, is also available from other ceramic minerals such as quartz and clay. Therefore, the requirement ratio of glass sand will be adjusted accordingly, and the future consumption of glass sand will be derived from the quantities reported by the producers. The forecast is presented in Appendix B, Table B6.

METALLIC MINERALS

Domestic Zinc Market

Zinc is used as an input for finished or semi-finished products in many industries in Thailand, and local utilization of zinc is mostly for galvanizing, die casting, brass, dry cell battery, and zinc oxide manufacturing (see Appendix D, Table D10). The galvanizing industry is the largest user of zinc (with consumption exceeding 60 percent of the total consumption in 1988). In this industry, zinc is used to prevent corrosion of steel products including structural steelworks, sheets, tubes, wires, and nails. The major end user of zinc is, therefore, the construction sector. Zinc diecastings are an important component of the automotive and domestic appliance industries. Zinc mixed with copper in about 35-40: 65-60 proportion is called brass which is used for household utensils, surgical instruments, and musical instruments, for example.

In economies where technology is more advanced, the competition of minerals and materials with zinc are available, although zinc can still compete with its substitutes in most uses. The principal substitutes are aluminum, magnesium, and plastics.

The domestic consumption of zinc is increasing over time along with an increase in the GDP. The consumption was approximately 18,578 metric tons in 1970, and increased to 34,752 metric tons in 1980, and to 64,379 metric tons in 1988. Approximately 90 percent of domestic consumption comes from domestic supply (see Appendix D, Table D11).

Before 1985, when zinc was not produced locally, Thailand had to import zinc for domestic consumption, but after local production was started, the quantities of imported zinc were reduced. Once Thai government realized the importance of having domestic zinc production, in 1985, the government and a private investor, cooperating with two

Belgian firms, Vieille-Montagne International and Machim S.A, established the Padaeng Industry Company to mine zinc deposits and to build a refinery in Thailand. To date, Padaeng Industry is the only Thai zinc producer, with a capacity of approximately 67,000-70,000 metric tons per annum.

There are three main price quotations for internationally traded zinc: the U.S. producers' price, the European Producer Price (EPP), and the London Metal Exchange (LME) price. The U.S. producers' price is based on high-grade zinc and reflects a weighted average of prices charged by individual North American producers. The EPP is quoted for GOB zinc, equivalent to Prime Western, by most producers outside the United States. The EPP's settlement was canceled at the end of 1988.

About 10 percent of the zinc in the world market is sold at the LME price. Prior to 1984, LME was quoted for GOB zinc, but since 1984 it has been quoted for high-grade zinc. The LME has a strong influence on the producers' price and reflects the difference between long-term sales contracts and the current supply-demand situation. These three price quotations usually move in correlation, with the exception of the period from 1973-1974 (the oil crisis period), during which the LME price was significantly higher than the EPP and the U.S. producers' prices. Because the LME price is set based on the supply-demand situation, it is more flexible than the EPP and the U.S producers prices, which are always set under the long-term contract.

Because zinc consumed in Thailand comes from both imports and domestic production, its prices differ. The price of zinc sold by Padaeng Industry is set based on the price in the world market. Prior to 1988, it was based on the EPP, but it has been changed to reflect the LME price after the cancellation of the EPP settlement. However, under the agreement with the government to set domestic prices, the producer will add another portion (varying with the agreement) to the LME price and then subtract 3 percent. The portion added to the LME price is assumed to be the amount equal to the transportation costs from London to Bangkok.[9] The transportation costs from the refinery are usually paid by consumers.

The price of imported zinc is equal to world price plus freight, insurance, and import duty. The rate of the import duty has increased from 6 percent to 20 percent since 1985.

Export & Import Zinc Markets

The zinc produced in Thailand is distributed to domestic consumers first, and the remainder is exported. As domestic demand increases, the quantities exported continue to decline. While 35.9 percent of the supply was exported in 1985, only 20.7 percent of the supply was exported in 1988. The export markets include both the ASEAN countries, namely Indonesia, Malaysia, the Philippines, and Singapore and the nonASEAN countries such as the People's Republic of China, the Republic of Korea, Taiwan, and Japan.

Forecast for Zinc Consumption

The zinc consumption equation is specified as a function of (1) the domestic price (using the posted price from the DMR as a proxy) at a previous period, (2) the producer price index of construction materials at a previous period, and (3) the GDP. The forecast is made for two different scenarios.

Case 1 assumes Padaeng Industry still has the same privilege in setting domestic price, and that the posted price from the DMR is still based on Padaeng sale price plus transportation costs from Tak Province to Bangkok.

Case 2 assumes the posted price of zinc will be equal to LME price plus transportation costs from Tak Province to Bangkok. No additional portion is added to inflate the price (see Appendix A, Figure A4).

The results are not very different for the forecast of both cases (see Appendix B,Table B7). The consumption of zinc in Case 1, where domestic price is higher, is slightly less than in Case 2, where domestic price is lower.

Domestic Tin Market

Tin is mostly used as a protective coating or as an alloy with other metals and is used predominantly in the tinplate, solder, pewter, and bronze industries.[10] The tinplate industry is the major consumer of tin in the domestic market, using approximately 60 percent of total domestic tin consumption, while the solder industry uses approximately 30 percent of total consumption (see Appendix D, Table D12).

Alternative materials can be found to substitute for tin including aluminum, tin-free-steel, glass, paper, and plastics.[11]

The domestic consumption of tin outpaces domestic production. In the past, the consumption was approximately 2 percent to 3 percent of production. In 1970 approximately 64 metric tons of tin were consumed domestically as compared with 22,096 metric tons of production. Consumption has continuously increased, while production has declined (see Appendix D, Table D13). Since 1986 domestic consumption has greatly increased because of the expansion of the tin-using industries—especially the tinplate industry. The domestic consumption accounted for about 19 percent of total production in 1989. Currently, there is only one tinplate producer operating at capacity about 360,000 metric tons per annum (1988 figures). Two new producers are expected by 1993 with a production capacity of 90,000 and 120,000 metric tons per annum.[12]

The production of tin depends on several factors. In addition to climate and soil conditions—and internal factors such as costs, labor, and environmental problems—the world supply and demand have great influence on domestic production. Thailand was a member of the International Tin Council (ITC) before it was collapsed in October 1985, and the country is currently a member of the Association of Tin Producing Countries (ATPC). The quantities of Thai tin exported, were controlled by ITC quotas and are now usually controlled by an ATPC quota. These export controls greatly affected production because the domestic market is limited. During the periods of export control, production will decline.

Locally produced tin comes from both primary and secondary sources (see Appendix D, Table D14). There are seven tin-smelting companies in the country with a total capacity of 46,040 metric tons per annum, and five tin-smelting companies with total capacity of 248 metric tons per annum produce tin from scrap (so-called secondary tin).[13] There are three world tin markets: Kuala Lumpur Tin Market (KLTM), London Metal Exchange (LME) and New York market. The price of domestic tin is based on the KLTM prices.

Within Thailand, tin ore is sold directly to the refinery (for refinement to be tin metal for export, and domestic consumption) or sold to middlemen for further distribution to the refinery.

Export & Import Tin Markets

In the past, tin was one of the major export-revenue-generating economic products for Thailand which was the third largest producer of tin ore in the world after Malaysia and Bolivia. Presently, tin's importance as an export product is less, but its export revenues are still greater than those of any other mineral. Thailand is now the fourth largest producer of tin after Brazil, Malaysia, and Indonesia.

During 1956 to 1985, Thailand was a member of the ITC which integrated a large number of producers and consumers of tin. The dual objectives in forming the ITC were (1) to ensure adequate supply of tin at a "reasonable price" and (2) to prevent excessive fluctuation in tin price. The ITC had two important tools which influenced the market: buffer stock and export control. The buffer stock was a method to control the supply and demand of tin. The stock was released to the market to increase supply when price was high and was built to increase demand in the market when price was low. The buffer stock was intended to be the first tool to mitigate the serious downward pressures on price. If the buffer stock contained less than the given amount, a control period could be declared. When a control period was established, the ITC would allocate quotas to producers according to their production or export figures in the last four consecutive quarters.

The ITC collapsed in October 1985 when it ran out of money to buy the excess supply of tin in the market in order to raise the price; The untenable situation of a low demand and a high supply of tin in the world market had occurred since 1980. The low demand had resulted from the emergence of tin-saving technology and more viable substitutions for tin. A high supply had resulted from a new development of high-grade tin from Brazil, and the General Service Administration (GSA) stockpile sales by the United States.

Although the ITC collapsed in 1985, Thailand is still a member of the Association of Tin Producing Countries (ATPC) which includes Malaysia, Indonesia, Bolivia, Zaire, Nigeria, and Australia. The objective of establishing the ATPC is to set a production quota for the members to stabilize tin prices.

Before 1965 tin was exported in concentrates because domestic smelting companies were less efficient. The country started exporting tin metal after the Thailand Smelting & Refining Company (THAI SARCO) was set up in 1965. Since then the government has allowed only tin metal export.[14]

About 90 percent of locally produced tin is exported because domestic demand is limited. The quantities of tin export fluctuate, and exports are usually decreased during the control periods.[15] The current quota from the ATPC is set at 15,000 metric tons per annum, however, the actual amounts exported are less than the quota because of the decline in domestic production.

The major export markets for tin are Japan, the Netherlands, and Singapore, and other markets include the United States, the Republic of Korea, and Italy.

As one of the major tin-exporting countries, Thailand rarely imports tin except in some items that are unavailable in the country. The values of tin imports are, however, small, compared to those of export and production.

Forecast for Tin Consumption

The forecast for tin consumption is made via the forecast of tinplate consumption. The tinplate consumption is specified as a function of (1) the ratio of tinplate price to aluminum price, and (2) the GDP originated from the food industry. After tinplate consumption is estimated, the consumption of tin in the tinplate industry and other industries is predicted.

The forecast is made in two cases.

Case 1 assumes the future nominal price of tinplate increases at its average growth rate during the sample period which is around 3.54 percent per annum.

Case 2 assumes the future nominal price of tinplate increases at the same rate as the forecasted inflation rate (see Appendix A, Table A4).

Based on these assumptions, the future real price of tinplate in Case 1 will have a declining trend, while Case 2 is relatively constant, causing the real price ratio of tinplate to aluminum in Case 1 to rise at a slower rate than in Case 2 (see Appendix A, Figure A5).

In the past, 8 kilograms of tin were required to produce 1 ton of tinplate. But due to the emergence of tin-saving technology, electrolytic tinplate can currently be produced using only 5-6 kilograms of tin for 1 ton of tinplate. By using an average of 5.5 kilograms per ton of tinplate, the future amount of tin required for the tinplate industry can be estimated.

The future expansion of the domestic tinplate industry (to replace imports) will increase tin consumption. Approximately 70 percent to 75 percent of tin consumption will be from the tinplate industry, while 25 percent to 30 percent will be from other end-use industries. By using this relationship, the consumption of tin in the other tin-consuming industries can be predicted. The results are reported in Appendix B, Table B8.

ENERGY MINERAL: COAL

There are four types of coal—lignite, subbituminous, bituminous, and anthracite—ranking from the lowest to the highest qualities of ore. The majority of coal types found in Thailand are the low-quality, lignite and subbituminous types.

Since the second international oil crisis in 1979, the Thai government has planned to reduce its dependence on energy imports by developing indigenous energy sources. Natural gas from the Gulf of Thailand and domestic crude oil and coal sources have been extensively developed for domestic consumption. The consumption of coal shows an increasing trend over time and, currently, coal use accounts for approximately 10 percent of the total domestic energy consumption.

Domestic Coal Market

Domestic coal is used in both the power and the nonpower sectors. The nonpower sector users include the cement, tobacco-curing, and boiler-using industries, but presently, no household consumes domestic coal.

The power sector, which is the major coal user, consumes more than 80 percent of total domestic coal (see Appendix D, Table D15). The share of coal used for electricity generation is increasing over time to replace petroleum product usage. In 1979 the use of coal for electricity generation accounted for approximately 12 percent of total fuel consumption, but by 1988, coal use increased to 23 percent (see Appendix D, Table D16). Total coal consumption (domestic coal and import coal) was 8.2 million tons in 1988, compared with 4.5 million tons in 1985.

The cement industry is the major consumer of coal in the nonpower sector and represents approximately 10 percent of total domestic coal consumption, or 50 percent of the coal consumption in the nonpower sector. The cement industry switched from oil to coal due to the perceived security of the international coal market and the stability of coal prices. However, international coal prices and transportation costs have greatly increased,

and the Thai cement industry is currently seeking long-term supplies from domestic coal sources. Coal consumption in this sector has increased significantly from 0.6 million tons in 1985 to 1.3 million tons in 1988.

At present, there are some 4,000 industrial boilers in Thailand, most of which use heavy fuel oil, wood, and bagasse, while only a few use coal (including the food processing and pulp and paper industries). Industrial boilers used about 0.1 million tons of coal in 1986, increasing to 0.2 million tons in 1987, and 0.4 million tons in 1988—or approximately 3 percent of total domestic consumption.

The tobacco industry's coal use has declined from 3.6 percent of total domestic coal consumption in 1984 to 2.1 percent in 1985, and 0.5 percent in 1988.

The systematic exploration of coal in Thailand has been carried out by the government, the Department of Mineral Resources (DMR), and the Electricity Generating Authority of Thailand (EGAT) for more than thirty years. The private sector, which did not participate in coal exploration until five years ago, now has an intensive exploration program.

The production of coal has been increasing, especially for use in the power sector. All coal supplied for electricity generation is produced by EGAT (from the reserves at Mae Moh and Krabi) and the National Energy Administration (NEA) has started coal production (in the Li Basin) for the tobacco-curing and cement industries. The private sector has subleased rights from the NEA to produce coal for industrial uses. The two largest coal producers— Ban Pu Coal and Lanna Lignite—generated about 80 percent of the total output for the industrial sector in 1988.

Coal was produced about 7.38 million metric tons in 1988, of which 6.09 million metric tons was used in the power sector, and 1.29 million metric tons was used in the industrial sector (see Appendix D, Table D17).

The production costs for lignite depend on several factors including the depth of the coal seam and the design of the pit slope. Lignite prices from different mines depend on production costs plus mine-to-market transportation costs.

EGAT's lignite production costs range from 356.7 baht to 393.7 baht per ton, whereas the transfer price of lignite to the power plant is 450 baht per ton. Since EGAT

produces coal for its own consumption for electricity generation, the transferred price of coal is not determined by market force. Instead, this price will be determined by adjusting the difference between the import prices of coal and the production costs from domestic sources.

The production costs for private mines excluding taxes, royalties, and marketing expenses ranges from 141 baht to 185 baht per ton at ex mine. The consumer price will vary according to the transportation distance.

Forecast for Coal Consumption

According to the World Bank study (1989), domestic coal consumption is forecast by analyzing the requirements of the four consuming industries: the power sector, the cement industry, industrial boilers, and the tobacco-curing industry.

The demand for electricity in Thailand is projected to grow at approximately 12 percent per annum from 1990-1991, 9 percent per annum from 1992-1996, and 7 percent per annum from 1997-2000. Due to this great projected increase in demand, EGAT has planned to expand production capacity from 7,000 megawatts to 17,400 megawatts by the year 2000. From a least-cost analysis, 6,300 megawatts out of 10,400 megawatts should be coal fired. The demand for coal is thus projected to be approximately 8.03 million metric tons in 1990, 20.75 million metric ton in 1995, and 33.97 million metric ton in 2000. As a result, the proportion of coal used for electricity generation, compared to other fuels, will be 53 percent by the year 2000.

Energy consumption in the cement industry is projected to increase by approximately 7 percent per annum until the year 1995 and by 6 percent per annum thereafter. Along with this increase, the consumption of domestic coal will increase from 1.97 million tons per annum in 1990 to 2.73 million tons per annum in 1995 and to 3.47 million tons in 2000.

Only a select group of industrial boilers have the potential for coal use, especially when considering technical and financial viability. The World Bank has projected the use of coal for industrial boilers at approximately 0.34 million metric tons per annum in 1990, 0.52 million metric tons per annum in 1995 and 0.82 million metric tons per annum by the year 2000.

The consumption of domestic coal in the tobacco industry is projected to increase only moderately for four reasons: (1) the declining trend in the export of Virginia tobacco, (2) the cost comparison of using coal and other fuels in tobacco curing, (3) the perception that coal is a "dirty" substitute fuel, and (4) the possibility of promoting other measures to reduce wood consumption. Consumption is expected to be 0.13 million metric tons in 1990, 0.11 million metric tons in 1995, and 0.10 million metric tons in 2000.

In summary, the total consumption of domestic coal for all sectors is projected to grow from 7.6 million tons in 1988 to 10.47 million metric tons in 1990, to 24.11 million tons in 1995, and to 38.36 million tons by the year 2000. The power sector continues to be the major consumer and the cement industry is still the largest consumer of the nonpower sector. The forecast is shown in Appendix B, Table B9.

The forecasts of all minerals under the study are summarized in Table 6.1 (see also Appendix B, Table B10 and Figures B.1-B.11 for more detail).

Table 6.1 Forecast for Mineral Consumption

Unit : Metric Ton

Year	Limestone[a] (000)	Shale (000)	Iron Ore (000)	Gypsum (000)	Glass Sand[b] (000)
1990	20,558-20,629	6,688-6,711	136-137	904-907	474
1991	24,903-25,446	8,105-8,281	165-169	1,096-1,120	548-552
1992	29,354-29,635	9,554-9,645	195-197	1,292-1,304	597-606
1993	33,788-34,348	10,997-11,179	224-228	1,487-1,511	745-757
1994	35,701-39,00[illegible]	11,616-12,694	237-259	1,571-1,716	840-852
1995	39,024-43,499	12,696-14,156	259-289	1,717-1,914	-
2000	55,262-58,598	17,959-19,041	367-389	2,428-2,574	-
2005	60,776-65,300	19,700-21,144	402-432	2,664-2,859	-
2010	65,277-72,761	21,057-23,411	430-478	2,847-3,165	-

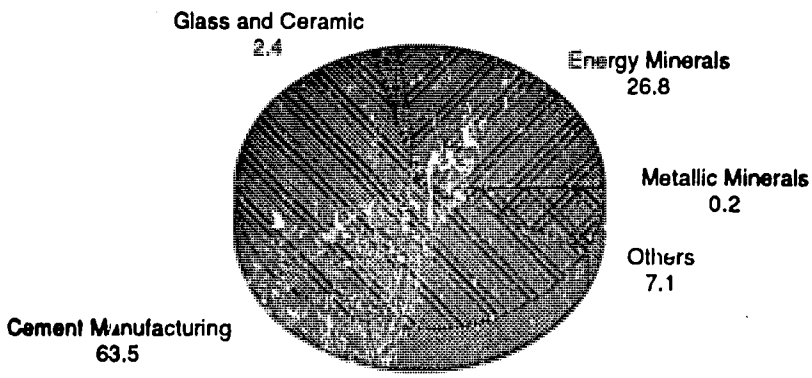
Year	Feldspar[b] (000)	Kaolin (000)	Ball Clay (000)	Zinc	Tin	Lignite
1990	237	280	186	88,046	2,013-2,027	10,470
1991	303	359	239	97,197-97,397	2,156-2,178	-
1992	347	417	277	108,993-109,243	2,317-2,345	-
1993	394	463	308	120,390-120,674	2,481-2,514	-
1994	400	463	308	132,085-132,421	2,650-2,687	-
1995	-	-	-	144,113-144,502	2,822-2,863	24,110
2000	-	-	-	203,514-203,960	3,682-3,736	38,360
2005	-	-	-	298,331-298,887	4,670-4,736	-
2010	-	-	-	486,475-487,507	6,034-6,122	-

Notes: [a] From cement industry plus glass industry.

[b] From glass industry plus ceramic industry.

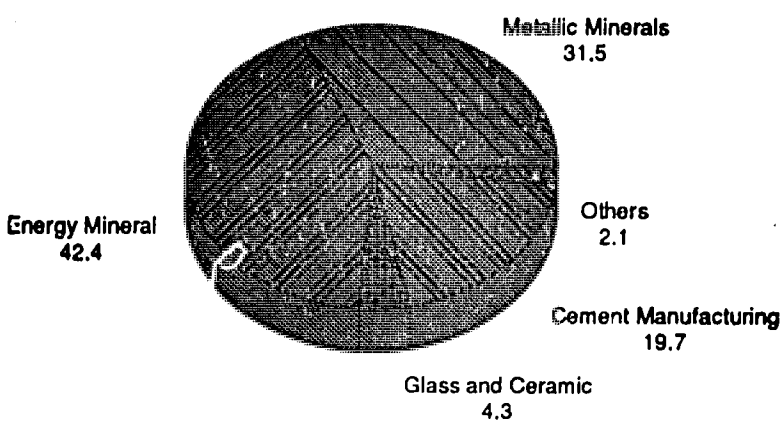
End Notes

1.



Quantity

Unit: Percent



Value

Unit: Percent

2 Currently, there are three local companies operating in the domestic cement market: Siam Cement, Siam City Cement, and Cholapratan Cement. Siam Cement has four plants, operating at full capacity of 9.40 million metric tons including the Bang Saeo plant, the Tha Luang plant, the Kaeng Koi plant, and the Tung Song plant. Siam City Cement has one plant, the Kaeng Koi plant, which is operating at a full capacity of 4.55 million metric tons. Cholaprathan Cement has two plants including the Takli plant and the Cha-Am plant, operating at full capacity of 1.20 million metric tons. There are a total of seven plants, most of which are located in the Central Region.

3 The newest companies include Witsanu Cement, and Krung Thep Cement (with the capacity of 1.5 million metric tons each); Thai Petro Chemical Industry and Asia Cement Company (with the capacity of 2 million metric tons each); Sapha Cement (with the capacity of 1.8 million metric tons); and some small producers (with the total capacity of 1 million metric tons).

4 Until 1988 there was only one company producing flat glass in the country: Thai-Asahi Glass. Siam Plate Glass Industry is a new flat glass producer and began operations in December 1989. However, of the total flat glass production, 88 percent comes from the former and 12 percent is from the latter. There are five producers in the country for glass bottles and glass tableware and kitchenware. About 70 percent of total production of glass bottles comes from Thai Glass Industry and Bangkok Glass Industry, and 60 percent of the total production of glass tableware and kitchenware comes from Union Glass and Ocean Glass.

5 Thai-Asahi Glass Company is the major producer of flat glass. The production has been made from three plants: two sheet processes (S1 and S2) and one float process (F1), with the capacity of 55,000, 27,000 and 137,000 metric tons per annum, respectively. The total capacity of the Thai-Asahi Glass Company is about 219,000 metric tons per annum.

Siam Plate Glass is a new flat glass producer in the country and began operation in December 1989 at a production capacity approximately 31,000 metric tons per annum. Besides these two companies, the

government has permitted a new entrant into the business, namely, the Bangkok Float Glass and, lately, the Guardian Company. The Bangkok Float Glass will start operation in 1991, and the Guardian company is expected to start operation by 1993. Each company will have the production capacity of 131,000 metric tons per annum.

6 The producers of glass bottles include Thai Glass Industry—the largest producer; Bangkok Glass Industry; Glass Organization; SGI; and Union Glass.

7 The producers of glass tableware and kitchenware include Union Glass—the largest producer; Ocean Glass; Thai Glass Industry; Thai Neutral Glass; and Glass Organization.

8 At the beginning, the Board of Investment (BOI) mandated that 30 percent of the products from the latest plant (float process - F1) and 50 percent of the products from the expansion portion (12,000 metric tons) of the first plant (sheet process - S1) of the Thai-Asahi Company must be exported. The glass products from the second plant (sheet process - S2) were for the domestic market. However, after the entrance of the new producers, the BOI has announced that the products from the Thai-Asahi Company can be supplied domestically, and 50 percent of the products from the Bangkok Float Glass and the Guardian Industry Company must be exported.

9 Padaeng price plus the transportation costs, from Tak Province to Bangkok will be used as the price base for collecting zinc royalties.

10 In the tinplate industry, tin is used as a coating for steel containers. Tin is alloyed with lead and sometimes other metals for use as solders for engine bearings, coating engine parts, and for joining pipes and electrical conductors. Pewter, a tin alloy, is normally hardened with antimony and used to make decorative items. Bronze, a copper-tin alloy, is used for the manufacture of construction tools and weapons.

11 Aluminum, tin-free steel, glass, paper, and plastics can be used to substitute for tinplate. Aluminum alloys, other copper-base alloys, and

plastics can be substituted for bronze. However, no satisfactory substitutes have been found for tin in solder, although lowering the tin content of solder may be possible in some applications.

12 The existing tinplate producer is Thai Tinplate Production, and the two new producers are Siam Tinplate and Cha-Am Pineapple.

13 Among these companies, Thailand Smelting & Refining (THAI SARCO) is the largest with capacity of 38,000 metric tons per annum, or about 82.5 percent of total primary tin capacity. Siam Metal Production is the largest secondary tin smelter and has a capacity of approximately 150 metric tons per annum, or 60.5 percent of total secondary tin capacity.

14 THAI SARCO was the only exporter of tin until 1981 when the Thai Pioneer Company came into existence. However, the export proportion of the Thai Pioneer Company is much less than that of the THAI SARCO.

15 The control periods under the ITC agreement were 1957-1960, 1968-1969, 1973, 1975-1976, and 1982-1985.

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Chapter 7

Balancing Supply and Demand: Optimal Resource Extraction

The mineral supply required for domestic consumption can be derived from both domestic production and imports. While domestic mineral reserves still exist, the country has several options for satisfying domestic demand: obtaining the minerals either entirely from domestic sources, entirely from imports, or from both sources by comparing the cost of using domestic resources with the cost of imports. Obviously, the entire supply will need to be derived from imports once domestic reserves are economically exhausted.

Chapter 6 provides an estimate of future mineral demand, and chapter 7 approaches the question of how to satisfy this demand. The purpose of the present chapter is to (1) identify possible mineral shortages in the domestic market by comparing future domestic demand with domestic reserves; (2) to examine possible mineral shortages in the world market by comparing future world demand with world reserves; and (3) to examine optimal resource extraction, taking environmental problems into account.

BALANCING DOMESTIC DEMAND AND DOMESTIC SUPPLY

By definition, reserves are known deposits that have been geologically identified and are currently economically exploitable. Since determining current reserves involves geological accuracy and technological and economic circumstances, current domestic reserves frequently change in response to technology, costs, prices, and the information derived from exploration. A lowering of the cut off grade for ores, caused by changes in prices or costs, can also have a strong upward impact on the level of mineral reserves since it increases the amount of economically recoverable metal in known deposits. The most reliable data on domestic reserves can be obtained from the Department of Mineral Resources (DMR). While the reserve figures reported by the DMR are not definitive,

they can be used as an indicator of the availability of domestic mineral resources and can provide an estimate of future import needs.

The domestic reserves of the minerals under discussion are compared with cumulative demand and summarized in Table 7.1. While the forecasted results discussed in Chapter 6 indicate a high consumption of limestone, its cumulative demand up to the year 2010 is far less than the estimated reserves. The cumulative demand for iron ore is also small relative to the estimated reserves. Thus, shortages of these two minerals for domestic consumption are not anticipated.

A shortage of tin is not likely to occur before the year 2010. The cumulative demand for tin during 1990 to 2010 is about 0.08 million metric tons, compared with 0.14 million metric tons of reserves. However, due to the small difference between the reserves and the expected future demand, exploration activity for new reserves is necessary.

Based on the capacities of the domestic glass and ceramic industries, the cumulative demand for glass sand, kaolin, and feldspar up to 1994 will be very small relative to the current reserves. If the consumption of these minerals during 1995 to 2010 continues at the same growth rate as projected for 1990 to 1994, the reserves will be sufficient for domestic consumption up to the year 2010.

Shortages of gypsum and zinc are indicated. Zinc reserves in 1989 were estimated at about 3.8 million metric tons, and, based on this amount, a shortage is expected to occur by 1993. Considering domestic demand alone, gypsum reserves will be depleted by the year 2007. In fact, the total gypsum production is around 3 million metric tons per annum, and 80 percent of this annual production is for export. Thus, if the production rate continues to be the same, gypsum reserves will be exhausted by 2003.

Table 7.1 Thailand's Mineral Reserves

Unit: Million Tons

Minerals	Reserves[e]				Cumulative Demand[f] (1990-2010)
	Measured	Indicated	Inferred	Total	
Limestone[a]	n/a	n/a	n/a	5474	1047-1123
Gypsum[b]	12	19.8	10.5	42.3	46-49
Iron Ore[c]	----- 23.1 ------		11.7	34.8	6.9-7.4
Shale	-	-	-	-	340-364
Glass Sand[b]	-	19.2	-	19.2	3.2[d]
Kaolin[a]	-	-	-	58.7	2.0[d]
Feldspar[b](Potash and Soda Feldspar)	-	-	43.0	43.0	1.7[c]
Ball Clay	-	-	-	-	1.3[d]
Zinc[c]	-	3.8	-	3.8	4.87-4.89
Tin[b]	-	-	0.14	0.14	0.07-0.08

Notes: [a] Estimated in 1989

[b] Estimated in 1988

[c] Estimated in 1985

[d] Cumulative demand for 1990-1994

Sources: [e] Division of Economic Geology, Department of Mineral Resources

[f] Estimated (see Appendix B, Table B10)

Because the estimated reserves for ball clay and shale, are not available, the shortage projections cannot be given at this time.

It should be noted that the word "shortage" mentioned above refers to the case where the quantity of domestic reserves falls short of the expected future domestic demand, and the statement is made without considering the possibility of additional discoveries, improvement in recovery through technological development, or imports. Given the existence of the mineral world market, a "real" domestic shortage would not occur unless there was a worldwide shortage because minerals can always be imported. An analysis of world supply and demand is necessary to determine the projected real mineral shortages.

BALANCING WORLD DEMAND AND WORLD SUPPLY

Are there possible future shortages of minerals on a worldwide basis? Table 7.2 indicates abundant world reserves of the selected minerals previously mentioned. The estimated reserves for gypsum, kaolin, ball clay, and zinc actually increased between 1970 and 1985, not decrease as expected.

Feldspar exists in great amounts in almost all igneous rock, which constitute a large portion of the earth's outer layers. Feldspar reserves are widely distributed throughout most of the world; very conservative estimates indicate world feldspar reserves of at least 1 billion metric tons. Granite is a potential major feldspar resource, although under present circumstances, recovering feldspar-silica mixtures from granite is only marginally profitable. However, large-scale exploitation of granite for its feldspar and silica contents can become economically feasible in the future. Granite is widely distributed and is available in unlimited quantities. The world supply of feldspar is virtually unlimited if granite is added as a supply source.

Gypsum is the most common naturally occurring sulfate mineral, and it is found in very large deposits worldwide. The reserves were conservatively estimated at 2,600 million metric tons in 1985, while the estimated figure in 1980 was 1,860 million metric tons.

Table 7.2 World Mineral Reserves

Unit: Million Tons

	Reserves			Production		
	1970	1980	1985	1970	1980	1985
Limestone	n/a	n/a	Large	97	117	124
Gypsum	n/a	1,860	2,600[a]	n/a	78	89
					(0.04)	(0.03)
Iron ore	254,334	195,048	n/a	n/a	873.6	845.3
					(0.004)	
Shale	n/a	n/a	Adequate	n/a	n/a	n/a
Glass sand	n/a	n/a	Large	n/a	195	n/a
Kaolin	n/a	11,068	11,794	n/a	n/a	n/a
Feldspar	n/a	907	n/a	2.5	3.2	4.3
					(0.004)	
Ball clay	n/a	1,007	1,089	n/a	n/a	n/a
Zinc	90	135	170	n/a	5.5	5.8
					(0.041)	(0.034)
Tin	n/a	10.0	3.1	n/a	0.3	0.2
					(0.030)	(0.065)

Notes: [a] Estimated in 1989
Figures in parentheses are production/reserve ratios.

Sources: Mineral Commodity Summaries (1990) and United States Bureau of Mine (1985)

Iron is an abundant rock-forming element comprising about 5 percent of the earth's crust. World reserves of iron ore were estimated at 254,334 million metric tons in 1970, and they declined to 195,048 million metric tons in 1980.

World reserves of kaolin and ball clay (estimated in 1985) are around 11,794 and 1,089 million metric tons, respectively. Most kaolin reserves are located in Europe, while most ball clay reserves are distributed in North America.

World reserves of zinc and tin are small compared with other minerals. Zinc reserves (estimated in 1985) are around 170 million metric tons. Tin reserves declined from 10 million metric tons in 1980 to 3.1 million metric tons in 1985.

World reserve data are not available for limestone, glass sand, and shale. However, based on geological evidence it can be assumed that resources and reserves of these materials are virtually unlimited worldwide. (United States Bureau of Mines (1985)).

In addition to being produced as a primary product, some minerals are a coproduct with, and a byproduct of, other minerals.[1]

United States Bureau of Mines (1985) has forecasted the world demand for minerals up to the year 2000. Table 7.3 compares the cumulative demand with the estimated reserves to determine possible mineral shortages. The figures show an adequacy of reserves for world demand up to the year 2000 in all minerals except tin.

The growth rates for mineral demand are not expected to rise as strongly as they did in the past. An increase in the use of scrap or in the recycling of the final product is helping to reduce the demand for minerals from primary sources.[2]

Table 7.3 Balancing World Demand and Supply

Unit: Million Tons

Mineral	Demand in 2000			Cumulative Demand 1983-2000	Reserves
	Low	High	Probable		
Limestone	193	310	220	2976	Plentiful
Shale	n/a	n/a	n/a	n/a	Plentiful
Iron ore	551	1,141	772	10,913	195,048[a]
Gypsum	126	158	143	2,094	2,600[c]
Glass sand	254	331	298	4,299	Plentiful
Feldspar	4.9	5.5	5.1	79.6	907[a]
Kaolin	n/a	n/a	n/a	n/a	11,794[b]
Ball clay	n/a	n/a	n/a	n/a	1,089[b]
Zinc	7.8	11.4	9.4	129	170[b]
Tin	0.18	0.31	0.26	3.93	3.1[b]

Notes: [a] Estimated in 1980
[b] Estimated in 1985
[c] Estimated in 1989

Source: United States Bureau of Mines (1985)

The existence of substitutes is another factor restraining the growth of mineral consumption. This includes the substitution of more plentiful resources for less plentiful ones as well as the substitution of engineering materials or synthetics such as composites, polymers, and supermetals.[3]

Technological progress can help to increase mineral reserves and to reduce mineral demand, and technological advances in exploration, mining, beneficiation, transportation, and consumption will reduce production costs and increase reserves. New technology can reduce energy requirements, thereby lowering production costs, and it can reduce mineral demand through increased efficiency in mineral uses. (For example, electrolytic tin-plate technology has lowered tin usage per ton of tin-plate production.)

In general, it can be concluded that physical shortages of the mineral reserves are not expected. But, will economic reserve exhaustion occur? One method of evaluating the scarcity of resources is to monitor the price path of the minerals, since an increase in mineral resource scarcity is evidenced by a long-term upward trend in real prices. Historically, the real prices of most minerals tend to either decline or to moderately

increase. (The world price paths of some minerals under consideration are shown in Appendix C, Figures C1-C9). While the real prices of limestone, iron ore, ball clay, and gypsum decline over time, the prices of feldspar, kaolin, zinc, and tin are relatively constant. Only glass sand shows an increasing trend in the real prices, although the price rate increase is less than the interest rate. If technological progress, recycling, and substitution, continue at past rates, price increases and scarcities are not likely to occur.

EXPORT RESTRICTION POLICY

There are several arguments for supporting an export restriction policy on domestic minerals in order to prolong domestic reserves and to avoid imports. Because maintaining the domestic supply of minerals will guarantee a supply of mineral raw materials for domestic downstream industries, the government should restrict mineral exports to prolong domestic reserves. It is argued that without controls for mineral exports, existing mineral reserves might be exhausted quickly. Moreover, Thailand can increase the value added by exporting manufactured goods rather than raw minerals.

In actuality, an export restriction policy does not always provide benefits to the country. Imports will benefit the country if importing costs are less than domestic costs (including environmental costs). Thus, an export control policy must be considered on a case-by-case basis. For example, export controls might be appropriate for strategic minerals or for minerals with predicted prices rise but not for minerals in abundant supply. Prolonging reserves can be accomplished through the control of the mineral production or extraction rate, instead of through export restrictions.

The exhaustion of domestic minerals does not present any problem to the economy as long as a supply can be obtained from abroad at the same or lower prices (mineral prices plus transportation costs). Minerals whose production causes severe environmental problems might not be worth producing domestically considering the environmental cleanup costs and residual damage.

Regarding value added by manufacture, the country can also gain value added by importing a mineral for processing and then exporting the final product.

Export control increases consumers' purchasing power and reduces producers' (or miners') bargaining power. For example, if the export of kaolin is banned, all locally produced kaolin must be sold to domestic users, regardless of price. The user will have

the bargaining power to purchase kaolin at the lowest possible price. Thus the domestic prices of kaolin will be less than the export price, and the production will not be efficient. On the other hand, if kaolin can be traded freely, its domestic price will be equal to the (FOB) price since the producer has the choice of either selling kaolin domestically or of exporting it.

While minerals are nonrenewable resources, conservation of a mineral for future use is only worthwhile when the net real price (price minus cost) of the mineral increases at a rate greater than the interest rate. If the net real price of that mineral declines in the future, or if it increases at a rate less than the interest rate, it is more profitable to sell it as soon as possible.

Export control policy is also inappropriate if it is imposed on the minerals with related products that cannot be domestically produced at a comparative advantage since the country will have opportunity costs of producing a commodity in which it does not specialize. In this case, no export control policy is justified.

One method to analyze the comparative advantage of the country in producing a commodity is the Domestic Resource Cost (DRC)[4]. In theory, the DRC will compare the real opportunity cost of using domestic resources with a net marginal unit of foreign exchange earned (for an exportable goods), or saved (for an import substitute) when the domestic resources are traded. The costs of using domestic resources include both direct and indirect production-related costs such as raw materials, labor, and capital, and net social costs. Foreign exchange is in the form of a shadow exchange rate, reflecting a free-trade equilibrium in the balance of payment. If the DRC is higher than the marginal unit of the shadow exchange rate, the commodity in question is over produced and domestic production should be reduced. On the other hand, if the DRC is less than the shadow exchange rate, the implication is that the resource can be derived more cheaply from domestic production than from import and its production should be expanded. This type of product is appropriate for local production and has a comparative advantage for exporting as well.

In two recent studies on Thailand's DRC—Ajanant, Chunanuntathum, and Meenaphant (1986) and Tongpakdee et al. (1990 in Thai)—the former calculated the DRC using a 1975 Input-Output Table and the latter calculated the DRC using a 1985 Input-Output Table. Nine sectors (out of 180 sectors) related to this study were selected, including (1) coal and lignite, (2) tin ore, (3) limestone, (4) ceramic and earthenware, (5)

glass and glass products, (6) cement, (7) other nonmetallic products, (8) iron and steel, and (9) nonferrous metal. The DRC from two different points in time will be compared. The shadow exchange rates used as a cut-off point for comparison of the calculated DRC in 1975 and 1985 are 21.77 baht and 27.16 baht, respectively.

The calculated DRCs in 1975 and 1985 are compared in Table 7.4 which shows that a net unit of foreign exchange earned or saved of all sectors in 1985 was less than that in 1975. This implies that costs of using domestic resources increased or that the country had less comparative advantage of production in 1985 than in 1975. If this situation continues, the present and future costs of using domestic resources can be expected to be even greater than in the past. Several of Thailand's production sectors which were historically efficient producers may be losing their comparative advantage.

Table 7.4 Comparison of DRC in 1975 and 1985

Sector	DRC 1975[a]	Earned (Saved)	DRC 1985[b]	Earned (Saved)
Coal & Lignite	17.61	4.16	27.02	0.14
Tin ore	11.36	10.41	26.99	0.17
Limestone	19.72	2.05	26.58	0.58
Ceramics & Earthenware	20.67	1.10	33.32	(-6.16)
Glass & Glass Products	25.54	(-3.77)	36.94	(-9.78)
Cement	18.98	2.79	26.89	0.27
Other non metallic products	23.52	(-1.75)	43.99	(-16.83)
Iron & Steel	18.28	3.49	28.42	(-1.26)
Nonferrous Metal[c]	15.56	6.21	26.98	0.18

Notes: [a] Shadow exchange rate in 1975 is 21.77.
[b] Shadow exchange rate in 1985 is 27.16.
[c] Including antimony, chromite, columbite, tantalite, copper, manganese, monazite, zenotite, zinc, zircon, and lead ore.

Table 7.4 shows that in both 1975 and 1985, it was cheaper to import glass and glass products and other. nonmetallic products than to produce them domestically. Ceramics and earthenware, and iron and steel, which could be produced cheaper domestically in 1975, became the products which were cheaper to import in 1985. If the

country does not have a comparative advantage in producing ceramics and earthenware, and glass and glass products, it will not benefit from export controls on the mineral raw materials used for these industries (including glass sand, feldspar, limestone, kaolin, and ball clay). On the other hand, the results of the calculated DRC suggested a comparative advantage from the cement industry, which leads to the question: "Should export controls be placed on cement mineral raw materials (including limestone, shale, iron ore, and gypsum)?" The export control might not be needed for iron ore, limestone, or shale, because iron, according to the calculated DRC, is not worth the expansion of domestic production, and the country has large enough limestone and shale reserves for the foreseeable future. Gypsum constitutes a more serious problem; Thailand's reserves are expected to be exhausted before 2010 based on domestic demand alone, and not including demand for export. If we consider that world reserves of gypsum are large, and that the world price of gypsum in real terms has been declining (from a high of US$12-13 during the period from 1955 to 1972 to approximately US$7-8 in the last decade), it is not necessary to implement any restrictions on gypsum export. Currently, the domestic price of gypsum is very low, approximately 200 baht per ton, while the costs of shipping gypsum from Australia—the nearest source of importable gypsum for Thailand—are prohibitively high at approximately 1,000 baht per ton. Gypsum is still exported from Thailand at the low price of 200 baht per ton. Because gypsum exporters are usually the producers who have a concession license to produce gypsum, but do not have their own gypsum-related industries, all production must be exported. Because locally used gypsum comes from the producers who own both the gypsum reserves and the gypsum-related industry, gypsum does not require export controls, but can benefit from more competition in the domestic market.

It should be mentioned that the DRC calculation does not include environmental costs. As a result, it underestimates the real cost of using domestic resources for the domestic production of minerals. The costs of using domestic resources in 1985 (excluding environmental costs) for the sectors with positive earnings ranged from 26.58 baht to 27.02 baht per unit of production. A comparison to the shadow exchange rate at 27.16 baht shows that the foreign exchange earned or saved was minimal (approximately 0.52-2.14 percent of the exchange rate). If environmental costs or costs for compensating for environmental damages resulting from mining are taken into account, the country will find that the domestic production in many sectors is not financially viable.

It is apparent that, over time, Thailand is losing its comparative advantage in the production of minerals and mineral-related products. This may be due to the fact that high-grade ore deposits do not occur in Thailand which, in turn, results in high production costs and low-quality, low-priced ores. Thailand is currently a marginal mineral producer in the world market and will continue to lose comparative advantage, especially when mineral prices in the world market decline. This is specifically true in the long run because resources will be shifted from the low-profit sectors to the higher-profit sectors. The DRC study shown in Table 7.4 indicates that an export control policy would not benefit the country.

OPTIMUM RESOURCE EXTRACTION

The production of a commodity in a competitive market, assuming profit maximizing behavior, will be made at the level where price is equal to marginal cost. The production of a mineral resource is, however, different from the production of other commodities. A mineral resource is nonrenewable; the greater the quantity of a resource used today, ceteris paribus, the less is available for the future. The depletion of some of the resource will create an opportunity cost because the resource will not be available for future use, which implies a responsibility for the resource users, who in essence have to pay society for forgone future benefits. This opportunity cost—called a "user cost" or a "scarcity rent"—thus has to be counted as another component of costs, and the optimum production of a mineral resource at any period will be at the point where price is equal to marginal cost plus user costs.

The user cost is demanded by the government in the form of a royalty payment. The royalty rate that miners pay to the government is one of the factors that may affect the development of the mineral industry. Excessive royalties can discourage exploration, while uncollected royalties are foregone public revenue. Actually, royalties should be collected out of the surplus or "economic rent" of production. Economic rent is defined as a portion greater than what is necessary to maintain a factor of production in its current activity. Because economic rent is a surplus, a portion of the economic rent should be returned to society as compensation for using public resources, and where there is no economic rent, royalties should not be paid. A royalty as a percentage of mining profits does not effect the rate of extraction.

The payment of a royalty as a percentage of prices will have negative effect on the development of the mining industry because a miner must unfairly pay a royalty even during the period of loss when mineral prices are lower than costs.

Mineral production often causes environmental damage; in addition to the land-use problems related to mining development such as forest destruction and top soil removal, the mining production process can create other environmental problems, such as air and water pollution. Society is faced with these negative externalities, and both the producers and consumers who create these externalities must provide some compensation. It is, therefore, essential that the government provides controls, or have some enforcement, to assure that environmental costs are included in production costs. By excluding environmental costs from production costs and/or by not taking user costs into account, private production costs will be less than social costs. In this case, the mineral price would be lower and production would be higher than the socially optimal levels.[5]

To secure optimum resource extraction and the maximum long-term contribution of the mining industry to Thailand's economy, the following control mechanisms are proposed:

An Environmental Fund: The fund would ensure that all minerals are extracted in an environmentally sound manner and in a way that integrates mining with other resource values and land uses.

A New Royalty Structure: Royalties would be applied only to the rents or surplus revenues after all mining costs including environmental costs are paid and the industry has received a fair return for its investment and entrepreneurship.

A Thai Miners' Environmental Fund

The proposed fund would consist of (1) a miners' land reclamation bond that would be applicable to all mines and minerals and (2) a miners' forest protection bond that would be applicable to mining in forest reserves. These bonds would be (1) financed in such a way as to leave the mining industry no worse off in the short run and better off in the medium-to long-run and (2) refundable with interest upon fulfillment of the terms and conditions of environmentally sound mining.

A Miners' Land Reclamation Bond: The objective of this bond is to restore all mined land to the condition of its prior use or to another acceptable and sustainable form of land use. The environmental bond, or reclamation guarantee, expressed in baht per ton, would differ from mineral to mineral depending on land intensity and likely environmental impact, and if expressed in baht per rai of operating concession area, the bond would be the same for all minerals. The proposed rate is 1,500 baht per rai per year (at 1989 prices) based on a estimated reclamation cost of 30,000 baht per rai, which was the actual cost of reclamation of tin-mined land in Ranong Province (see Table 7.5) and for an average mine life span of 20 years. For certain minerals the life span of the mine is shorter, and the annual rate should be adjusted accordingly. This applies to all onshore mining.

Table 7.5 Cost Estimates of Basic Mined-Land Reclamation

Determined End Use	Location	Average Costs Baht/Rai (1989 Price)	Status
Recreational city park	Phuket Tin-mined land	53,850	Completed
Reforestation	Ranong Tin-mined land	29,320	Completed
Agriculture and reforestation	Krabi Lignite mine	35,770	On-going
Agriculture and reforestation	Mae Moh Lignite mine	39,830	On-going

Source: See Environmental Rehabilitation in Chapter 5

The onshore industry's annual contribution to the bond would be approximately 397 million baht or 62 percent of the onshore royalty in 1989 (see Table 7.6). Therefore, it is proposed that the land reclamation bond is funded by a 62 percent reduction in mining royalties. The average royalty for most minerals, presently 4 percent of the DMR's posted prices, generated roughly 758 million baht in 1989 (645 million baht for onshore mining and 113 million baht for offshore mining), or 1 percent of the mining GDP in 1989 (62,664.6 million baht). The mining industry, which has experienced reduced profitability, has been seeking a royalty reduction. At any rate, the royalty revenues are being diverted to the Ministry of Finance and expended as general revenues which do not directly benefit the industry. In fact, with the development of tax revenues from manufacturing and service sources, the government no longer needs to depend on mineral royalties for its general budget.

Under the proposed Thai miners' environmental fund, 62 percent of the total royalty would no longer be a royalty but rather be an environmental bond that would be deposited in an escrow account to be administered by the DMR, by the DMR jointly with the Mining Industry Council of Thailand (MICT), and the Office of National Environment Board (ONEB), or by an autonomous body. The environmental bond would accumulate and earn interest in the escrow account, and when the mining of a given site was completed and the site was restored to its original use (or to an acceptable and prespecified alternative), the accumulated environmental bond and interest would be returned to the mining company in full, regardless of the actual cost of reclamation.

For offshore mining (mainly tin), there is no reclamation cost, but there is a significant environmental pollution cost. While the potential damage to fisheries, tourism, and coral reefs are not estimated here, a charge of 500 baht per rai for offshore concessions is proposed to maintain parity with onshore tin mining.[6]

Table 7.6 Estimated Reclamation Costs for Selected Minerals (1989 Prices)

Mineral	Operating Area (Rai)	Production (1,000 Tons)	Royalty (Million Baht)	Est.Costs of Reclamation		As % of Royalty	Proposed Royalty Rate(a) (%)	Royalty Reduction (Baht/Rai/Yr)
				Cost/Year (Million Baht)	Cost/Ton (Baht)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Tin	136,497	12	165.30	204.70	17058.00	124.00	0.00	-1,211
Lignite	12,562	8,899	137.00	18.80	2.11	13.70	3.50	-1,500
Zinc	250	413	73.70	0.50	1.21	0.70	1% reduction	-1,500
Limestone	16,241	15,966	60.20	24.40	1.53	40.50	2.40	-1,500
Gypsum	2,929	5,477	54.20	4.40	0.80	8.10	3.70	-1,500
Iron Ore	1,490	177	2.40	2.20	12.43	91.70	0.40	-1,500
Shale	3,558	2,452	8.80	5.30	2.16	59.10	1.60	-1,500
Glass Sand	689	296	4.20	1.00	3.38	23.80	3.00	-1,500
Kaolin	7,013	176	3.40	10.50	59.66	303.00	0.00	-485
Feldspar	8,144	503	11.20	12.20	24.25	107.10	0.00	-1,375
Ball Clay	1,277	135	1.90	1.90	14.07	100.00	0.00	-1,500
Others(b)	73,730	-	122.90	110.60	-	88.00	-	-1,500
Subtotal Onshore	264,380		645.20	396.60		62.00		
Offshore (Tin)	261,478	7,854.60	112.80	134.00	17,058.00	118.80	0.00	-431
Total	528,858	-	758.00	530.60	-	-	-	

Note: Environmental bond for offshore tin is equal to 500 baht/rai/year and nonrefundable, for other minerals is equal to 1,500 baht/rai/year and refundable.

(a) Assume current royalty is flat rate of 4% of price.

(b) The proposed royalty rates for other minerals should be calculated based on a reduction of current rates for each mineral.

(4) = ((1)*30,000 baht)/life of mine; Assume life of mine for all mineral is 20 years, for zinc is 16 years.

(5) = (4)/(2)

(6) = (4)/(3) *100

(7) = ((100-(6))/100) * current royalty rate

It should be mentioned that the onshore mining industry's annual contribution to a miners' land reclamation bond (397 million baht) is a relatively small amount compared to the value added of the mining sector and the industry's profit. The contribution to the bond is only 0.6 percent of the mining GDP in 1989. Assuming a 20 percent profit rate of the mining GDP in 1989, the annual bond fee accounts for only 3 percent of the industry's profit. Assuming efficient mining and reclamation, however, the ultimate cost of environmental improvement to the industry may be as low as 1.5 percent of the profit. In the final analysis, nearly 200 million baht of the current royalty payments could be recovered through environmentally conscious mining. It is also important to note that a mining company need not wait 20 years to retrieve its reclamation bond. It can always offer to reclaim mining sites that are currently being phased out of production and in return request a bond refund for currently active mines.

A Miners' Forest Protection Bond: While a mechanism such as the miners' land reclamation bond is certain to improve both the environment and the mining industry's image, the opening of forest reserves to mining may require some affirmative action beyond land restoration. To address the legitimate concern that mining roads may lead to increased forest encroachment and to compensate for the loss of aesthetic values, it would be appropriate for the mining firm to offer to protect a larger forest area around the mine and to reforest denuded areas nearby. The physical presence of the company and its work force in the area may ensure that the protection and reforestation of an area, for example, an area five times the size of the concession, would not be very costly.

The reforestation and protection of 500 rai, approximately a 100-rai concession, at 2,000 baht per rai, would cost 1 million baht over the life span of the mine or 50,000 baht a year (or 500 baht per rai of mining concession per year) assuming the mine has a 20-year economic life. On the other hand, the mining company might choose to protect an area of natural forest at the equivalent cost. In addition, the mining company would have to compensate the current occupant of the land (whether the occupant is the Royal Forestry Department (RFD) or a squatter) for the loss of the use of the concession area to mining. The annual net income from 1 rai of land planted for cassava farming, the lowest-earning crop, is estimated at 500 baht per year. Therefore, the annual compensation would be 500 baht per year or a lump sum payment of 5,000 baht per rai.

Thus, for mining in forest reserves, in addition to the 1,500 baht-per-rai-per-year reclamation bond, the recommendations are as follows:

1. The compensation of the occupant of the land, whether the occupant is the RFD or a squatter, at the rate of 500 baht per rai per year or a lump sum payment of 5,000 baht per rai as the opportunity cost of land in other uses.
2. A forest protection bond of 500 baht per rai per year on the assumption that for every rai of an operating mine concession, another rai of forest will be encroached upon or degraded. On the other hand, the mining company may choose to protect and/or reforest equivalent land area.

Both bonds are refundable with interest once reclamation is carried out and mining is completed without damage to the forest, or compensating reforestation has been carried out.

Mining is possible in the forest reserves classified as "protection forests" if these forests fall into the Class 1B category which includes gradual sloped areas. Because mining operations in class 1B areas usually cause soil erosion, measures to prevent erosion, both during and after operations, are necessary. A retaining dike must be constructed downstream from a dumping area or from the exposed surface of the mine. In addition, a good drainage system should be constructed to allow surface water runoff to discharge to the appropriate point without creating excessive erosion. The suspended solids are retained by the dike and relatively clear water is discharged.

Based on an operating concession area of 100 rai, a dike with an estimated length of 500 meters is to be constructed in a shape that will depend on the engineering design for the particular topography of the area. A drainage system consisting of a series of ditches is estimated to be about 1,500 meters in total length, and assuming the dike and drainage system have a 10 year life span, costs per rai per year for the dike and drainage system, including annual maintenance costs, will be 510 baht and 240 baht, respectively. Therefore, mining in the protection forest Class 1B should require a deposit of (1) 500 baht per rai per year for reforestation and (2) 750 baht per rai per year for soil erosion prevention.[7] The structure of the environmental fund in different land areas is summarized in Table 7.7.

Table 7.7 Structure of Proposed Thai Miner's Environmental Fund (at 1989 Prices)

Unit: Baht/Rai/Year

Area of Mining	Environmental Fund		
	Land Reclamation	Forest Protection Bond	Compensation of Owner/Occupant
Offshore mining	500[a]	-	-
Onshore mining			
-Outside Forest Reserves	1,500	-	Market price
-Inside Forest Reserves			
Economic Forest	1,500	500	500
Protection Forest (Category 1B)	1,500	1,250	500

Note: [a] Nonrefundable pollution charge

Fund Management

To manage the two bonds, the miners' environmental fund should be operated as a semi-automonous, private/public sector institution with representation from the DMR, the MICT, the ONEB, and the RFD. The fund would (1) collect the bond payments, (2) set rules for land reclamation and forest protection, (3) invest the bond funds to earn interest on behalf of the miners, and (4) return the bond with interest to the depositors once the terms of the bond were met.

It is recommended that the fund engage the outside services of an environmental auditor's unit to determine whether land reclamation and forest protection mandates have been met according to the rules and regulations. The legal framework, organization, and operation of the fund for the environmental auditing system has been set up and will be described in a subsequent supplement.

In order to demonstrate how environmentally sound mining could be practiced and how land reclamation and forest protection could be accomplished, the fund could,

with the assistance of the MICT, the DMR, the ONEB, and the RFD, establish a mining "showcase" or demonstration mine that would operate profitably and in an environmentally conscious manner.[8]

A New Royalty Structure

The concept of a new royalty structure is based on the idea that royalties should be collected from the surplus or rent after taking into account all costs, including environmental costs and not as a percentage of posted gross prices. For tin, kaolin, feldspar, and ball clay, a zero royalty payment at the current price level is recommended because the reclamation costs equal or exceed the current royalty payment: appropriate royalty rates should be set for higher prices. For example, at the current tin price of 157,000 baht per ton, the average tin royalty of 13,775 baht per ton is lower than the annual reclamation cost of 17,058 baht per ton, and no royalty should be collected. Thus the following or a similar royalty structure for tin is proposed:

FOB Tin Price (Baht per Ton)	Royalty
Below 160,000	0
160,000 - 200,000	0.25 (FOB price - 160,000)
Above 200,000	0.50 (FOB price - 200,000)

This royalty structure applies to both onshore and offshore tin mining. For all the remaining minerals— lignite, zinc, limestone, gypsum, iron ore, shale, and glass sand—a royalty reduction corresponding to the reclamation costs involved is proposed: for example, a 1 percent reduction of the zinc royalty and a 40 percent reduction of the limestone royalty. (The proposed royalty rates are summarized in Table 6.6).

The proposed miners' environmental fund and the new royalty structure approach will provide several advantages to the mining industry and to the country: (1) the mining industry has an opportunity to improve its public image and attendant goodwill to ensure its long-term health at little or no short-term cost, and to acquire considerable long-term profit by making acceptable the opening of forest reserves to mining; (2) miners will have an incentive to mine in a careful and efficient way so as to minimize environmental damages; (3) production will be socially optimum when user costs and environmental costs are compensated for society; and (4) it ensures a balanced, multiple use of forest

land and shows how mineral activities can be environmentally sound and coordinated with other land uses and values.

End Notes

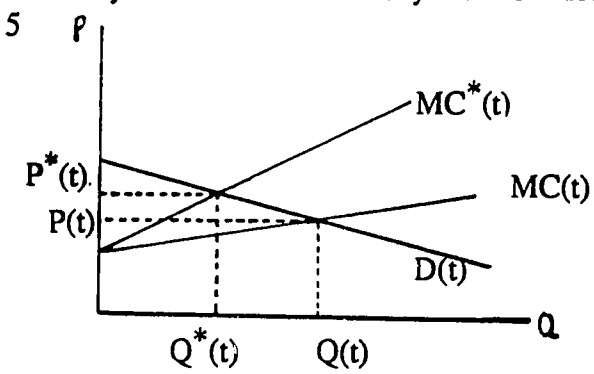
[1] Gypsum, for example, can be recovered as a byproduct of chemical operations and flue gas desulphurization plants. Feldspar can be obtained as a coproduct from lithium ores and from coproduct recovery of mica, clays, and stone. Iron can be a byproduct or coproduct of ores mined for vanadium, titanium, chromium, manganese, nickel, other copper base metals, and sulphur. Magnetite concentrates from iron ore can be recovered from titanium and copper ores, or from iron oxide residues obtained from processing sulfides such as pyrite or pyrhotite.

[2] Iron ore can be derived from flue dust, mill scale, and steel-furnace slag. Tin metal can be reclaimed from tin-base and tinplate scrap. The recycling of glass containers--either broken up as cullet for remelting to make new bottles or crushed for use in road-surfacing mixtures--will reduce the consumption of glass mineral raw materials such as feldspar.

[3] Aluminum, tin-free steel, enameled steel, glass, paper, and plastics can replace tinplate in beverage cans. The principal substitutes for zinc are aluminum, magnesium, and plastics. The substitution of gypsumboard products and plaster products can be made by plywood and particleboard, cement and concrete, steel, lime mortars, and wood. The raw materials used in place of feldspar in glass and ceramic manufacture are aplite and nepheline syenite. Other materials are talc, pyrophyllite, electric-furnace slag, lithospar (which is a naturally occurring mineral mixture of feldspar and spodumene), and corn-wall stone. Aluminum and plastic containers are frequently being substituted for glass containers causing a slower rate of glass sand consumption.

[4] The DRC operates in a static framework which is one of the disadvantages of the DRC method. The calculated DRC can be made and compared with the foreign exchange at each point in time, and can show that the costs of using domestic resources during a specific year are greater than or less than the foreign exchange. Because only two years of the calculated DRC, 1975 and 1985, are available, a finite statement about the comparative advantages of the sectors at present and in the future is difficult to make. This is especially true for an industry like the ceramic industry that has undergone extensive development.

[5]



where D(t) = Social demand,

MC(t) = Private marginal cost,

MC*(t) = Social marginal cost,

Q(t) = Rate of resource production at time t when environmental cost is excluded,

Q*(t) = Optimal rate of resource production at time t,

P(t) = Mineral price when environmental cost is excluded,

P*(t) = Optimal price.

[6] Additional environmental costs per ton, from either onshore or offshore mining, should be equal (approximately 17,058 baht per ton). Based on the current production rates of offshore tin, the environmental costs are 134 million baht which is distributed over a concession area of 261,478 rai. Thus the cost per rai are 512 baht, or approximately of 500 baht, which will be collected for pollution charge.

[7] The construction of a dike with an average cross-sectional area of 8.5 square meters and a compacted earth filling, including slope finishing, would cost around 255,000 baht (using a unit cost of 60 baht per cubic meter). A maintenance cost of 10 percent per year is assumed, and costs of a drainage system are based on a unit rate of 15 baht per meter length. A high maintenance cost of 30 percent per year is assumed to keep drainage ditches in good condition.

[8] A similar mining showcase was established recently (1987) in the United States to demonstrate that minerals can be extracted from the earth in an environmentally sound manner and in a way that integrates other resource values and uses of land.

Chapter 8

Conclusions and Recommendations:

Thailand's mining industry has made substantial contributions to the country's economy over the past several decades. Mining exports were a major source of foreign exchange at a time when Thailand had little else other than rice and timber to export. The investable surplus generated and the foreign exchange earned from mining have fueled industrialization in its early, difficult years. The dominant tin-mining industry has been a major source of employment in South Thailand, and mining in general also has been a conduit for the transfer and development of new technologies, some of which have found applications in other sectors such as manufacturing. Finally, mining has been a source of many basic materials for the Thai construction and manufacturing industries.

In recent years the Thai mining industry has begun to face increasing difficulties. The structural changes occurring in the economy have gradually reduced the relative importance of the mining industry. Inadequate reclamation of mined-out areas, increased public awareness of the environmental impacts of extractive activities, and land-use conflicts between mining and other sectors have become serious constraints to the expansion of the mining sector. For the companies granted mineral exploration rights, the lack of security of tenure discourages mineral exploration and diversification.

STRUCTURAL CHANGES

One major problem confronting the mining industry is the structural change that is the price of the industry's success. Having played a critical role in Thailand's industrialization, mining in general, and tin mining in particular, have lost the spotlight to the thriving manufacturing and service sectors. This inevitable outcome of any successful development affects all primary sectors including agriculture, forestry, and fisheries. The newly developed, highly productive and profitable manufacturing industries are the primary recipients of competing capital investment and skilled labor. While minerals are

a basic material for much manufacturing, the development of the basic metal industry has not slowed the decline in the relative share of mining any more than agroprocessing has slowed the decline in the share of agriculture.

Another source of difficulty for the mining sector arises from the decline in the prices of most minerals driven by the discovery of new reserves, substitution, and the development of new mining technologies. Of the minerals mined in Thailand, tin has been most profoundly affected by these changes. The International Tin Council (ITC), whose purpose was to stabilize tin prices, collapsed in 1985, and the Thai tin mining industry has been operating below capacity ever since. The relatively high production costs of Thai tin mines, due to low-grade and low-accessibility ore deposits, have further eroded the competitiveness of the Thai tin-mining industry in world markets. The rise in production costs is, again, an inevitable consequence of past cumulative production. The mining industry, with assistance from the Department of Mineral Resources (DMR), has made relatively successful efforts to diversify its mining activities to minerals such as zinc and lead. However, the deposits of most of these minerals are limited and of relatively low grade, although large areas of the country have yet to be explored. On the positive side, the domestic demand for mineral raw materials is expected to continue to increase, especially in the cement, glass, ceramics, zinc, and tin industries as well as in the area of power generation.

These structural changes underscore the need for mining industry restructuring, and mineral diversification is one way to cope with such changes. To facilitate the diversification, mineral exploration must be encouraged, and this call for reform the existing concession policy.

In addition, as a result of the high growth of the domestic downstream industries, the development of mineral resources has been directed toward more internal consumption with a smaller surplus left for export. The growth of mineral exports has thus declined, and the growth of exported manufactured products and process minerals has increased. The issue at hand is whether to support calls for an export restriction policy on domestic minerals in order to prolong the domestic reserves and to avoid the need to import minerals and raw materials. However, the issue of optimal trade policy for a nonrenewable resource is intrinsically linked to optimal resource extraction.

OPTIMUM MINERAL EXTRACTION, COMPETITION, AND TRADE POLICY

There are certain advantages to satisfying internal mineral demand with domestic supplies: (1) savings of foreign exchange, (2) employment generation, (3) increase in value added, and (4) a secure mineral supply. There are also certain disadvantages to domestic mineral production, particular environmental pollution which can be avoided by satisfying demand through imports.

On the other hand, Thailand has a comparative advantage in exporting certain minerals such as limestone. Given the amount of capital investment in the tin industry, there is a short-term advantage to exporting, and if the price of tin increases, there is a likely long-term comparative advantage. However, a true comparative advantage requires that the foreign exchange earned fully covers all domestic resource costs **including environmental costs**. The critical question is not whether to produce minerals for export or for domestic use, but rather how to produce minerals at such a rate and in such a manner that the production makes a maximum contribution to the economy while taking into account all costs, including environmental costs.

In the past, an important policy issue has been whether the government should prohibit the export of certain minerals with growing domestic demand. This prohibition would, in theory, help to conserve the limited reserves for domestic consumption and to increase value added through downstream processing. Indeed, the projections in Chapter 6 indicate a great increase in the domestic demand for minerals. The demand for some minerals—especially industrial minerals like gypsum and limestone—is expected to double in the next few years. Nonetheless, an export restriction on minerals is not recommended.

While the known domestic reserves of some minerals such as gypsum and zinc are less than the cumulative domestic demand up to the year 2010, no increase scarcity of these minerals is expected worldwide. It is even more likely that mineral reserves will increase due to technological progress that will lead to lower production costs and an increase in the availability of substitutes. Therefore, despite increasing demand, Thailand is not facing mineral shortages. Export restrictions are not recommended. Such restrictions tend to subsidize inefficient and wasteful domestic use of mineral resources and to shelter domestic processors from competitive pressures that are necessary for improving efficiency and attaining international competitiveness.

As long as the mineral extraction rate is optimal, export controls are not suggested. Four conditions must be met to optimize mineral resource extraction:

1. The competition must prevail.
2. The protection against imports and restriction of exports must be avoided.
3. Royalties must be collected in proportion to profitability (rents) after deduction of environmental costs. Excessive royalties discourage exploration, while uncollected rents are untapped public revenues.
4. Mineral-bearing lands should be put to their best possible use—in other words, they should be open to mining if the mining industry can fully recover all social costs involved (including environmental costs), and the land can be reclaimed for other uses.

Some restriction of strategic minerals exports may be justified on the grounds of national security. However, the use of protective measures against imports of processed minerals and products such as zinc, glass, and cement, is inappropriate except in the special case of truly "infant industries" with promising future comparative advantage. Protection that aims to sustain unprofitable or inefficient domestic producers taxes and distorts the economy and reduces its international competitiveness, especially since domestic users are denied access to lower cost sources of processed minerals from import.

Instead of imposing export controls on, or protection from imports to induce import substitution for minerals and their related products, measures to increase the competitiveness of Thailand's minerals in the international market should be taken. One essential measure is the improvement of existing processing technology. Due to the current lack of suitable technology in the country, some domestic industrial minerals, such as kaolin and gypsum, cannot be processed to meet the high-quality needs of either the domestic or export markets. The promotion of R&D for technology improvement is thus required for effective competition in the world market.

ENVIRONMENTAL IMPACTS AND LAND-USE CONFLICTS

A major source of the mining industry's difficulties arises from land-use conflicts. Ninety-eight percent of the pending mining applications are located in national forest reserves, and rapid deforestation over the past three decades, related natural disasters, and

increasing environmental awareness have culminated in a nationwide ban on logging and closure of forest reserves (40 percent of the country's area) to all extractive activities, including mining. The government, under pressure from a strong environmental advocates including the Royal Forestry Department (RFD), environmental groups, the media, and the general public, has resisted repeated calls from the mining industry to allow mining at least in the economic forests and the unclassified forest reserves. The mining industry has unconvincingly argued that the pending area of mining concessions, while large for the industry, is negligibly small for the country (these areas are claimed to amount to less than 1 percent of the National Forest Reserves).

Environmental advocates has argued, however, that while the area actually mined is small, the environmental impacts extend to areas are several times larger. There are several elements that are brought into the counterargument. First, there is a perceived need for support areas including: (1) locations for the disposal of overburden and discarded ore, (2) locations for mining ponds, and (3) areas for the settlement of mining workers. Second, a fairly substantial forest area would be taken up by mining roads, but most importantly, these roads would make the forests more accessible to illegal loggers and encroachers. There is no guarantee that mine workers, or villagers disguised as mine workers, would not engage in activities that lead to deforestation. Third, mining generates air and water pollution that is, at best, incompatible with natural forests and at worst may damage the remaining forest and affect human health. Fourth, the trail of abandoned mines and unreclaimed sites and mine tailings left by the mining industry in the past—a practice that continues today despite regulations—does not help the image of the industry and its case for opening forest reserves to mining activities. Forest reserves are generally found on steep slopes, fragile lands, and watersheds where mining activities, without proper protection and reclamation, might lead to soil erosion and landslides. It is apparent that the mining industry must recognize that there is a certain incompatibility between mining and forestry; the aesthetic value of the forest is diminished by the presence of mining activities.

A good part of the forest reserves is no longer forest due to illegal logging and encroachment by farmers and, in theory, the presumed impacts of mining on the forest are not real. The environmentalists' counterargument is that the government, by declaring this area a forest reserve, has expressed its intent to restore the forest; allowing mining activity would make forest restoration even more difficult. A more justified argument in favor of mining is that the objective of economic forests is, by definition, economic, and

therefore the land should be put to its best possible use, which in some cases is clearly mining. While on environmental grounds it is difficult to argue strongly in favor of a vast eucalyptus plantation over a small mine of equal economic value, at least the intent of an economic forest is both economic and environmental. Unless the mining industry effectively addresses the issues of forest protection, mining pollution, land restoration, and compensation for loss of aesthetic value and social impacts, there is little prospect that forest reserves would be opened to mining: the objections of the RFD, local people, environmental groups, and the general public would prove too firm an obstacle. Indeed, unless the issues of land restoration and control of mining pollution are addressed in current mining operations, the mining industry risks not only its image and credibility, but also risks the imposition of restrictive government regulations and prohibitions in response to environmental disasters and public pressures. If the logging industry had acted responsibly and preemptively and practiced sustainable forestry, there would have been little justification and public demand for a logging ban.

A Proposed Initiative: A Thai Miners' Environmental Fund

A workable solution to the problems of Thailand's mining industry must take into account the following: (1) the industry's difficult economic situation (high production costs and low prices) and its need to maintain its competitiveness; (2) the RFD's difficult mandate to preserve as much of the remaining forest as possible and to promote reforestation; (3) the growing environmental awareness and the demand for a cleaner and greener environment by the general public; and (4) the requirement that the funds needed for environmental improvement of mining activities be generated from within the mining industry (according to the "polluter pays principle"), that they should be used by the industry, and that they should ultimately benefit the industry. (This last requirement is important for ensuring fairness, efficiency, and competitiveness).

One initiative that could fulfill all the above conditions is the establishment of a Thai miners' environmental fund that would ensure that all minerals are extracted in an environmentally sound manner and in a way that integrates other resource values and uses of land. The miners' environmental fund, a dual bond provision, would be composed of a land reclamation bond, to improve the environment and the industry's image, and a forest protection bond, which would serve to convince the government to open forest reserves for mining activities. Both bonds would be refundable upon the miner's fulfillment of the terms and conditions of environmentally sound mining. These bonds would provide the company with incentives to minimize the cost of acceptable reclamation through careful mining. Because the bonds would be based on the actual

reclamation costs of sites which were carelessly mined in the past, the miner would be able to earn substantial savings through careful removal of topsoil and nondestructive mining.

One approach for accommodating the mining industry's economic interests would be through the use of cost minimization incentives. Under these incentives, reclamation might cost about one-half the current amount. This implies that only half of the environmental bond (or the equivalent of 0.25 percent of the royalty) will be used for reclamation while the rest will be returned to the miner with interest.

A second approach is through the improvement of the mining industry's image and credibility. With firmer public backing, the industry would be more successful in convincing the government to open up lucrative concessions in such closed areas as the economic forests, and it could recoup some of its financial losses. At present, the mining industry pays 758 million baht annually in royalties to the government. Under the proposed scheme, the industry would ultimately pay three-quarters of that amount (in royalties and reclamation costs) and would get back an improved environmental and public image, more profitable concessions in currently closed areas, and less restrictive government regulations. The environmental bond or reclamation guarantee, expressed in baht per ton, would differ from mineral to mineral depending upon the intensity of land use and the likely environmental impact of the type of mining.

This approach would ensure a balanced, multiple application use of forest land and show how mineral activities can be environmentally sound and coordinated with other land uses and values. The RFD, which is currently seeking ways to protect the forest and prevent deforestation, should welcome such an approach. By paying the full environmental costs and by still being able to afford affirmative action of the type described, the mining industry will prove that the site is as rich in valuable minerals as is claimed. The marginal mining sites in forest reserves are best left undisturbed; they could not afford their own environmental costs and would create a bad image for other sites that are richer and potentially more profitable.

MINING RIGHT AND CONCESSION POLICY

Some pieces of legislation have proved to be factors preventing the mining industry's development, and one of them is the legislation on concession right. The existing prospecting licensing system does not guarantee that the person who has a

permit from the government to conduct the exploration will obtain a mining right for the area he has applied for. Only for gold mining is the company entitled to obtain the right to mine gold over the area after the exploration stage.

In the mining codes that have recently been drafted by most developing countries, the right to explore is a condition based upon quantifiable work and an expenditure program that will be regularly monitored with a full financial guarantee. The mining rights for the holder of an exploration license are more secure and are subjected to a feasibility study to determine whether or not the deposit could be developed on a commercial basis.

The proposed mines and minerals acts of Sierra Leone are an example of this feasibility testing. In this case, a mining license will be granted to the holder of an exclusive prospecting license after the exploration has taken place and the feasibility of the program of proposed mining operations is assessed. In the Chile Constitutional Organic Law on Mining Concessions and Mining Code, the concession regime covering both prospecting and mining is established and states that **mining concessions can be either for exploration or exploitation. Whenever the law refers to the concession or concessions, it is understood that it includes one and the other.** This system provides the concessionaire with the exclusive right to freely explore and exploit the concession without intervention from any other authority or person and reflects a "promining" approach for Chile, a country where mining is the main source of prosperity.

In 1988 a new type of rights-granting procedure, a *Concession Regime*, was proposed to the DMR for incorporation into the Minerals Act by SNC Inc., the DMR's mineral development project consultant. The introduction of a concession regime would provide special prospecting and mining conditions for mining companies offering important benefits to Thailand and would be made available to mining companies (1) when special circumstances would warrant it and (2) following a public invitation to submit proposals. The concession regime would be substantially different from the present licensing system; the holder of the concession would primarily be subject to the provisions of the chapter in the Minerals Act that would mainly deal with the concession regime. In the proposed concession regime, an exploration right would be granted with special benefits offered to the government, and the feasibility study would be carried out after exploration but prior to granting the mining permit, while taking proper account of environmental protection.

While this system may be suitable for large-scale or important projects, it would not cover the concession system of normal small- to medium-scale projects and mining projects for other minerals not specified by the Ministry of Industry (MOI). To anticipate the fact that the opportunities for mineral exploration and mining in most of areas of Thailand will become more difficult because mineral deposits are scattered and the majority of them are located in the forest, the use of mineral-bearing lands must be efficient and productive. Once the exploration was carried out and a mineral was discovered in a sizeable quantity, mining should be allowed to be carried out, provided all environmental conditions have been met. Where the concession regime could not be applied to a call for public bidding, a systematic approach for granting mining rights in general cases should be contemplated.

The study proposes a package concession system for small- to medium-scale mining projects and mining for minerals in general, which would exclude those projects or minerals specified by the MOI as being subject to a special case or a major project. The proposed concession system should be guaranteed mining rights after exploration and should be subjected to a feasibility study of the project. According to this system, a provisional concession for a large area of public land or for a national forest area would be granted. The exploration activity would be carried out following the plan submittal, and the exploration result would be used to delineate the area of a discovered ore body.

A study would then be conducted to determine the project feasibility and a final report would be submitted in applying for a mining license for the area. The area covered by the provisional concession would be reduced to the minimum necessary for mining as indicated in the study. Proper mining plans and reclamation plan would be required at this stage. If the study indicated that the project was feasible, taking all costs into account including environmental costs, the mining license should be issued, and the nonproductive area relinquished to the government. On the other hand, if the study failed to prove the project feasible, the provisional concessions would be cancelled.

Mining rights should be transferable from the company who was granted the exploration right, subject to the DMR's approval. The company with exploration rights might not be the one that specializes in the mining of the particular mineral and may prefer to sell its mining right to others, instead of making further investment in the production stage. By allowing the transfer, the deposits could be mined by the company that had more technical capability or more specialization in the production of a particular mineral. This would help improve efficiency in both mining and processing. Moreover,

in cases when the company granted exploration was in a period of financial difficulty, it could shift the rights to healthier, more efficient companies without damaging the mineral resource and the environment by working at low efficiency. (see Figure 8.1 which illustrates the functional procedures of the system).

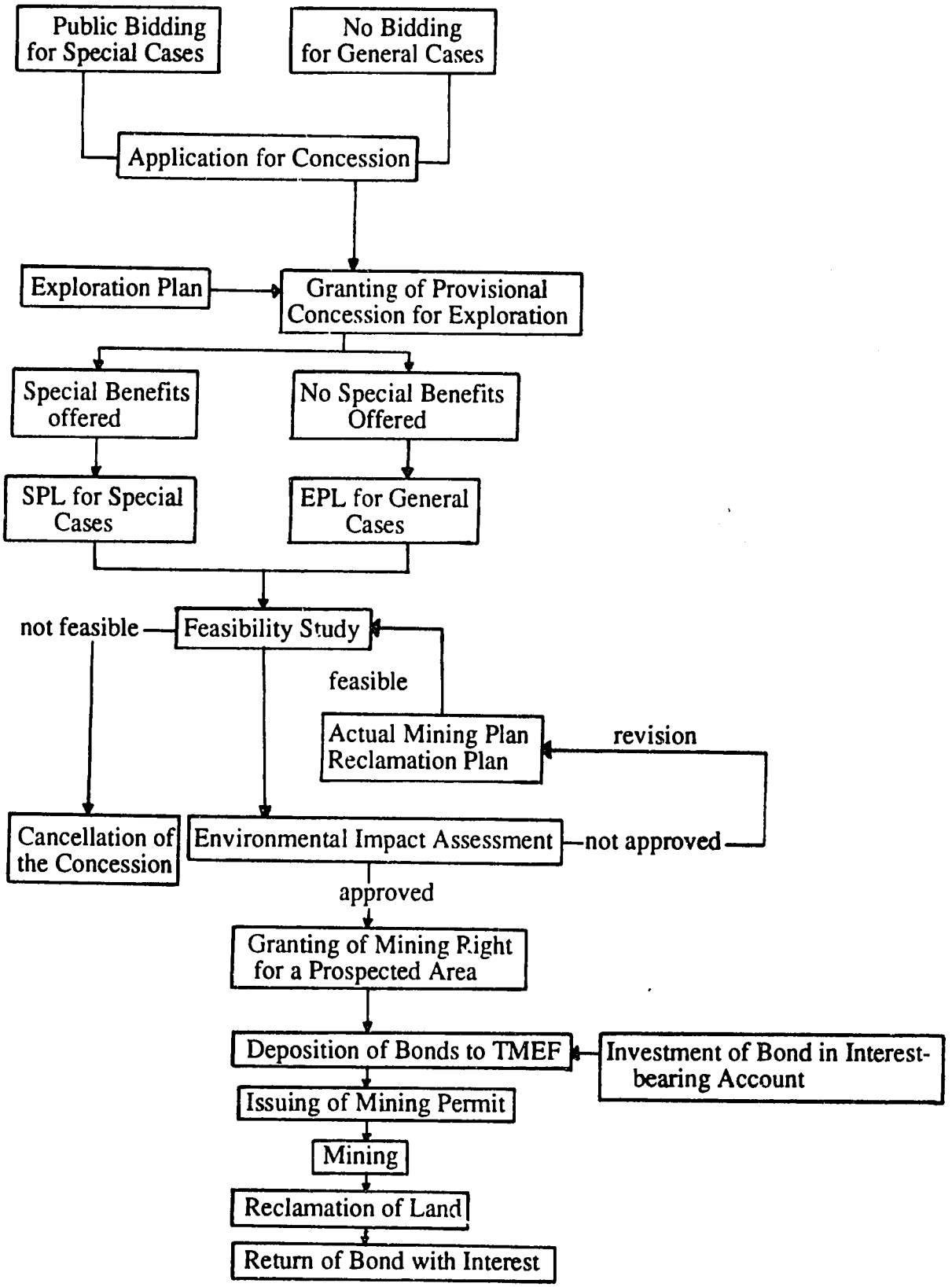
There are, therefore, two concession systems for exploration and mining to be proposed as follows:

1. "Special" cases, large-scale, or "important" projects as defined by the MOI and the area designated by the DMR as an economic mineral potential area. A concession is granted for these area based on the main criteria as follows:

   - The public invitation is announced for bidding in the area of mineral potential designated by the DMR for the prequalified company.
   - The SPL is issued for exploration rights after the DMR's approval of the exploration plan.
   - The special benefits are offered to the government in the form of profit sharing (apart from royalty).
   - The mining right is issued after (1) the feasibility study and (2) the environmental impact study have been assessed and accepted.
   - A proper account of reclamation and environmental protection is taken and bonds are deposited into the Thai Miners Environmental Fund according to the areas to be mined.

2. The second category includes small- to medium-scale mines as well as mining for minerals neither specified by the MOI nor found in the area designated by MR in item 1 above. A concession is granted based on the following criteria:

   - A suitable applicant applies with sufficient financial and technological support.
   - The EPL is issued for exploration rights after the DMR's approval of the exploration plan.
   - The mining right over a relinquished area of concession is issued after the feasibility study and the environmental impact study have been assessed and accepted.



TMEF = Thai Miners Environmental Fund; EPL = Exclusive Prospecting License; SPL = Special Prospecting License

Figure 8.1 Functional Procedures of Proposed Concession systems

- A proper account of reclamation and environmental protection is taken and bonds are deposited into the Thai miners environmental fund according to the areas to be mined.

It is also recommended that the DMR include more areas and minerals in the so-called "special cases" that go for public bidding where the DMR has better knowledge of the geological information of the area. Therefore, in the long run special cases will become general cases for bidding in which all prospective miners have an equal opportunity to compete.

The basic concepts underlying these two systems are sets of standard practices to be transferred into the Minerals Act through modifications and additions. The system would provide advantages including: (1) encouraging exploration in potentially mineral-rich areas, (2) ensuring that the area applied for will be properly used for mining and that nonproductive areas are released, (3) stimulating a prospective investor to conduct efficient exploration with more intensive use of technology, especially for large scale projects, (4) assuring additional benefits to the government in the case of large-scale and important projects, (5) enabling more reliable estimates of the country's mineral reserves and (6) generating benefits from small-scale mining without damages to the environment.

The proposed concession system packages would serve as a practical instrument for allocating limited land resources to their best use and would ensure that mineral extraction is done with maximum efficiency—both economically and environmentally.

CONCLUSION

Thailand's mining industry has historically operated like most mining industries around the world: as an extractive enclave that has made important economical contributions but, by in large, has remained insulated from the rest of the economy and society. The mining industry's relative importance to the economy has diminished due to the development of the dynamic manufacturing sector, and conflicts with other sectors are more extensive and visible because of both an accumulation of past incidents and an increased public awareness. Several overall factors make a change in traditional mining culture imperative: (1) the growth and structural change of the economy, (2) the development of mass communication, (3) the advent of the environmental movement, and (4) the growing level of public environmental awareness. The mining culture must move from insulation to integration into the norms of society.

At this critical juncture, the mining industry has two alternatives: (1) it can restructure itself into a relatively small but an efficient and environmentally conscious industry that is fully integrated into the changing norms of Thai society, or (2) it can resist the inevitable change and keep a business-as-usual attitude, relying on its past accomplishment and considerable political influence to further its short-term interest at the expense of its long-term future.

The Mining Industry Council of Thailand (MICT) (which functions as the industry's conscience) and the DMR (which functions as its regulator and guardian) have a responsibility to the mining industry and to society at large to ensure that the right choice is made, and the sooner this is done, the better. Improved communication with the public and cosmetic changes do not constitute the necessary in-depth changes; what is required is a recognition of the fundamental conflict between short-term profits and a sustainable future for both the industry and the economy. The industry needs to change both its mode of operation and its image from that of an extractive enclave which leaves behind scarred landscapes and toxic pollutants to one that of an environmentally conscious contributor whose interests are compatible with multiple land use and sustainable development.

In response to the industry's assumption of a more responsible attitude towards the environment through the establishment of the Thai miners environmental fund and the practice of environmentally sound mining, the government should act to remove the obstacles that prevent efficient mineral development, through the following policy changes:

1. More area should open to mining and mineral-bearing areas in forest reserves (Class 1B) should be demarcated provided the appropriate forest protection and reclamation bonds are posted by the industry, and the least destructive mining practices are adopted.

2. The royalty should be reduced by at least 60 percent from its current level, and its base should be changed from posted prices to mining profits on a sliding scale (low rates when profits are low, higher rates when profits are high).

3. The system of granting exploration (SPL and EPL) and mining licenses must be changed to provide more assurance to those who explore for

minerals that they will be granted the mining rights for their discoveries which they should be free to extract or sell as long as the government receives its agreed-upon share. It is also recommended that the DMR should increase the geophysical survey maps and aeroelectro-magnetic anomaly maps to designate the areas of mineral-bearing land for competitive bidding.

These changes in mining policy would improve the efficiency, and encourage exploration and the diversification of the mining industry, so that the contribution of the sector to the national economy can be maximized while the natural environment is being protected.

Appendices

Appendix A
Theoretical Approach

This appendix presents the details of the econometric study of the demand. Econometric models are constructed for the products for which a planned capacity is not reported. Those products include cement, glass bottles, glass tableware and kitchenware, zinc, and tinplate.

THEORETICAL MODEL

The empirical models are constructed based on the theoretical model of demand theory. The basic explanatory variables are price, the prices of substitutes, and economic activity. Other variables are added in the model when they are appropriate.

The general form of the function is

(1) $$C_t = f(P_t, P^S_t, Y_t)$$

where C is consumption, P is its own price, P^S are prices of substitutes, and Y is the level of relevant economic activity.

Price is expected to have a negative relationship to consumption while the price of substitutes and the level of economic activity are expected to have positive relationship to consumption. The negative relationship between price and consumption indicates that consumers will reduce their consumption when prices are higher and increase their consumption when prices are lower. This inverse relationship is justifiable for two reasons. First, higher mineral prices result in higher production costs for the final products. If these costs are passed on to consumers, demand for the final products and, thus, demand for the mineral, will decline. Second, a higher mineral price can induce firms to substitute a lower-priced mineral.

Economic activity has a positive relationship to consumption, indicating that the consumption of the product will increase along with an increase in purchasing power in the economy.

The changes in the prices of substitutes will positively affect mineral consumption, although it usually takes time. The consumption of the product can be lowered when prices of substitutes decline, since the consumers will switch from the old

product to the cheaper one if both products can be substituted. Substitution is easily made for the final product and market price is an effective variable in determining substitution. For minerals, the market prices of substitutes usually cannot explain substitution. Prices of substitutes should refer to "shadow prices" rather than "market prices." Substitution among minerals requires time and budget to facilitate an adjustment of the production process. The market prices of substitutes usually do not express real differences in transferring costs, such as costs of modifying existing machinery. Thus, they do not reflect real opportunities for substitution. An increase or a reduction in market prices of substitutes might not change demand for a metal if the transferring costs are excessive. However, in an empirical model, it is difficult to quantify transferring costs and, thus, shadow prices. The market prices are adopted as proxies.

METHODOLOGY

The equation is estimated by using the Ordinary Least Square (OLS) estimation method. A random error process is first assumed for the equation. However, the existence of a serial correlation of error terms is also investigated. The Durbin-Watson statistic is used if the equation does not include a lagged dependent variable as an explanatory variable, and the Durbin-h test is used if it does. If evidence of serial correlation of error terms is shown in any equation, that equation is re-estimated using the Cochrane-Orcutt iterative technique.

The performance of the estimated models are evaluated using the following three validation criteria:

1. Mean Absolute Percentage Error (MAPE)
2. Root Mean Square Percent Error (RMSPE)
3. U Coefficient

EMPIRICAL MODELS

The empirical models are constructed for cement, glass bottles, glass tableware and kitchenware, zinc, and tinplate. The models are estimated using data from 1970-1988. The specific variables included in each model are explained as follows:

Cement Model

In this study, the term cement refers to mixed cement and portland cement—the predominant types used in Thailand. The consumption of cement is specified as a function of (1) its price and (2) economic activity which is represented by the GDP originating from the construction sector.

Glass Model

The glass models include glass bottle production, and glass tableware and kitchenware production. The production equation rather than the consumption equation is estimated for glass. Because of the high annual rate of glass bottles recycling, using the quantities of glass bottles consumed during any period to estimate the quantities of the mineral used will result in overestimation. The glass production level will better reflect the quantities of minerals consumed. For glass tableware and kitchenware, the consumption data is not available. Production is considered to be a good representative of consumption, however, because most glass tableware and kitchenware produced in Thailand serves the domestic market. The quantities of export and import are small compared with the quantities produced.

Glass bottle production is determined as a function of (1) its price at a previous period, (2) the GDP, and (3) the value added of the beverage industry. The production and price have a positive relationship: an increase in price induces an increase in production. An inclusion of the GDP is specifically meant to reflect the purchasing power of the economy: an increase in the GDP implies higher purchasing power, higher consumption of the products using glass bottles, and, thus, higher consumption and production of glass bottles. Growth in the beverage industry directly affects glass bottle production since the beverage industry is a major consumer of glass bottles.

Glass tableware and kitchenware production is determined as a function of (1) its price at a previous period, (2) the GDP, and (3) production of ceramic tableware and kitchenware—lagged two periods. Ceramic tableware and kitchenware products are a close substitute for similar glass products. An increase in the production of ceramic tableware and kitchenware could lower the product price, induce higher consumption of ceramic tableware and kitchenware, and lower consumption and production of similar glass products.

Zinc Model

The demand for zinc in this study refers to immediate consumption; not demand for storage. Domestic production of zinc, which started in 1985, was preceded by total

importation. Therefore, the quantity of zinc consumed from 1970-1984 is equal to the quantity imported, and the quantity consumed from 1985-1988 is equal to the quantity imported plus sales to domestic consumers by Padaeng Industry. The model is specified as a function of (1) domestic price during a previous period, (2) producer price index of construction materials during a previous period, and (3) the GDP. Construction materials are complementary goods with zinc, and the prices of construction materials have a negative relationship to zinc consumption. An increase in the price of construction materials ultimately reduces the demand for zinc. The GDP, instead of the specific industry production index, is used to represent economic activity, because zinc is widely used in the economy.

Prices of substitutes are experimented to include in the model, using price of aluminum (LME price) as a proxy for the substitutes for zinc. However, the coefficient had the wrong sign and was statistically insignificant, so the variable was omitted. This may be justifiable for several reasons. First, aluminum is not a good representative of zinc's substitution in Thailand. Second, the market price of aluminum is not a good proxy for shadow prices. Third, mineral substitution is not widespread in Thailand due to the limitation of technological progress. Finally, zinc has some preferred properties to other minerals causing substitution to be limited.

Tinplate Model

The forecast for tin consumption is made by using the forecast for tinplate consumption. The econometric model of tinplate consumption is constructed by specifying consumption as a function of (1) the ratio of tinplate price to aluminum price, and (2) the value added of the food industry. The price ratio is included to capture the effect of the substitution between tinplate and other products, using aluminum as a proxy. The relationship between the price ratio and tinplate consumption is negative, and raising the price ratio will induce consumers to switch from using tinplate packaging to other close substitutes such as aluminum, paperboard, or plastic. The value added of the food industry and tinplate consumption are positively related. Tinplate is used in the packaging industry, and fast-growing food industry will increase the consumption of tinplate.

All the models, except tinplate, are constructed in logarithmic form.

The model results are satisfactory with a high adjusted R-squared. The explanatory variables show the corrected signs. No evidence of serial correlation appears

in the error terms of any models except tinplate. This equation is thus re-estimated using the Cochrane-Orcutt iterative technique.

All estimated equations are shown in Table A1 (with t-statistics presented in the parentheses). The description of the variables is presented in Table A2.

Table A1 Estimated Equations

Cement Consumption

$$LCCE_t = \underset{(0.543)}{0.734} - \underset{(-2.678)^{**}}{0.556}\ LRPCE_t + \underset{(19.961)^{***}}{1.124}\ LGDPCO_t$$

Adjusted R-squared	0.962
Durbin-Watson Statistics	1.514
F-Statistic	216.220

Glass Bottle Production

$$LQGB = \underset{(-3.067)}{-19.677} + \underset{(2.558)^{*}}{1.437}\ LRPGB(-1) + \underset{(2.073)}{0.623}\ LGDP$$

$$+ \underset{(4.673)^{***}}{1.094}\ LVABEV$$

Adjusted R-squared	0.972
Durbin-Watson Statistics	2.500
F-Statistic	196.328

Glass Tablewares & Kitchenwares Production

$$LQGTK = \underset{(-4.299)^{**}}{-32.329} + \underset{(1.971)}{1.165}\ LRPGTK(-1) + \underset{(6.494)^{***}}{2.809}\ LGDP$$

$$- \underset{(-2.380)}{0.734}\ LQCTK(-2)$$

Adjusted R-squared	0.872
Durbin-Watson Statistics	2.309
F-Statistic	19.200

Table A1 (Continued)

Zinc Consumption

$$LCZN = -\underset{(3.579)^{***}}{10.303} - \underset{(-1.510)}{0.152}\ LRPZN(-1) - \underset{(-4.266)^{***}}{0.659}\ LPPIC(-1) + \underset{(8.325)^{***}}{1.853}\ LGDP$$

Adjusted R-squared	0.938
Durbin-Watson Statistics.	2.354
F-statistic	86.800

Tinplate Consumption

$$TPC = \underset{(3.485)^{**}}{56240.841} - \underset{(-5.693)^{***}}{105687.18}\ RTPAL + \underset{(16.773)^{***}}{4.305}\ VAFOOD - \underset{(-3.015)^{**}}{0.700}\ AR(1)$$

Adjusted R-squared	0.958
Durbin-Watson Statistics	2.661
F-statistic	91.608

Notes: * indicates the significant level at $\alpha = .10$

** indicates the significant level at $\alpha = .05$

*** indicates the significant level at $\alpha = .01$

Table A2 Description of the Variables

Variable	Description	Source
LCCE	Consumption of cement, mixed cement and portland cement in logarithmic form, (domestic sales plus import) (thousand metric tons)	Department of Domestic Trade and Department of Customs
LCZN	Consumption of zinc metal in logarithmic form (metric tons)	Padaeng Industry
LGDP	Gross Domestic Product at constant 1984 price, in logarithmic form (million baht)	National Economics and Social Development Board
LGDPCO	Gross Domestic Product originating from construction sector at constant 1984 price, in logarithmic form (million baht),	Natioal Economics and Social Developmet Board
LPPIC	Producer price index of construction materials, in logarithmic form (1984=100)	Bank of Thailand
LQCTK	Production of ceramic tableware and kitchenware, in logarithmic form (metric ton)	Bank of Thailand and Ministry of Industry
LQGB	Production of glass bottles, in logarithmic form (metric ton)	Producers
LQGTK	Production of glass tableware and kitchenware, in logarithmic form (metric ton)	Producers
LRPCE	Wholesale price of mixed cement at constant 1984 price, in logarithmic form (baht per ton)	Department of Business Economics
LRPGB	Average retail price of glass bottles at constant 1984 price, in logarithmic form (baht per ton)	Producers

Table A2 (Continued)

Variable	Description	Source
LRPGTK	Average retail price of glass tableware and kitchenwares at constant 1984 price, in logarithmic form (baht per ton)	Producers
LRPZN	The DMR posted price of zinc at constant 1984 price, in logarithmic form (baht per ton)	Department of Mineral Resources
LVABEV	Value added of beverage industry at constant 1984 price, in logarithmic form (thousand baht)	National Economics and Social Development Board
RTPAL	Ratio of price of tinplate and price of aluminum at constant 1984 price (baht per ton)	Producers and World Bank
TPC	Domestic consumption of tinplate, (production plus import minus export) (metric ton)	Krung Thai Bank and Department of Customs
VAFOOD	Value added of food industry at constant 1984 price (thousand baht)	National Economic and Social Development Board

MODEL VALIDATION

Table A3 presents the results of the model validation during the sample period (1970-1988). The results of the model validation are acceptable with the MAPE less than 10 percent, the RMSPE varying from 0.055-0.093, and the U-coefficient ranging from 0.001-0.045. Because the forecast can represent the actual values reasonably well during the sample period, the estimated models can be expected to be good enough to portray the future trends of consumption/ production. These models will be further used to forecast products and raw material consumption/production during the period from 1990-2010.

Table A3 The Results of the Model Validation: Domestic Demand

Products	MAPE[a]	RMSPE[b]	U Coefficient[c]
Cement (1971-1988)	6.10	0.078	0.030
Glass Bottles (1971-1988)	6.99	0.092	0.044
Glass Tableware and Kitchenware (1977-1985)	8.53	0.093	0.045
Zinc (1971-1988)	6.67	0.084	0.003
Tinplate (1976-1988)	7.23	0.091	0.037

Notes:

[a] $\text{MAPE} = (1/T)\sum_{t=1}^{T}\left|\frac{Y_f - Y_t}{Y_t}\right| * 100\%$

[b] $\text{RMSPE} = \sqrt{(1/T)\sum_{t=1}^{T}\frac{(Y_f - Y_t)^2}{Y_t}}$

[c] $\text{U coefficient} = \frac{\sqrt{(1/T)\sum_{t=1}^{T}(Y_f - Y_t)^2}}{\sqrt{(1/T)\sum_{t=1}^{T}Y_f^2} + \sqrt{(1/T)\sum_{t=1}^{T}Y_t^2}}$

FORECASTING ASSUMPTIONS

The consumption of the minerals of interest will be forecast for the period from 1990-2010. The forecasts are made for two scenarios based on different assumptions about exogenous variables including the following:

Cement Equation: In both cases, the GDP from the construction sector is assumed to increase at the rate forecast by TDRI.

Case 1 assumes the future real price of cement follows an historical trend. It is forecast using an exponential smoothing method called the Holt-Winter Additive Effect. The error of the price forecast is about 5.77 percent.

Case 2 assumes the future nominal price of cement increases at the same rate as the forecasted inflation rate.

Glass Bottle Equation: In both cases, the GDP and the GDP from the beverage industry are assumed to increase at the rate forecast by TDRI.

Case 1 assumes the future nominal price of glass bottles increases at average growth rate of price during the sample period, which is about 6 percent per annum.

Case 2 assumes the future nominal price of glass bottles increases at the same rate as the forecasted inflation rate.

Glass Tableware and Kitchenware Equation: In both cases, the GDP is assumed to increase at the rate forecast by TDRI. The production capacity of ceramic tableware and kitchenware is reported by the producers to be 69,000 metric tons in 1990, 79,300 metric tons in 1991, 87,200 metric tons in 1992, and 96,000 metric tons in 1993-1994. The study assumes, in both cases, that the capacity is constant at 96,000 metric tons per annum during the period from 1993-2010, and that the capacity is fully utilized.

Case 1 assumes the future nominal price of glass tableware and kitchenware increases at an average growth rate during the sample period, which is about 6.5 percent per annum.

Case 2 assumes the future nominal price of glass tableware and kitchenware increases at the same rate as the forecasted inflation rate.

Zinc Equation: In both cases, the GDP and the producer price index of construction material are assumed to increase at the rate forecast by TDRI.

Case 1 assumes Padaeng Industry still has the same privilege in setting domestic price, and that the posted price from the DMR is still based on Padaeng's sale price plus transportation costs from Tak Province to Bangkok. To forecast the posted price, four elements are required: (1) LME price, (2) the additional portion at Padaeng Industry (which is claimed to be equal to transportation costs from London to Bangkok), (3) transportation costs from Tak Province to Bangkok, and (4) the United States (US) exchange rate during 1990-2010.

The forecast for the LME price during 1990-2000 is made by adjusting the forecast series of the World Bank with some constant terms to represent more reasonable values. The forecast for the period from 2001-2010 is made by using an exponential smoothing method called "double smoothing." The error of the forecast is approximately 5.23 percent.

The additional portion at Padaeng Industry is around US$71 per ton and transportation costs from Tak Province to Bangkok are approximately 466 baht per ton in 1990. Both costs are assumed to increase at the same growth rate as inflation.

The US exchange rate is assumed to increase at a 2 percent growth rate every five years, which is the rate consistent with the actual data.

Case 2 assumes the domestic price of zinc will follow world price, without any privilege for Padaeng Industry. The domestic price will include the LME price plus transportation costs from Tak Province to Bangkok. The assumptions on transportation costs and US exchange rates are still the same as in Case 1.

Tinplate Equation: In both cases, the GDP of the food industry is assumed to increase at the rate forecast by TDRI. The future nominal price of aluminum is made by adjusting the forecast series of the World Bank with some constant terms to represent more reasonable values.

Case 1 assumes the future nominal price of tinplate increases at average growth rate of price during the sample period, which is about 3.54 percent per annum.

Case 2 assumes the future nominal price of tinplate increases at the same rate as the forecasted inflation rate.

Table A4 presents the forecasts for growth rates of exogenous variables, and Figures A1-A5 present the price patterns predicted for the future.

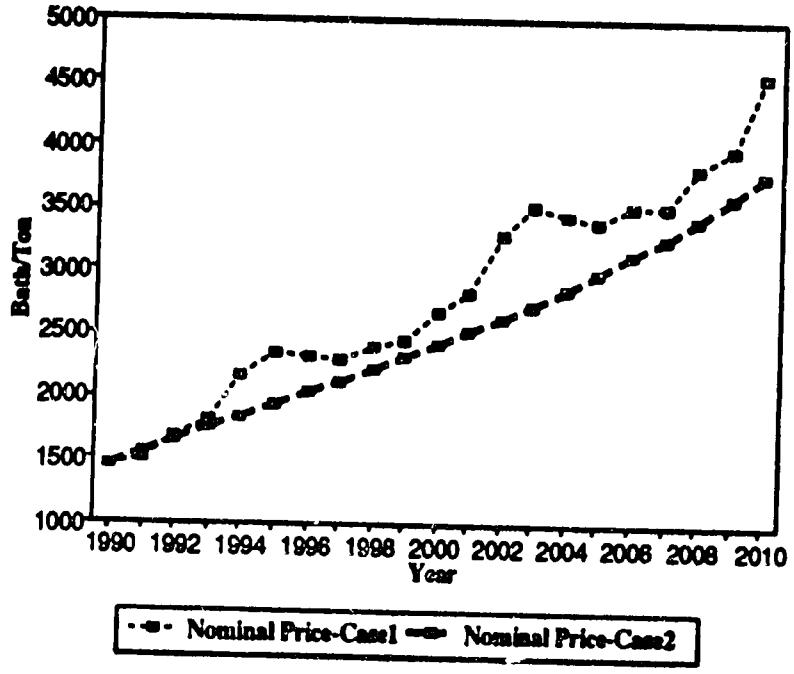
Table A4 Forecast for Real Growth Rates of Exogenous Variables, 1990-2010

Variable	1990	1991	1992	1993-95	1996-99	2000-05	2006-10
GDP	9.50	10.00	10.10	9.10	7.30	6.10	6.40
GDP from Construction	19.80	18.80	16.80	12.00	6.10	2.40	2.60
GDP from Food Industry	6.40	8.10	8.20	7.50	6.00	5.20	5.50
GDP from Beverage	9.00	8.70	8.40	7.50	6.00	5.20	5.50
Inflation	7.30	6.80	6.20	5.33	4.55	4.35	4.76
Cement Price							
Case1	0.01	-2.94	5.82	6.15	-3.46	1.99	3.02
Zinc Price[a]							
Case1	15.30	3.32	5.15	3.00	6.98	5.46	3.74
Case2	13.75	3.16	5.10	2.89	7.09	5.53	3.70
LME Price	-4.85	3.12	3.03	2.86	6.59	4.22	3.27
Producer Price Index of Construction Sector	10.70	11.10	11.80	11.10	8.20	4.55	3.40
Alumnum Price[a,b]	8.57	4.07	5.99	3.63	3.74	3.12	2.82

Note: [a] Nominal Price

Sources: TDRI Projection

[b] World Bank (1989b)



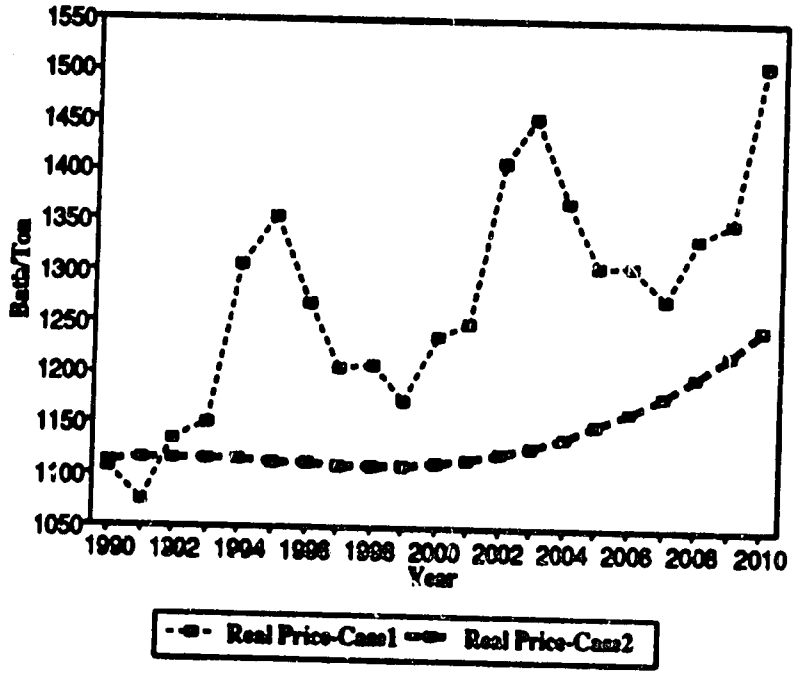
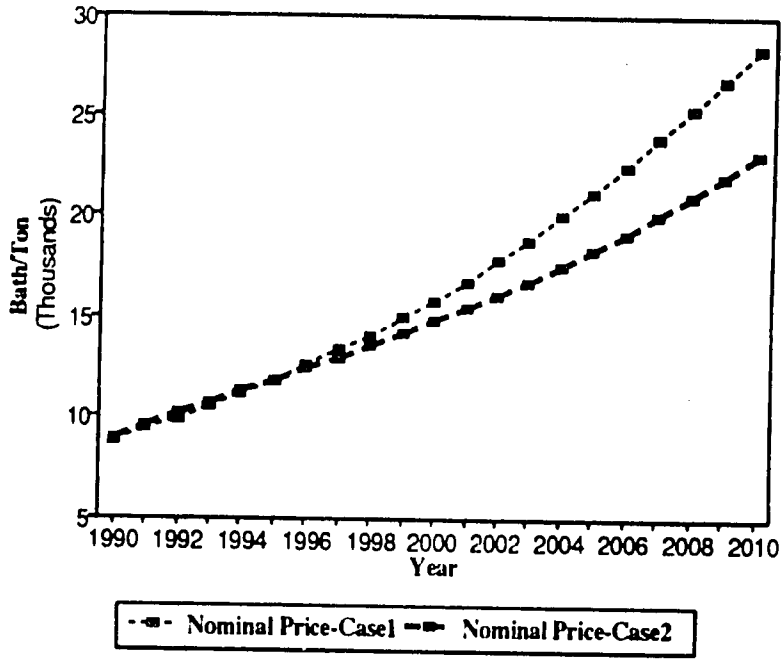


Figure A1 Cement Price



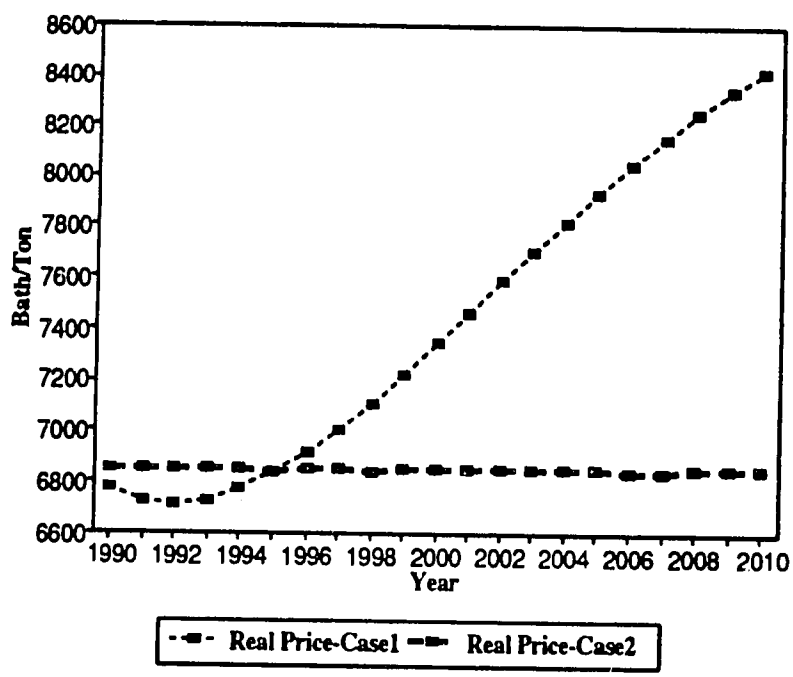
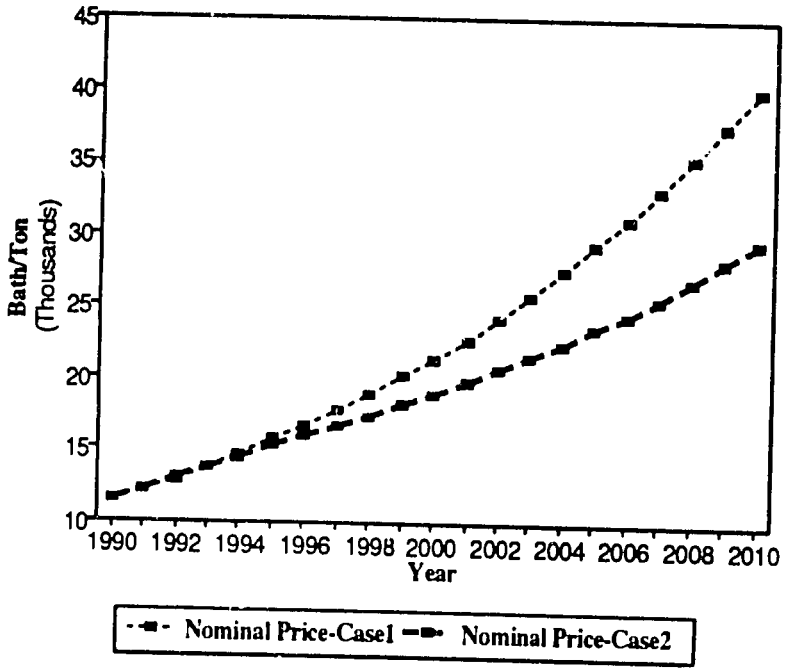


Figure A2 Glass Bottle Price



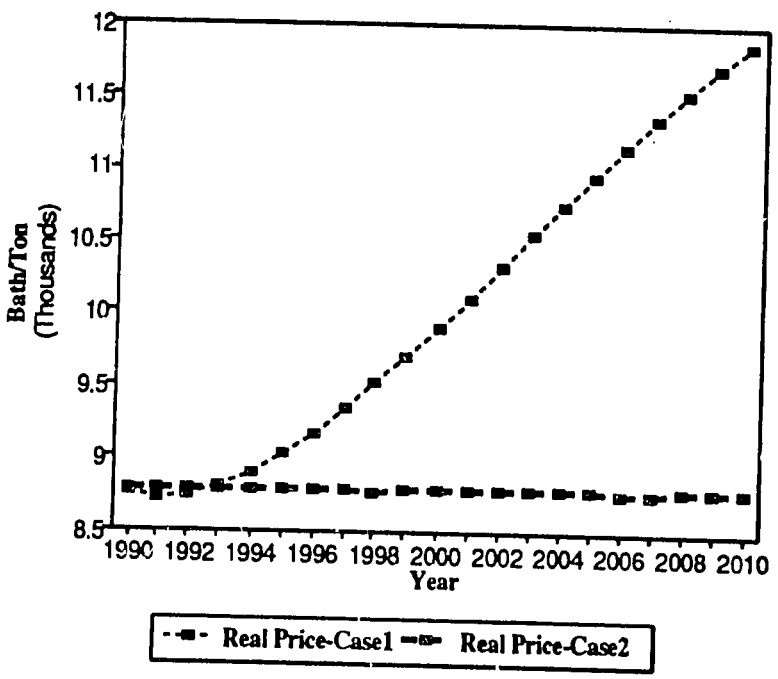
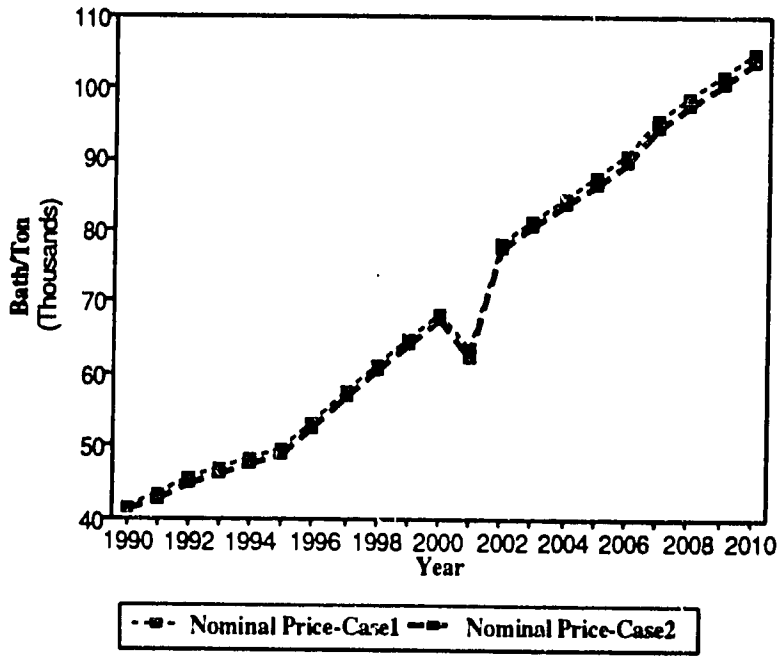


Figure A3 Glass Tableware and Kitchenware Price



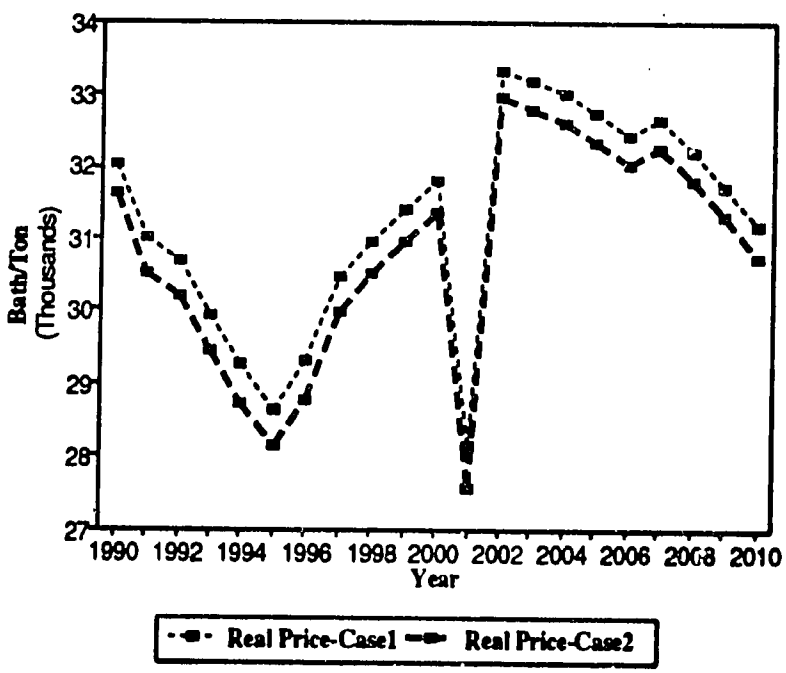
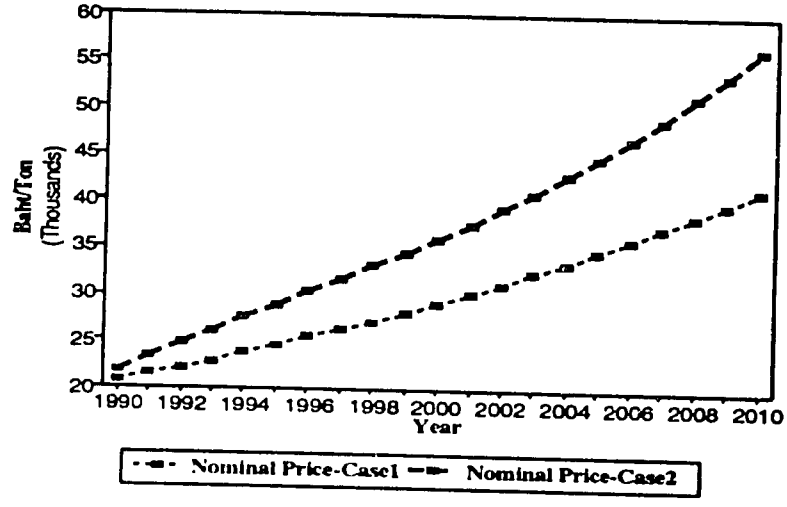


Figure A4 Zinc Price



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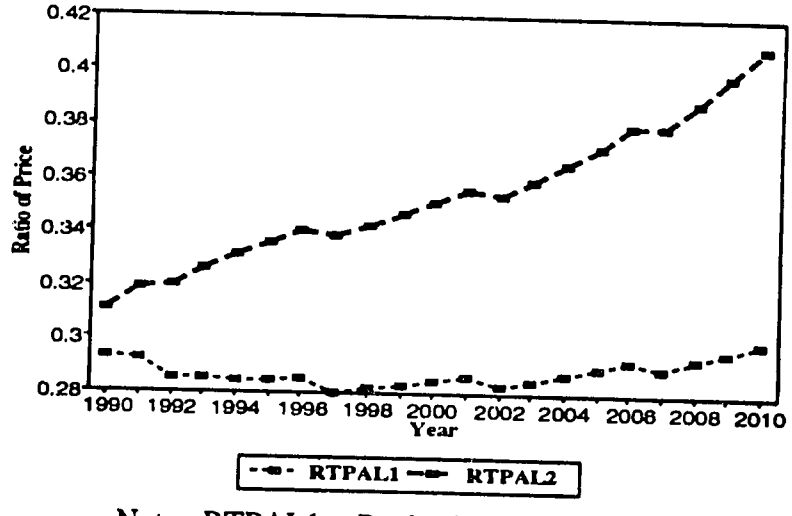

Note : RTPAL1 = Real price of tinplate to Alumnum (case 1).
RTPAL2 = Real price of tinplate to Alumnum (case 2).

Figure A5 Tin Price

Appendix B

Forecast for Product and Mineral Consumption

Table B1 Forecast for Domestic Cement Consumption

Unit : Thousand Metric Tons

	Capacity[a]	Consumption[b]		Excess[c] (Shortage)	
		Case 1	Case 2	Case 1	Case 2
1990	15,150	17,121	17,062	(1,971)	(1,912)
1991	16,450	21,126	20,675	(4,676)	(4,225)
1992	20,700	24,373	24,605	(3,673)	(3,905)
1993	24,210	28,054	28,518	(3,844)	(4,308)
1994	36,610	29,634	32,384	6,976	4,226
1995	36,610	32,387	36,113	4,223	497
1996	36,610	36,757	39,562	(147)	(2,952)
1997	36,610	40,657	42,572	(4,047)	(5,962)
1998	36,610	43,037	45,085	(6,427)	(8,475)
1999	36,610	45,616	47,036	(9,006)	(10,426)
2000	36,610	45,815	48,574	(9,205)	(11,964)
2001	36,610	46,819	49,845	(10,209)	(13,235)
2002	36,610	44,908	50,941	(8,298)	(14,331)
2003	36,610	45,152	51,965	(8,542)	(15,355)
2004	36,610	47,789	52,946	(11,179)	(16,336)
2005	36,610	50,255	53,940	(13,645)	(17,330)
2006	36,610	51,552	54,979	(14,942)	(18,369)
2007	36,610	53,752	56,101	(17,142)	(19,491)
2008	36,610	53,869	57,217	(17,259)	(20,607)
2009	36,610	55,256	58,422	(18,646)	(21,812)
2010	36,610	53,718	59,723	(17,108)	(23,113)

Sources: [a] 1990-1994 from Federation of Industry of Thailand,
1995-2010 assume no any capacity expansion
[b] estimated
[c] (1)-(2)

Table B2 Forecast for Cement Raw Materials

Unit : Thousand Metric Tons

	Case 1				Case 2			
	Lime-stone	Shale	Iron Ore	Gypsum	Lime-stone	Shale	Iron Ore	Gypsum
1990	20,545	6,711	137	907	20,474	6,688	136	904
1991	25,351	8,281	169	1,120	24,810	8,105	165	1,096
1992	29,248	9,554	195	1,292	29,526	9,645	197	1,304
1993	33,664	10,997	224	1,487	34,221	11,179	228	1,511
1994	35,561	11,616	237	1,571	38,860	12,694	259	1,716
1995	38,864	12,696	259	1,717	43,336	14,156	289	1,914
1996	44,109	14,409	294	1,948	47,475	15,508	316	2,097
1997	48,789	15,938	325	2,155	51,086	16,688	341	2,256
1998	51,645	16,871	344	2,281	54,102	17,673	361	2,389
1999	54,740	17,882	365	2,418	56,443	18,438	376	2,493
2000	54,978	17,959	367	2,428	58,289	19,041	389	2,574
2001	56,183	18,353	375	2,481	59,814	19,539	399	2,642
2002	53,890	17,604	359	2,380	61,130	19,969	408	2,700
2003	54,183	17,700	361	2,393	62,358	20,370	416	2,754
2004	57,347	18,733	382	2,533	63,535	20,755	424	2,806
2005	60,306	19,700	402	2,664	64,728	21,144	432	2,859
2006	61,863	20,208	412	2,732	65,975	21,552	440	2,914
2007	64,502	21,071	430	2,849	67,321	21,991	449	2,973
2008	64,643	21,117	431	2,855	68,660	22,429	458	3,032
2009	66,307	21,660	442	2,929	70,106	22,901	467	3,096
2010	64,461	21,057	430	2,847	71,667	23,411	478	3,165

Source: Estimated

Table B3 Forecast for Glass Production

Unit : Thousand Metric Tons

	Flat Glass[a,b]	Glass Bottle		Glass Tableware & Kitchenware	
		Case 1	Case 2	Case 1	Case 2
1990	247.0	508.6	507.9	54.2	53.9
1991	302.0	575.2	584.6	45.5	45.6
1992	300.0	659.7	677.8	45.5	45.8
1993	433.0	770.1	793.3	53.3	53.5
1994	499.0	863.6	891.1	64.1	63.8
1995	499.0	994.4	1,010.5	76.3	75.0
1996	512.0	1,134.3	1,137.1	96.4	93.3
1997	497.0	1,288.3	1,270.6	120.3	114.3
1998	512.0	1,455.7	1,408.5	148.2	137.9
1999	485.0	1,637.8	1,550.3	180.7	164.4
2000	447.0	1,837.8	1,702.1	219.0	194.7
2001	444.0	2,059.6	1,863.7	264.3	229.4
2002	447.0	2,308.8	2,041.1	319.0	270.4
2003	512.0	2,588.5	2,235.9	385.0	318.6
2004	499.0	2,901.2	2,448.4	464.8	375.6
2005	497.0	3,254.7	2,687.3	562.2	444.0
2006	512.0	3,651.9	2,954.2	680.6	526.1
2007	512.0	4,100.7	3,250.0	826.0	624.8
2008	485.0	4,606.8	3,581.9	1,003.9	743.9
2009	512.0	5,174.0	3,957.6	1,221.9	889.1
2010	379.0	5,807.8	4,376.3	1,489.1	1,065.0

Notes: [a] Planned capacity as reported by the producers, including the capacity of Thai-Asahi Company, Siam Plate Glass, Bangkok Float Glass (starting in 1991) and Gardian Industry Company (starting in 1993).

[b] The capacity has time allotted for repair and maintenance. Sheet process has to be repaired every 8 year and float process has to be repaired every 9 year, so the product on capacity during that year will be half of the usual capacity.

Source: Estimated

Table B4 Forecast for Mineral Raw Materials Used in Glass Industry

Unit : Thousand Metric Tons

	Glass Sand					Limestone				Feldspar
	Flat Glass	Glass Bottle		Glass T&K		Glass Bottle		Glass T&K		Flat Glass
		Case1	Case2	Case1	Case2	Case1	Case2	Case1	Case2	
1990	153	254	254	27	27	76	76	8	8	22
1991	187	288	292	23	23	86	88	7	7	27
1992	186	330	330	23	23	99	102	7	7	27
1993	268	385	397	27	27	116	119	8	8	39
1994	309	434	446	32	32	130	134	10	10	45
1995	309	497	505	38	38	149	152	11	11	45
1996	317	567	569	48	47	170	171	14	14	46
1997	308	644	635	60	57	193	191	18	17	45
1998	317	728	704	74	69	218	211	22	21	46
1999	301	819	775	90	82	246	233	27	25	44
2000	277	919	851	110	97	276	255	33	29	40
2001	275	1,030	932	132	115	309	280	40	34	40
2002	277	1,154	1,021	160	135	346	306	48	41	40
2003	317	1,294	1,118	192	159	388	335	58	48	46
2004	309	1,451	1,224	232	188	435	367	70	56	45
2005	308	1,627	1,344	281	222	488	403	84	67	45
2006	317	1,826	1,477	340	263	548	443	102	79	46
2007	317	2,050	1,625	413	312	615	487	124	94	46
2008	301	2,303	1,791	502	372	691	537	151	112	44
2009	317	2,587	1,979	611	445	776	594	183	133	46
2010	235	2,904	2,188	745	532	871	656	223	160	34

Source: Estimated

Table B5 Planned Capacity of Ceramic Products, 1990-94

Unit : Metric Ton

	Tiles	Sanitary ware	Tableware & Kitchenware
1990	647,000	67,000	69,000
1991	830,700	93,000	79,300
1992	972,000	103,000	87,200
1993	1,082,000	113,000	96,000
1994	1,082,000	113,000	96,000

Source: Producers

Table B6 Forecast for Mineral Raw Materials used in Ceramic Industry, 1990-1994

Unit: Thousand Metric Tons

	1990	1991	1992	1993	1994
Kaolin[a]	**280**	**359**	**417**	**463**	**463**
Tiles	239	307	360	400	400
S.W.	20	28	31	34	34
T&K	21	24	26	29	29
Feldspar[a]	**215**	**276**	**320**	**355**	**355**
Tiles	181	233	272	303	303
S.W.	17	23	26	28	28
T&K	17	20	22	24	24
Ball Clay[a]	**186**	**239**	**277**	**308**	**308**
Tiles	149	191	224	249	249
S.W.	23	33	36	40	40
T&K	14	16	17	19	19
Glass Sand[b]	**40**	**50**	**58**	**65**	**65**

Notes: S.W. refers to sanitaryware,
T&K refers to tableware and kitchenware.

Sources: [a] estimated from planned capacity (Table B5)
[b] As reported by the producers.

Table B7 Forecast for Zinc Consumption

Unit: Metric Ton

	Case 1	Case 2
1990	88,046	88,046
1991	97,197	97,397
1992	108,993	109,243
1993	120,390	120,674
1994	132,085	132,421
1995	144,113	144,502
1996	156,379	156,827
1997	167,805	168,257
1998	178,732	179,165
1999	190,701	191,138
2000	203,514	203,960
2001	217,654	218,113
2002	238,845	239,565
2003	251,558	252,009
2004	273,282	273,780
2005	298,331	298,887
2006	326,835	327,460
2007	359,716	360,425
2008	395,799	396,559
2009	438,265	439,147
2010	486,475	487,507

Source: Estimated

Table B8 Forecasts for Tinplate and Tin Consumption

Unit : Metric ton

	Tinplate		Tin in Tinplate Industry		Tin in Other Industry		Total Tin Consumption	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
1990	266,818	264,958	1,467	1,457	489-629	486-625	1,957-2,096	1,943-2,082
1991	286,706	283,825	1,577	1,561	526-676	520-669	2,103-2,253	2,081-2,230
1992	308,715	305,054	1,698	1,678	566-728	559-719	2,264-2,426	2,237-2,397
1993	330,913	326,557	1,820	1,796	607-780	599-770	2,427-2,600	2,395-2,566
1994	353,744	348,806	1,946	1,918	649-834	639-822	2,594-2,779	2,558-2,741
1995	376,879	371,446	2,073	2,043	691-888	681-876	2,764-2,961	2,724-2,919
1996	399,958	394,084	2,200	2,167	733-943	722-929	2,933-3,143	2,890-3,096
1997	423,569	417,433	2,330	2,296	777-998	765-984	3,106-3,328	3,061-3,280
1998	446,464	440,009	2,456	2,420	819-1,052	807-1,037	3,274-3,508	3,227-3,457
1999	468,773	461,987	2,578	2,541	859-1,105	847-1,089	3,438-3,683	3,388-3,630
2000	491,819	484,725	2,705	2,666	902-1,159	889-1,143	3,607-3,864	3,555-3,809
2001	515,367	507,955	2,835	2,794	945-1,215	931-1,197	3,779-4,049	3,725-3,991
2002	540,260	532,669	2,971	2,930	990-1,273	977-1,256	3,962-4,245	3,906-4,185
2003	566,556	558,628	3,116	3,072	1,039-1,335	1,024-1,317	4,155-4,452	4,097-4,389
2004	593,753	585,440	3,266	3,220	1,089-1,400	1,073-1,380	4,354-4,665	4,293-4,600
2005	623,563	614,812	3,430	3,381	1,143-1,470	1,127-1,449	4,573-4,899	4,509-4,831
2006	655,199	645,994	3,604	3,553	1,201-1,544	1,184-1,523	4,805-5,148	4,737-5,076
2007	689,576	680,049	3,793	3,740	1,264-1,625	1,247-1,603	5,057-5,418	4,987-5,343
2008	725,911	715,785	3,993	3,937	1,331-1,711	1,312-1,687	5,323-5,704	5,249-5,624
2009	764,532	753,742	4,205	4,146	1,402-1,802	1,382-1,777	5,607-6,007	5,527-5,922
2010	805,980	794,458	4,433	4,370	1,478-1,900	1,457-1,873	5,911-6,333	5,826-6,242

Source: Estimated

Table B9 Forecast for Domestic Coal Consumption, 1990-2000

Unit: Million Metric Tons

	1990	1995	2000
Power sector	8.03	20.75	33.97
Non-power sector	2.44	3.36	4.39
Cement industry	1.97	2.73	3.47
Industrial boilers	0.34	0.52	0.82
Tobacco curing industry	0.13	0.11	0.10
Total consumption	**10.47**	**24.11**	**38.36**

Source: World Bank (1989 a)

Table B10 Forecast for Selected Mineral Consumption

Unit: Metric Ton

	Limestone[a] (000)	Shale (000)	Iron Ore (000)	Gypsum (000)	Glass Sand[b] (000)
1990	20,558-20,629	6,688-6,711	136-137	904-907	474
1991	24,903-25,446	8,105-8,281	165-169	1,096-1,120	548-552
1992	29,354-29,635	9,554-9,645	195-197	1,292-1,304	597-606
1993	33,788-34,348	10,997-11,179	224-228	1,487-1,511	745-757
1994	35,701-39,004	11,616-12,694	237-259	1,571-1,716	840-852
1995	39,024-43,499	12,696-14,156	259-289	1,717-1,914	-
1996	44,293-47,660	14,409-15,508	294-316	1,948-2,097	-
1997	48,997-51,297	15,938-16,688	325-341	2,155-2,256	-
1998	51,877-54,342	16,871-17,673	344-361	2,281-2,389	-
1999	54,998-56,716	17,882-18,438	365-376	2,418-2,493	-
2000	55,262-58,598	17,959-19,041	367-389	2,428-2,574	-
2001	56,497-60,163	18,353-19,539	375-399	2,481-2,642	-
2002	54,237-61,524	17,604-19,969	359-408	2,380-2,700	-
2003	54,566-62,804	17,700-20,370	361-416	2,393-2,754	-
2004	57,770-64,040	18,733-20,755	382-424	2,533-2,806	-
2005	60,776-65,300	19,700-21,144	402-432	2,664-2,859	-
2006	62,385-66,625	20,208-21,552	412-440	2,732-2,914	-
2007	65,083-68,060	21,071-21,991	430-449	2,849-2,973	-
2008	65,292-69,502	21,117-22,429	431-458	2,855-3,032	-
2009	67,034-71,065	21,660-22,911	442-467	2,929-3,096	-
2010	65,277-72,761	21,057-23,411	430-478	2,847-3,165	-

Table B10 (Continued)

Unit: Metric Ton

	Feldspar[b] (000)	Kaolin (000)	Ball Clay (000)	Zinc	Tin	Lignite
1990	237	280	186	88,046	2,013-2,027	10,470
1991	303	359	239	97,197-97,397	2,156-2,178	-
1992	347	417	277	108,993-109,243	2,317-2,345	-
1993	394	463	308	120,390-120,674	2,481-2,514	-
1994	400	463	308	132,085-132,421	2,650-2,687	-
1995	-	-	-	144,113-144,502	2,822-2,863	24,110
1996	-	-	-	156,379-156,827	2,993-3,038	-
1997	-	-	-	167,805-168,257	3,171-3,217	-
1998	-	-	-	178,732-179,169	3,342-3,391	-
1999	-	-	-	190,701-191,138	3,509-3,561	-
2000	-	-	-	203,514-203,960	3,682-3,736	38,360
2001	-	-	-	217,654-218,113	3,858-3,914	-
2002	-	-	-	238,845-239,565	4,046-4,104	-
2003	-	-	-	251,558-252,009	4,243-4,304	-
2004	-	-	-	273,282-273,780	4,447-4,510	-
2005	-	-	-	298,331-298,887	4,670-4,736	-
2006	-	-	-	326,835-327,460	4,907-4,977	-
2007	-	-	-	359,716-360,425	5,165-5,238	-
2008	-	-	-	395,799-396,559	5,437-5,514	-
2009	-	-	-	438,265-439,147	5,725-5,807	-
2010	-	-	-	486,475-487,507	6,034-6,122	-

Notes: [a] From cement industry plus glass industry (Table B2 + Table B4)

[b] From glass industry plus ceramic industry (Table B4 + Table B6)

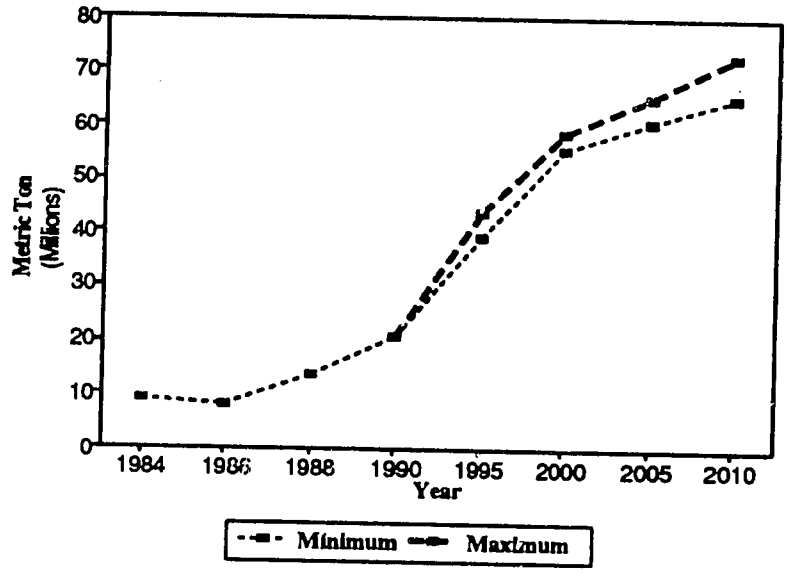

Figure B1 Forecast for Limestone Consumption

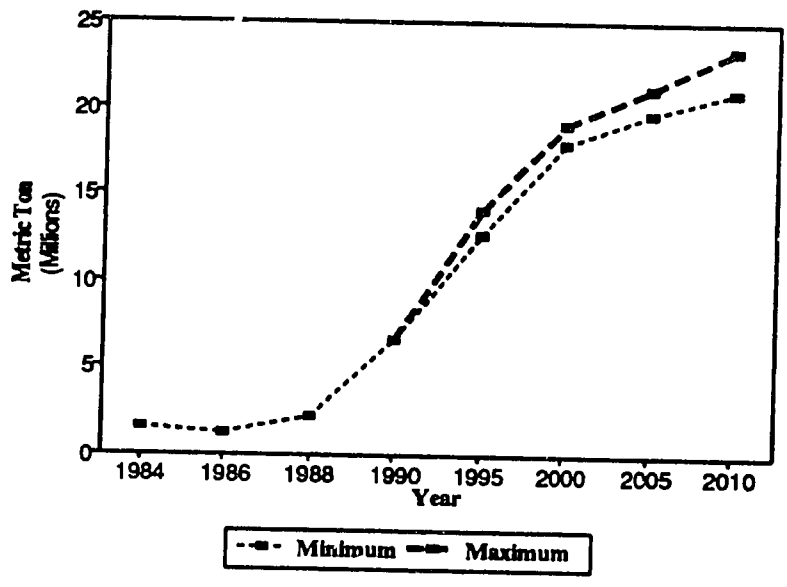

Figure B2 Forecast for Shale Consumption

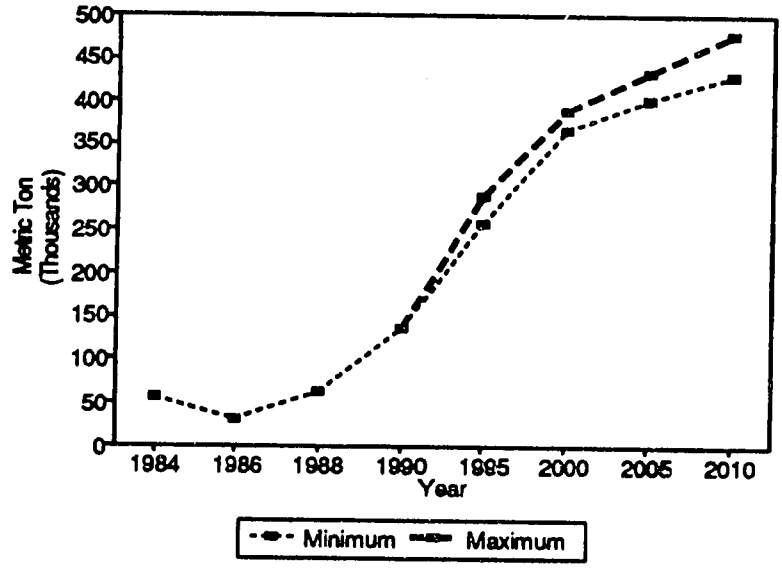

Figure B3 Forecast for Iron Ore Consumption

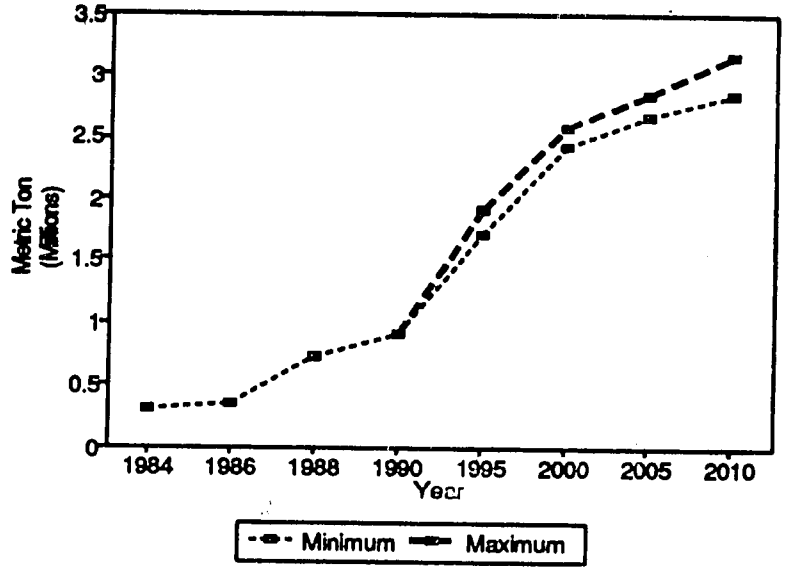

Figure B4 Forecast for Gypsum Consumption

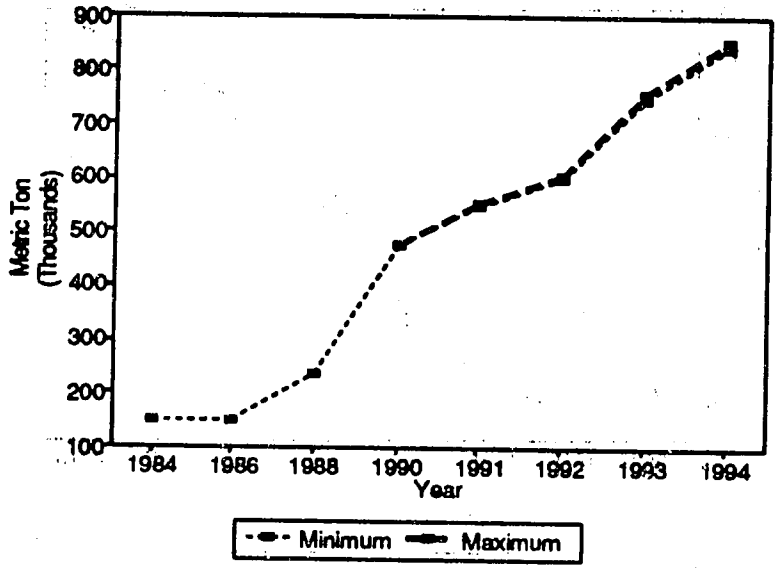

Figure B5 Forecast for Glass Sand Consumption

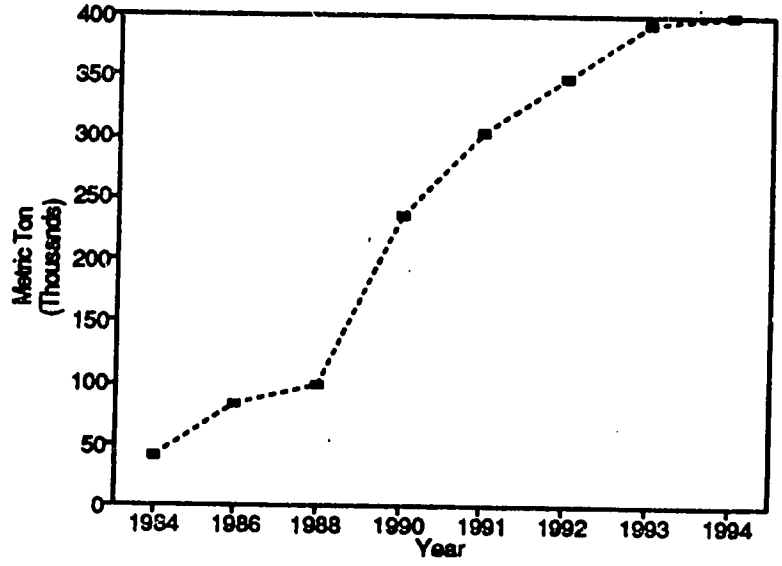

Figure B6 Forecast for Feldspar Consumption

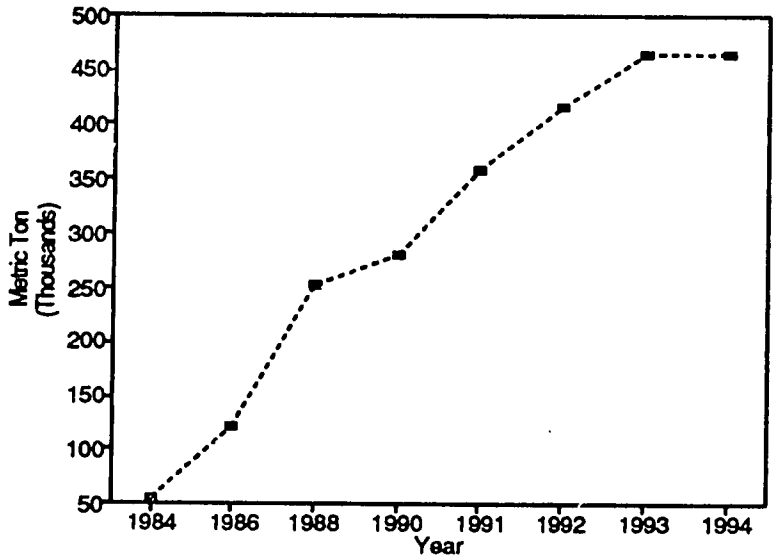

Figure B7 Forecast for Kaolin Consumption

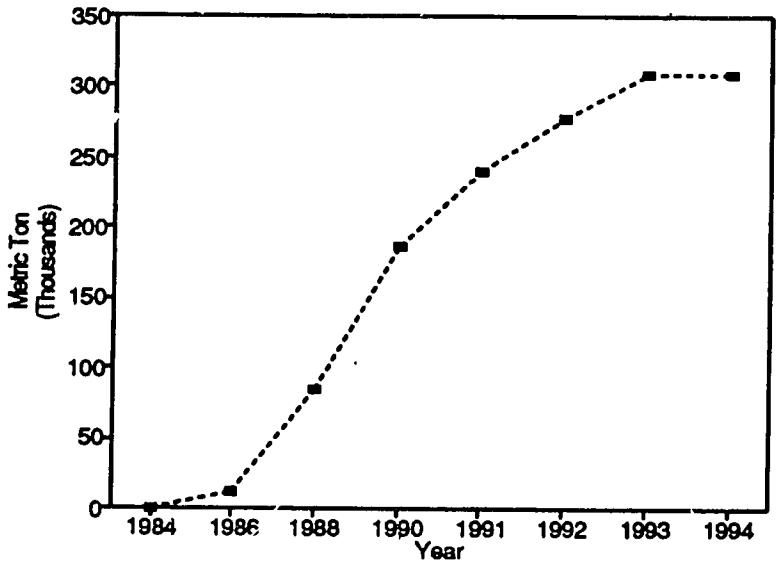

Figure B8 Forecast for Ball Clay Consumption

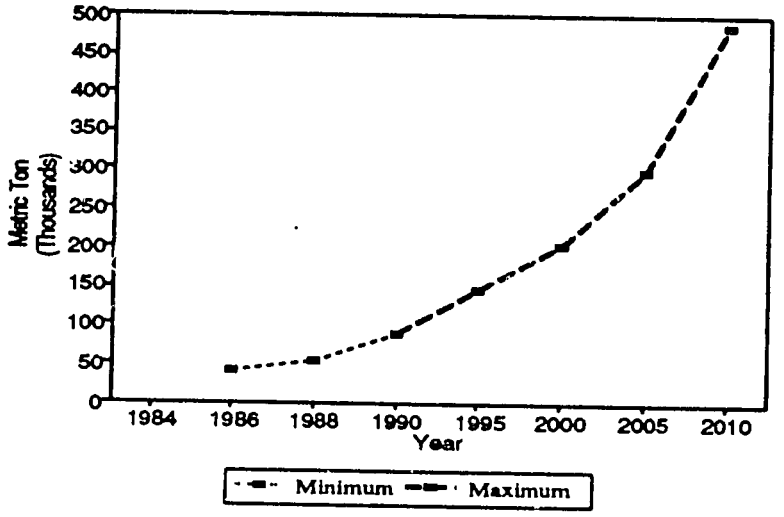

Figure B9 Forecast for Zinc Consumption

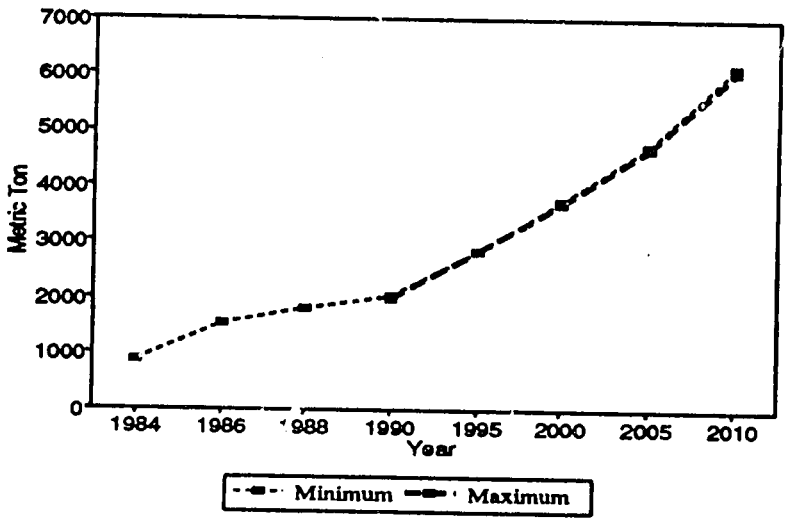

Figure B10 Forecast for Tin Consumption

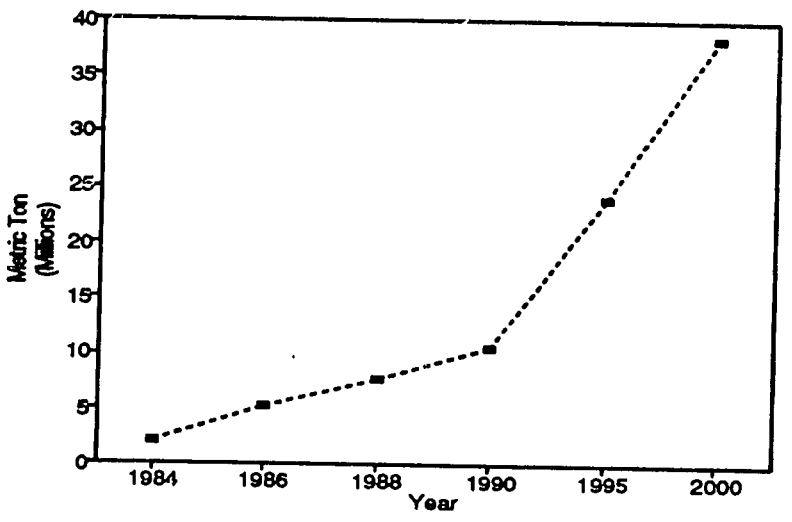

Figure B11 Forecast for Lignite Consumption

Appendix C
World Prices of Some Minerals Under Some Considerations

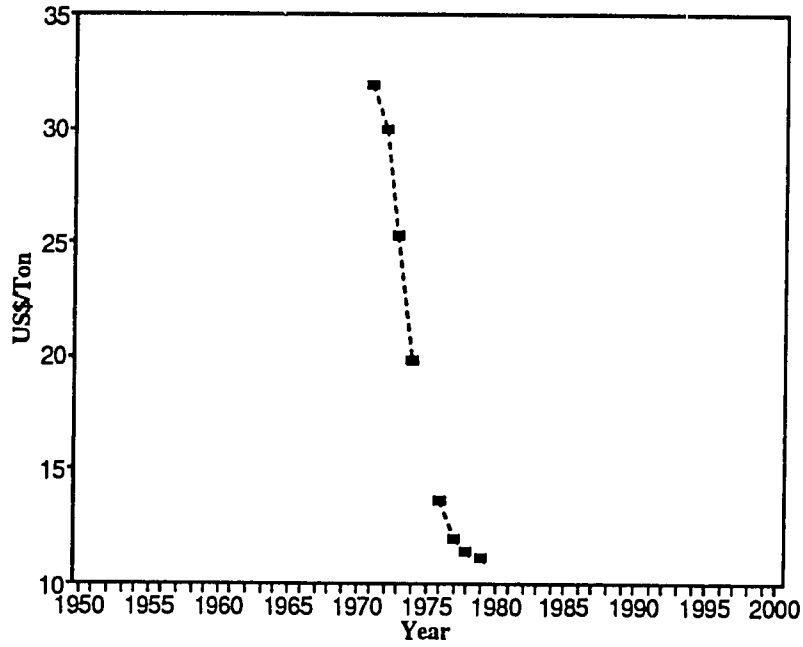

Figure C1 Real Price of Limestone

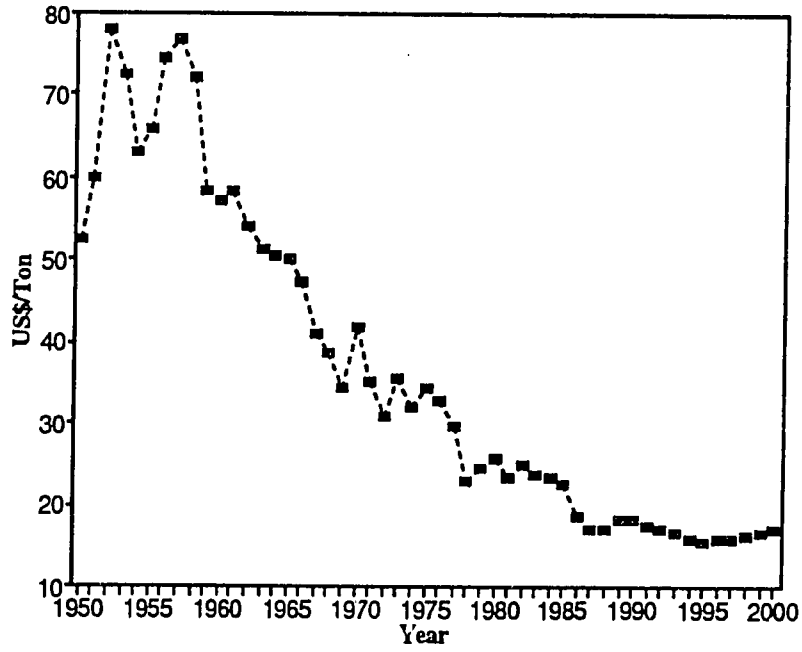

Figure C2 Real Price of Iron Ore

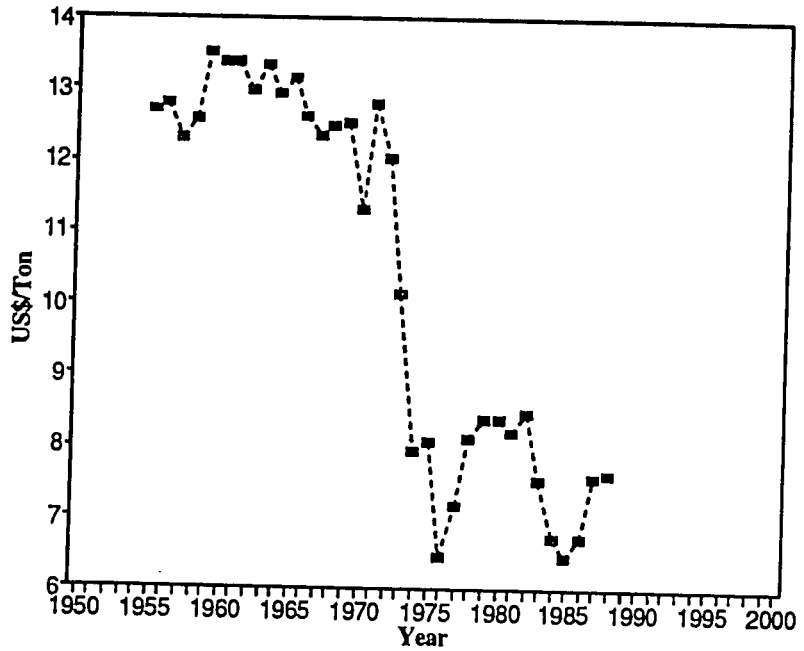

Figure C3 Real Price of Gypsum

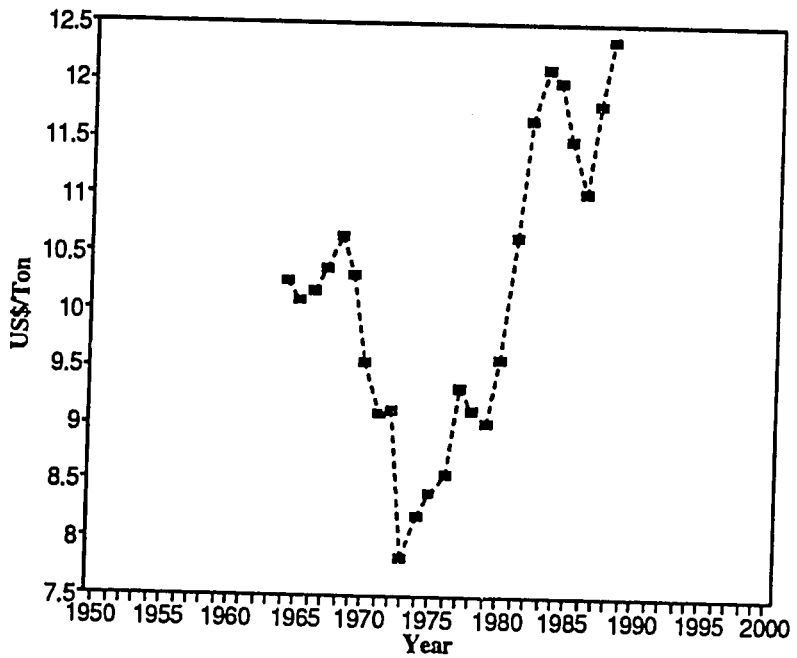

Figure C4 Real Price of Glass Sand

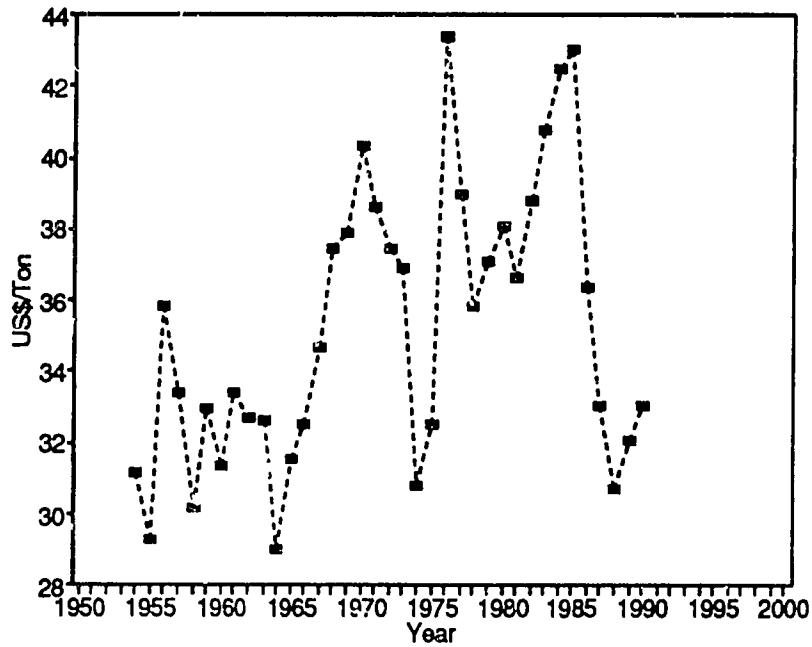

Figure C5 Real Price of Feldspar

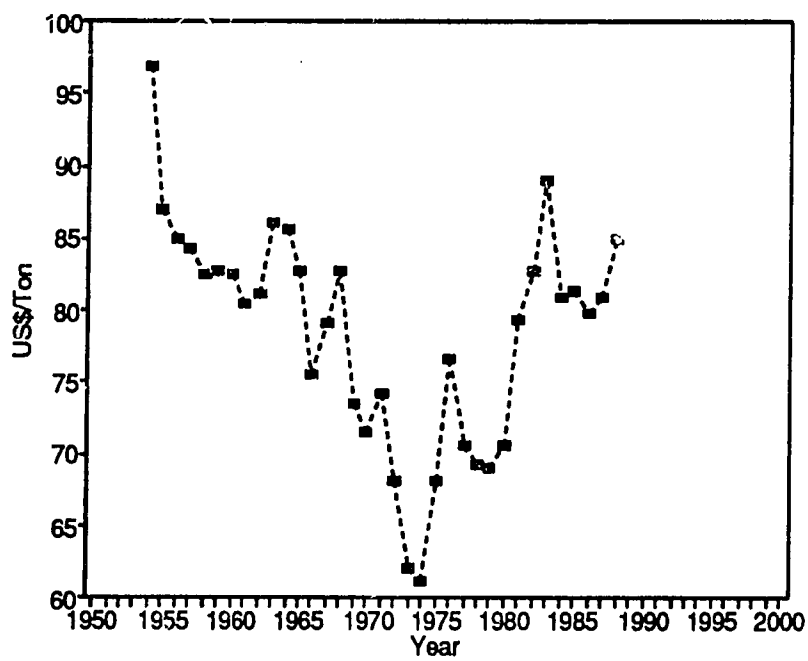

Figure C6 Real Price of Kaolin

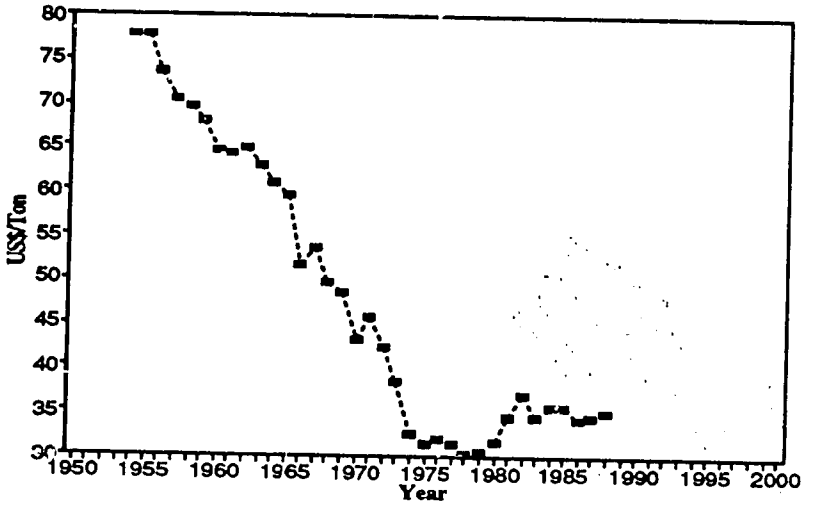

Figure C7 Real Price of Ball Clay

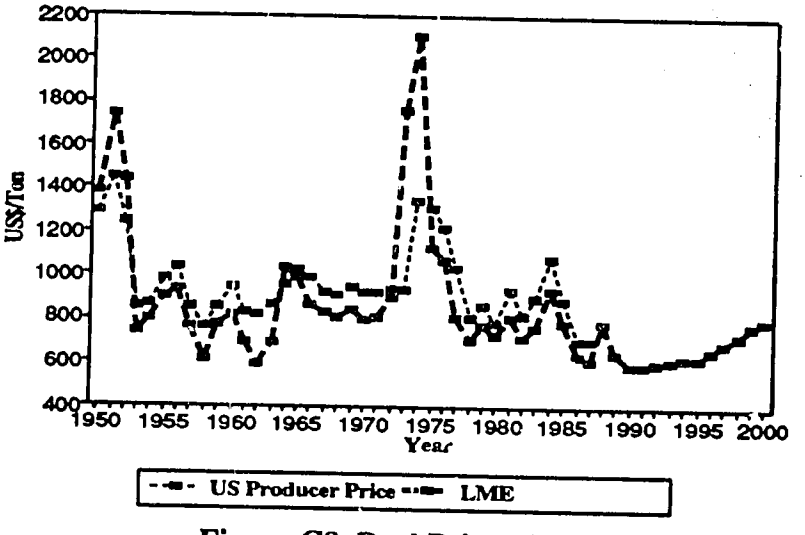

Figure C8 Real Price of Zinc

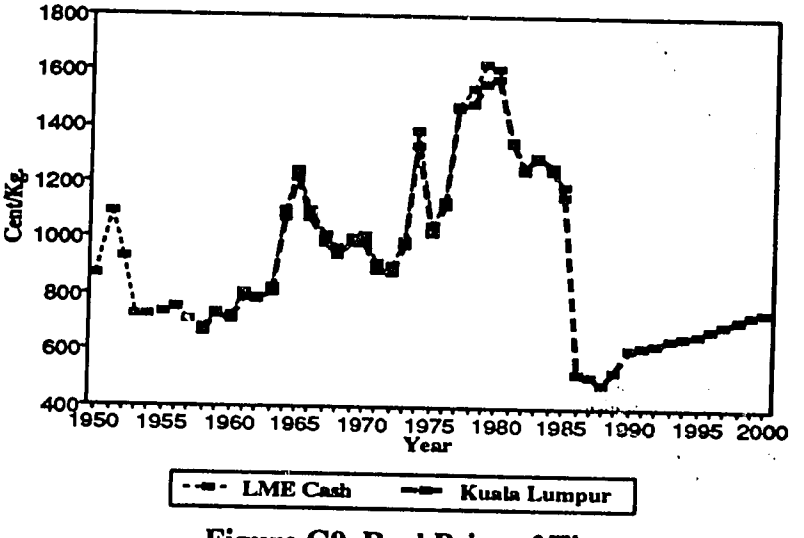

Figure C9 Real Price of Tin

Appendix D
Data

Table D1 Mineral Royalty Rates, 1988

Kind of Minerals	Royalty Rate (%)
Flat Rate	
(a). Ore	
Antimony	10
Arsenic	7
Asbestos	4
Barite	
- Ground	7
- Unground	2
Calcite	4
Chromite	4
Columbite	20
Columbium Tantalum	10
Copper	10
Diatomite	2
Dolomite	4
Emery	4
Feldspar	4
Fluorite	7
Gold	10
Graphite	4
Gypsum	4
Illmenite	2
Iron	4.5
Kaolin	
- for ceramic industry	4
- for chemical industry	2
- for paper industry	2
Kaolinite	4
Lignite	4
Limestone	
- for calcium carbide industry	4
- for cement industry	4
- in preparing lime for sugar industry	4
- in preparing lime for tannery industry	4
Magnezite	7
Manganese	
- Battery grade	7
- Chemical grade	4
- Metallurgical grade	2.5

Table D1 (Continued)

Kind of Minerals	Royalty Rate (%)
Marble	4
Molybdenum	10
Monazite	7
Phosphate	4
Pyrophyllite	4
Quartz	4
Rock salt	4
Rutile	7
Shale for cement industry	4
Silver	10
Talc	4
Tantalite	20
Xenotime	10
Zircon	4
(b). Slag	
Arsenic-bearing slag	10
Bismuth-bearing slag	10
Cadmium-bearing slag	10
Copper-bearing slag	10
Lead-bearing slag	10
Nickel-bearing slag	10
Tin-bearing slag	15
Tungsten trioxide-bearing slag	15
Zinc-bearing slag	10

Sliding Scale

	Posted Price	Royalty Rate (%)
Tin	0 - 3,000	0
	3,001 - 7,000	0.1
	7,001 - 9,000	5
	9,001 - 11,000	15
	11,001 - 14,000	30
	14,001 - 17,000	40
	17,001 - 20,000	50
	Above 20,001	60
Zinc	0 - 10,000	2
	10,001 - 20,000	5
	20,001 - 30,000	10
	Above 30,001	15

Note: Unit for posted price of tin is bath per picul, of zinc is bath per metric ton.

Source: Department of Mineral Resources

Table D2 Gross Domestic Product at 1984 Constant Prices by Industrial Origin

Unit : Million Baht

	1970	1975	1980	1985	1986	1987	1988	1989e
Agriculture	99642	120060	146270	186084	186730	186056	205233	218027
Mining and Quarrying	15375	12488	27342	34214	33599	36108	44168	54512
Manufacturing	67344	110617	174920	212151	240152	271622	321279	364474
Non Mineral-Based Manufacturing	47367	77777	115479	149816	161879	189282	222296	249057
Mineral-Based Manufacturing	19977	32840	59441	62336	78273	82339	98983	115417
Construction	26323	24357	43078	53206	51664	58545	71014	90007
Electricity and water supply	3383	6328	10677	20969	22322	25255	28430	31807
Transportation and communication	27265	33313	52369	71629	78176	84494	92458	102489
Wholesale and retail trade	67601	86961	126494	160010	168674	190551	219652	255529
Banking, insurance and real estate	11465	15848	24722	35145	35674	47115	58540	69716
Ownership of dwellings	29379	29257	27108	40325	42264	43808	47994	46732
Public administration and defence	15558	21879	34820	48208	50179	51768	54124	56123
Services	39019	59276	99079	138617	145682	164781	179171	199216
Gross Domestic Product(GDP)	402355	520385	766880	1000558	1055115	1160103	1322062	1488631
Mining and Quarrying as % of GDP	3.8	2.4	3.6	3.4	3.2	3.1	3.3	3.7
Mineral-Based Manufacturing as % of Manufacturing GDP	29.7	29.7	34.0	29.4	32.6	30.3	30.8	31.7
Mineral-Based Manufacturing as % of GDP	5.0	6.3	7.8	6.2	7.4	7.1	7.5	7.8
Mining & Quarrying & Mineral-Based Manufacturing as % of GDP	8.8	8.7	11.3	9.6	10.6	10.2	10.8	11.4

Note: Mineral-based manufacturing include chemicals and chemical products, petroleum refineries and petroleum products, non-metallic mineral products, basic metal industries, fabricated products, machinery, electrical machinery andsupplies and transport equipment.

Source: National Income of Thailand (New Series), National Economics and Social Development Board

Table D3 Capacity, Production and Consumption of Cement, 1970-1988

Unit: Thousand Metric Tons

Year	Capacity	Production	Consumption[a]
1970	3,544.4	2,626.9	2,471.4
1971	4,122.9	2,770.6	2,525.6
1972	4,122.9	3,377.7	2,728.1
1973	4,122.9	3,705.8	3,496.2
1974	4,122.9	3,929.3	3,026.3
1975	5,100.0	3,959.3	3,290.3
1976	5,100.0	4,422.1	3,840.1
1977	5,100.0	5,062.7	4,652.8
1978	5,297.5	5,044.5	5,236.7
1979	5,297.5	5,203.7	6,296.8
1980	5,620.0	5,336.8	6,389.6
1981	8,760.0	6,262.5	6,316.0
1982	8,884.8	6,609.0	6,424.9
1983	9,604.8	7,263.5	7,071.9
1984	9,604.8	8,240.0	8,244.9
1985	9,604.8	7,916.7	7,893.9
1986	9,637.2	7,913.6	7,906.7
1987	13,010.5	9,850.2	9,654.4
1988	13,026.0	11,514.4	11,471.4

Note: [a] Domestic sales plus import

Sources: Producers, Ministry of Industry, Department of Custom and Department of Domestic Trade

Table D4 Export and Import of Portland Cement, 1970-1988

Unit: Thousand Metric Tons

Year	Production	Export		Import	
1970	2,626.9	150.7	(5.74)	1.7	(0.06)
1971	2,770.6	237.5	(8.57)	1.2	(0.04)
1972	3,377.7	644.7	(19.09)	0.6	(0.02)
1973	3,705.8	291.8	(7.87)	0.0	(0.00)
1974	3,929.3	903.2	(22.99)	0.2	(0.01)
1975	3,959.3	669.3	(16.90)	0.3	(0.01)
1976	4,422.1	581.6	(13.15)	0.3	(0.01)
1977	5,062.7	309.3	(6.11)	0.3	(0.01)
1978	5,044.5	22.3	(0.44)	351.6	(6.97)
1979	5,203.7	21.7	(0.42)	1,227.7	(23.59)
1980	5,336.8	33.1	(0.62)	937.8	(17.57)
1981	6,262.5	50.5	(0.81)	108.4	(1.73)
1982	6,609.0	158.2	(2.39)	0.5	(0.01)
1983	7,263.5	125.2	(1.72)	10.8	(0.15)
1984	8,240.0	39.1	(0.47)	6.1	(0.07)
1985	7,916.7	31.3	(0.40)	1.9	(0.02)
1986	7,913.6	33.9	(0.43)	3.4	(0.04)
1987	9,850.2	138.1	(1.40)	3.1	(0.03)
1988	11,514.4	21.8	(0.19)	2.2	(0.02)

Note: Values in the parenthesis are calculated as percentage of total production.

Source: Calculated

Table D5 Production, Export, Import and Consumption of Flat Glass, 1970-88

Unit: Metric Ton

Year	Production	Export	Import	Consumption[a]
1970	30,953	0	4,342	34,134
1971	24,079	399	3,801	32,890
1972	44,241	6,738	3,813	38,458
1973	46,167	3,541	3,397	43,333
1974	44,994	948	3,450	39,842
1975	38,702	815	2,911	43,085
1976	49,387	5,048	3,647	45,019
1977	64,307	13,155	4,314	52,644
1978	67,833	15,193	4,429	61,714
1979	79,615	8,851	4,488	73,491
1980	74,956	7,640	5,735	75,434
1981	80,067	1,981	8,146	84,009
1982	82,858	8,300	8,141	62,579
1983	77,323	21,434	11,223	81,965
1984	127,682	37,296	8,097	82,193
1985	132,708	53,698	4,908	82,893
1986	145,961	53,645	5,375	87,866
1987	144,679	38,382	3,774	106,541
1988	162,710	22,575	4,732	124,730

Note: [a] Domestic sale plus import

Source: Thai-Asahi Glass Company

Table D6 Production of Glass Bottles and Glass Tableware and Kitchenware, 1970-1988

Unit: Metric Ton

Year	Glass Bottles	Glass Tableware & Kitchenware
1970	45,921	6,326
1971	44,843	4,530
1972	59,171	4,749
1973	70,957	6,819
1974	74,043	5,703
1975	87,614	4,344
1976	94,651	5,819
1977	156,515	12,911
1978	161,046	12,336
1979	198,569	15,382
1980	140,846	24,844
1981	138,086	25,554
1982	187,888	25,782
1983	201,399	26,237
1984	279,316	29,195
1985	279,416	27,867
1986	294,392	27,144
1987	299,902	28,463
1988	351,715	26,667

Source: Producers

Table D7 Production, Export, Import and Consumption of Ceramic Tiles, 1975-88

Unit: Metric Ton

Year	Production	Export	Import	Consumption[a]
1975	33,200	2,020	1,807	32,987
1976	37,700	14,379	1,934	25,255
1977	55,214	17,719	1,926	39,422
1978	66,204	28,915	592	37,881
1979	70,150	21,731	4	48,423
1980	64,746	19,986	32	44,793
1981	68,450	20,151	0	48,299
1982	72,846	21,414	6	51,438
1983	102,220	25,612	0	76,608
1984	111,700	23,477	138	88,361
1985	144,400	22,496	2	121,906
1986	156,150	36,500	5	119,656
1987	199,360	60,364	21	139,017
1988	221,200	73,151	0	148,050

Note: [a] Production plus import minus export

Sources: Industrial Economics & Planning Division, Ministry of Industry, Bank of Thailand, and Department of Customs.

Table D8 Production, Export, Import and Consumption of Ceramic Sanitary Ware, 1975-88

Unit: Metric Ton

Year	Production	Export	Import	Consumption[a]
1975	4,455	845	42	3,653
1976	6,706	1,333	135	5,508
1977	7,418	1,492	175	6,101
1978	9,289	1,526	100	7,863
1979	9,855	1,794	40	8,101
1980	10,619	1,667	17	8,969
1981	14,108	2,243	4	11,869
1982	14,929	2,050	102	12,981
1983	12,341	1,270	17	11,089
1984	15,436	2,370	5	13,071
1985	16,427	2,122	12	14,317
1986	18,403	2,804	4	15,603
1987	25,380	4,496	1	20,885
1988	n/a	11,039	4	n/a

Note: [a] Production plus import minus export

Sources: Industrial Economics & Planning Division, Ministry of Industry, Bank of Thailand, and Department of Customs.

Table D9 Production, Export, Import and Consumption of Ceramic Tablewares & Kitchenwares, 1975-88

Unit: Metric Ton

Year	Production	Export	Import	Consumption[a]
1975	9,092	129	550	9,513
1976	9,281	47	995	10,229
1977	8,160	96	1,409	9,473
1978	8,276	106	888	9,059
1979	7,730	144	1,815	9,401
1980	10,004	420	4,195	13,780
1981	12,975	821	5,461	17,615
1982	12,975	1,634	3,036	14,377
1983	13,442	2,071	47	11,418
1984	13,174	1,833	34	11,375
1985	13,770	1,657	12	12,126
1986	n/a	3,217	39	n/a
1987	n/a	7,644	3	n/a
1988	n/a	14,071	2	n/a

Note: [a] Production plus import minus export

Sources: Industrial Economics & Planning Division, Ministry of Industry, Bank of Thailand, and Department of Customs.

Table D10 Consumption Pattern of Slab Zinc in Thailand, 1988

Type of Industry	Metric ton	%
Galvanized industry	39,413	65.7
Die-casting	5,740	9.6
Brass	5,280	8.8
Dry cell battery	5,029	8.4
Zinc oxide	4,037	6.7
Others	478	0.8
Total	**59,977**	**100**

Source: Thailand's Metal Statistics, Metallurgy Division, Department of Mineral Resources

Table D11 Production, Domestic Sales, Export, Import and Apparent Consumption of Slab Zinc, 1980-1988

Unit: Metric Ton

Year	Production	Domestic Sales	Export	Import	Apparent Consumption
1980	n/a	n/a	n/a	34,752	34,752
1981	n/a	n/a	n/a	39,051	39,051
1982	n/a	n/a	n/a	31,114	31,114
1983	n/a	n/a	n/a	36,758	36,758
1984	n/a	n/a	n/a	45,530	45,530
1985	60,086	39,607	21,549	14,429	54,036
1986	58,552	45,309	27,672	5,065	50,374
1987	66,852	53,257	20,313	5,337	58,594
1988	64,693	59,977	13,404	4,402	64,379

Source: Metallurgy Division, Department of Mineral Resources

Table D12 Consumption Pattern of Tin, 1986-1988

Pattern of Tin Use	1986		1987		1988	
	Metric ton	%	Metric ton	%	Metric ton	%
Tinplate	840	53.6	1,054	60.1	1,117	60.3
Solder	538	34.4	485	27.6	497	26.9
Pewter	76	4.8	100	5.7	105	5.7
Bronze	70	4.5	60	3.4	63	3.4
Others	42	2.7	56	3.2	69	3.7
Total	**1,566**	**100.0**	**1,755**	**100.0**	**1,851**	**100.0**

Source: Metallurgy Division, Department of Mineral Resources

Table D13 Production, Consumption and Export of Tin, 1970-1989

Unit: Metric Ton

Year	Production	Consumption	Export
1970	22,096	63.7	21,847
1971	21,771	95.0	21,705
1972	22,281	92.0	21,351
1973	22,927	266.0	20,529
1974	19,827	322.0	19,468
1975	16,630	252.0	16,552
1976	20,337	283.0	19,616
1977	23,102	315.0	21,437
1978	28,945	384.0	28,944
1979	33,058	612.0	31,308
1980	24,689	734.0	33,955
1981	32,636	784.0	31,286
1982	25,479	705.0	25,586
1983	18,467	703.0	18,878
1984	19,729	870.0	19,538
1985	18,135	721.0	19,898
1986	19,710	1,562.0	19,118
1987	14,652	1,705.0	13,670
1988	13,385	1,826.0	13,478
1989	13,758	2,569.0	10,869

Source: Department of Mineral Resources

Table D14 Capacity of Primary and Secondary Tin

Product	Metallurgical Licenses	Capacity (Metric Ton/Year)
Primary Tin		
	Charoen Minerals and Ores Co.,Ltd.	360
	Liang Ngiab Co.,Ltd.	360
	Siam Tin Smelting Co.,Ltd.	360
	Thai Pioneer Enterprises Co.,Ltd.	3,600
	Thai Solder Industry Corp.	360
	Thai Tin Smelter Co.,Ltd.	3,000
	Thailand Smelting & Refining Co.,Ltd.	38,000
	Total	**46,040**
Secondary Tin		
	Business Union Goldship Ltd.,Part.	12
	Fair Way Ltd.,Part.	66
	Lohagumthai Factory Ltd.,Part.	15
	Metal Industry Ltd.,Part.	5
	Siam Metal Production Co.,Ltd.	150
	Total	**248**

Source: Metallurgy Division, Department of Mineral Resources

Table D15 Coal Consumption

Unit: Million Metric Tons

Industry	1984	1985	1986	1987	1988
Power	1.797	3.853	4.522	5.970	6.419
Domestic	1.797	3.853	4.522	5.970	6.419
	(85.7)	(88.9)	(86.9)	(85.5)	(84.1)
Cement	0.374	0.587	0.718	1.036	1.328
Domestic	0.224	0.387	0.518	0.736	0.896
	(10.7)	(8.9)	(10.0)	(10.5)	(11.7)
Import	0.150	0.200	0.200	0.300	0.432
Tobacco	0.076	0.092	0.064	0.078	0.039
Domestic	0.076	0.092	0.064	0.078	0.039
	(3.6)	(2.1)	(1.2)	(1.1)	(0.5)
Industrial Boilers	0	0.001	0.100	0.201	0.401
Domestic	0	0.001	0.100	0.201	0.281
	(0.0)	(0.0)	(1.9)	(2.9)	(3.7)
Import	0	0	0	0	0.120
Domestic Coal Consumption	2.097	4.333	5.204	6.985	7.635
Import Coal Consumption	0.150	0.200	0.200	0.300	0.552
Total Coal Consumption	2.247	4.533	5.404	7.285	8.187

Sources: Electric Generating Authority of Thailand, Provincial Electric Authority, and National Energy Administration.

Table D16 Fuel Consumption for Electricity Generation, 1979-1988

Unit: Thousand Metric Tons of Oil Equivalent

Year	Fuel Oil	Diesel Oil	Lignite	Natural Gas	Total
1979	2,098.7 (81.36)	165.8 (6.43)	314.9 (12.21)	-- --	2,579.4
1980	2,823.8 (85.25)	157.6 (4.76)	331.1 (10.00)	-- --	3,312.5
1981	2,312.5 (76.94)	85.4 (2.84)	383.4 (12.75)	224.2 (7.46)	3,005.5
1982	1,433.9 (47.38)	22.5 (0.74)	421.7 (13.93)	1,148.2 (37.94)	3,026.4
1983	1,724.5 (49.68)	35.2 (1.01)	393.0 (11.32)	1,318.5 (37.98)	3,471.1
1984	1,517.2 (39.43)	22.7 (0.59)	484.5 (12.59)	1,823.9 (47.39)	3,848.2
1985	840.5 (19.16)	16.1 (0.37)	1,142.4 (26.04)	2,387.4 (54.43)	4,386.3
1986	815.0 (19.12)	12.1 (0.28)	1,162.7 (27.28)	2,272.7 (53.32)	4,262.5
1987	541.2 (9.88)	9.1 (0.17)	1,420.4 (25.94)	3,504.7 (64.01)	5,475.3
1988	781.9 (12.14)	6.6 (0.10)	1,462.5 (22.71)	4,189.1 (65.05)	6,440.1

Note: Values in the parenthesis is the percentage of total consumption.

Sources: Electric Generating Authority of Thailand. Provincial Electric Authority. National Energy Administration.

Table D17 Domestic Coal Production, 1984-1988

Unit: Million Metric Tons

	1984	1985	1986	1987	1988
Power sector	1.82	3.94	4.57	5.76	6.09
Industrial sector	0.48	0.57	0.80	1.19	1.29
Total Production	**2.30**	**4.51**	**5.37**	**6.95**	**7.38**

Source: Coal Development and Utilization Study (June 13, 1989): A Joint Report of the World Bank and the Government of Thailand.

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