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Feasibility Study on Effective Use of Energy in the Cement Manufacturing Process

March, 2001

New Energy and Industrial Technologies
Development Organization (NEDO)
Entrusted to International Center for
Environmental Technology Transfer

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Study purpose

This survey was conducted in order to study the potential of CDM as to reduce green house gas and cost by transferring Japanese energy conservation technologies to Thailand's cement industry, which is one of Thai industry's largest energy consumers. Specifically, in cooperation with the Siam Cement Industry Company Limited(SCI), we investigated the use and consumption of energy in SCI's white cement production plant, which needs much energy consumption comparing gray cement production.

Introduction

In December 1997, the Third Session of the Conference of the Parties to the United Nations Framework convention on Climate Change (COP3) was held in Kyoto. The conference adopted the Kyoto Protocol, which targets a 5 percent minimum average reduction in greenhouse-effect gas emissions in developed nations from 1990 levels. This goal, scheduled for achievement between 2008 and 2012, seeks to prevent global warming caused by carbon dioxide and other greenhouse-effect gasses. Japan's reduction target is 6 percent.

The Kyoto Protocol specified measures for flexibly achieving these goals, including Joint Implementation (JI), in which developed nations can share the amounts of gasses to be reduced through international projects, and the Clean Development Mechanism (CDM) for joint implementation by developed and developing nations.

Considering the current circumstances in which development of nuclear energy and alternative energies faces rigorous restrictions, Japan must try to conserve energy jointly with developing nations through CDM and the like. We must reach our target by making good use of these systems. On the other hand, in developing nations, particularly those of Asia, energy conservation technologies have not been deployed well due to a shortage of engineers and funds as well as delays in plant modernization, although in recent years industrialization has been making rapid progress through industrial promotion policies. If Japan contributes to sustainable development in developing nations through the transfer of its energy conservation technologies, both Japan and developing nations will benefit.

Under these conditions, this survey aimed at the following three by transferring our energy-saving technology to the cement industry in Thailand, which consumes much, more energy.

- Reducing the emission of greenhouse effect gases
- Reducing the cost
- Possibility of Clean Development Mechanism (CDM)

To be concrete, we made a survey in cooperation with the Siam Cement Industry Corporation (SCI), which has the longest history in Thailand and produces the largest quantity now. Firstly, we surveyed the existing situation of energy application and consumption at Siam White Cement Corporation (SWCC), subsidiary of SCI, production equipment; and secondly proposed to introduce the gas turbine generator from the viewpoint of highly efficient utilization of energy to verify the estimated effect. We discussed the verification result with the SCI engineers and estimated the effect after improvement. These were included in our report to be reflected in the equipment improvement-working plan.

At the end of the joint survey, we hope not only the gas turbine generating technology is helpful for the white cement plants but also that the good effect will extend to the gray cement plants and other manufacturers. SCI is in no condition to carry forward the project immediately judging from the gas supply infrastructure and the demand for white cement. However, we will continuously contact with SCI, 1) to get SCI plan working information, 2) to provide SCI with information on CDM activities including COP6, and 3) to continue contacting with OEPP (Office of Environmental Policy and Planning) or Thai Government official agency of CDM. We will continue to discuss to realize the project with fixing our eyes on SCI's preparations to receive CDM.

Finally, we were deeply impressed during this investigation that SCI engineers and other members actively exchanged opinions based on various technical data. We are deeply grateful to many people in Thailand and Japan who gave us valuable information and honest opinions during the investigation.

March, 2001

Gosin Kura, Managing Director
International Center for Environmental
Technology Transfer

Report on Result of "Feasibility Study on Effective Use of Energy in the Cement Manufacturing Process"

Contents

[Introduction]

Summary

Rapid expansion of social and economical activities has produced various problems on the earth such as global warming, acid rain, and ozone layer depletion. Reduction of energy consumption is one of the essential conditions to solve these problems; and so, energy-saving measures are necessary. Development of energy-saving technology obtained a definite result in advanced countries. In developing countries, especially in Asian countries, the development of industry has been promoted lately. Though industrialization has been developed, the energy-saving measures are not fully infiltrated due to shortage of engineers, insufficiency of funds, late modernization of plant and equipment, and others.

There is a movement to prevent global warming in international society. "The 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change"(COP3) was held in Kyoto in December 1997. The adopted Kyoto Protocol aimed to reduce the mean emission value of greenhouse effect gases including CO_2 in 2008 - 2012 by minimum 5% compared to the level in 1990. The reduction goal of Japan was 6%, which was very high. At the same time, some flexible measures such as Clean Development Mechanism (CDM) were also proposed at the meeting. It is important for us to make efforts to achieve the goal by reducing the emission in Japan, but atomic energy development and natural energy development are severely restricted. It is also necessary for us to do our best in reducing the emission in cooperation with those in developing countries by considering CDM and others. CDM had no concrete progress at the last COP6, and it is behind in carrying out in 2000. Accordingly, it is difficult for developing countries to define their attitude to receive it openly.

Under these conditions, this survey aimed at the following three by transferring our energy-saving technology to the cement industry in Thailand, which consumes much, more energy.

- Reducing the emission of greenhouse effect gases
- Reducing the cost
- Possibility of Clean Development Mechanism (CDM)

To be concrete, we made a survey in cooperation with the Siam Cement Industry Corporation (SCI) as a member of the Siam Cement Group, which has the glorious history of 80 years or more and boasts of the top share in Thailand. Firstly, we surveyed the existing situation of energy application and consumption at Siam White Cement Corporation (SWCC), subsidiary of SCI, production equipment; and secondly proposed to introduce the gas turbine generator from the viewpoint of highly efficient utilization of energy to verify the estimated effect of the equipment improved. The white cement plant surveyed locates at Khao Wong District in Saraburi Prefecture, which lies approx. 150km northeast of Bangkok. The Plant is adjacent to Khao Wong Plant with the world top gray cement production capacity (10,000tons/day).

Three field surveys were carried out as follows:

1st survey:	Aug.30, 2000 to Sept.8, 2000; Controlling survey plan, Making survey of plant and equipment, etc.
2nd survey:	Nov.14, 2000 to Nov.23, 2000; Proposing and controlling the equipment improvement plan with introduction of gas turbine
3rd survey:	Feb.5, 2001 to Feb.10, 2001; Survey result report meeting and collecting data

In the first survey, we started to survey the existing condition of the plant and equipment and check the operation data and the maintenance and control.

The following four points were narrowed down to survey.

1. Introduction of gas turbine for power generation
2. Installation of air heat exchanger for kiln combustion by utilizing gas turbine exhaust gas
3. Installation of raw material heating vessels by utilizing gas turbine waste gas heat
4. Energy-saving effect by utilizing waste gas heat

After the first field survey, the investment amount was calculated tentatively. As the result, the equipment investment amount was too large due to the raw material heating vessels and the electric precipitator to be introduced. From the viewpoint of economical efficiency, we studied introducing "Steam injection gas turbine generator" because the investment amount is appropriate and because it has a good remaining production capacity increased. Accordingly, the following three were narrowed down for improvement.

1. Steam injection gas turbine generator will be introduced to provide the power currently being purchased.
2. A kiln combustion air heater will be introduced to provide additional heating by utilizing the gas turbine exhaust gas.
3. To promote calcinations prior to the kiln, the raw material preheater is modified with the introduction of a swirl calciner.

In the second survey, the Japanese side made some proposals of specifications of equipment to be improved, required cost, and expected effects according to the above result. We discussed the survey result with the SCI engineers, and decided to introduce the "steam gas turbine generator" as mentioned above. In addition; we examined possibility of technology transfer, energy-saving effect, greenhouse gas reduction effect, profitability, etc. and discussed the possibility of extension to the similar industries. These points proposed were included in the equipment improvement menu as a final proposal in our report to be reflected in the equipment improvement working plan by SCI. For reference, the report also contains the survey result for the project after the conversion from heavy oil to petrocoke promoted by SCI.

In the third survey; we reported to SCI on the energy-saving effect, greenhouse gas reduction effect, and profitability of the project. We also investigated the existing governmental CDM situations in Thailand.

As the result, the trial calculation of the total energy-saving effect including the power purchased shows as follows:

Energy-saving: 1,200 toe/year (in crude oil equivalent)

CO_2 reduction: 8,000 t-CO_2/year

These values are not so high, but output of clinker can be increased by approx. 18% by utilizing the electricity and waste gas heat from the gas turbine generator. The total investment will be 314.5 million Bahts, which may be actually recovered in less than 5 years thanks to the effect of increased production capacity. However, under the present conditions, this project cannot be carried forward immediately as the gas supply infrastructure is incomplete and as the demand for white cement cannot be expected to revive rapidly.

When the demand for white cement revives in future and when this project can be carried forward, CDM can be selected as one of the methods to raise funds including those for preparation of infrastructure. We will continuously contact with SCI, 1) to get SCI plan working information, 2) to provide SCI with information on CDM activities including COP6 Bonn meeting, and 3) to continue contacting with OEPP (Office of Environmental Policy and Planning) or Thai Government official agency of CDM.
We will continue to discuss to realize the project with fixing our eyes on SCI's preparations to receive CDM.

If this project is executed, Siam Cement can attain highly efficient energy utilization with natural gas at Khao Wong Plant. This project may be the pioneer in utilizing natural gas. There is a large possibility to extend natural gas to various industries. Accordingly; it can be expected to increase the domestic demand for natural gas, which may result in reducing dependence on the imported energy and reducing the environmental bad effect.

The domestic demand for cement drops due to the slow economic growth in Thailand accompanied by the currency and economic crisis. Siam Cement has been promoting to export the products to Vietnam, Bangladesh, and other Asian countries; and has endeavored to take energy-saving and resources-saving measures to increase the international competitive power. As an example, the Company examines to utilize waste matters (petrocoke, waste tire, waste oil) or substitute materials for clay (coal ash).

This project aims to utilize energy more efficiently with partly changing the production process. It is the first project in Thailand. If Siam Cement Industry Corporation, one of the leading companies in Thailand, executes the project; it can be expected to develop the application to other cement companies and other various industries with great effects on energy-saving and environmental improvement.

The manager for this project at Siam Cement told that the project FS was very useful for them to improve the technological level in the Company. The execution of the project can be greatly expected to contribute to the improvement of the technological level in the entire cement industry in Thailand.

Chapter 1. Basic data of the Project

This chapter describes the existing conditions of politics, economics, society, and energy in Thailand with a long history and outlines the plan for the future. It also includes the need of the CDM project; necessity to introduce energy-saving technology; and meaning, needs, effects, and the extension to the similar industries of this project.

Section 1. Existing conditions in Thailand

1.1.1 Political, economical, and social conditions

(1) Geographical features and natural features

The area of the Thai territory is 513,000 km^2 (approx. 1.4 times as large as the area of Japan) and the population is 61,660,000 (1999 end) (approx. half of the population of Japan). It lies in the center of the Indo-China Peninsula and bordered by four countries of Myanmar, Laos, Cambodia, and Malaysia. Bangkok, the capital of Thailand, is situated at the mouth of the River Chao Phraya. 5,660,000 people (1999 end), or 9.2% of the total national population, gravitate in Bangkok.

The River Chao Phraya runs down from the north mountain district, and makes the central plain. The land is completely irrigated by the tributary streams and the canal network. The soil is fertile and suited to the cultivation of rice. The plain has been the granary of Thailand for a long time. In the northern part, it is more rolling than the central plain. The rivers joining the River Chao Phraya form some basins. Chiang Mai and Sukhothai, the former capitals, are situated there. The mountain district where minority races live is not so high, or approx. 1,000 meters above the sea level. The northeastern part consists of rather low highlands (approx. 150 m above the sea level). The land is poorly irrigated and deforested. The infertile soil is not suited to agriculture and the people are mostly poor. The southern part extends hundreds kilometers on the Malay Peninsula. There are long mountains from the western part to the central part. The both sides of the land are coastal plains. The southernmost part is abundant in natural resources like rubber and ores including tin and tungsten, and produces rice and other crops. The people relatively live in plenty.

It is subject to tropical climate, and there are three seasons of hot season (March to May), rain season (June to September), and dry season (October to February). The humidity is high all the year round. It may be sometimes over 90%, but during the dry season it is relatively cool at low humidity. The temperature is between 25°C and 35°C.

In the northern part and the northeastern part, it is lower in winter. In Bangkok, the capital, the mean temperature for a year is approx. 29°C and the mean humidity is 75%. The southern part is subject to tropical monsoon climate. The most of the people are Thais (Thai, Lao, Shan, etc.)(approx. 80%). Others are Chinese (approx. 9%), Malay minorities who live in mountains (10%), and Vietnamese. The people mostly believe in Buddhism (95%) excepting Islam (4%) and Christianity (0.5%). The major language is Thai (official language) and some others are also spoken such as Vietnamese, Malay, Lao, and Cambodian.

(2) National government organization and political system

① Establishment of the present nation

The Thais are said to have moved from the southern part of China. They established the Sukhothai dynasty in the 13th century, which gave the place to the Ayutthaya dynasty in the 14th century. The dynasty was destroyed by the Burmese attack in 1762. The Chakri dynasty was established in 1782, and the capital was moved to Bangkok. These led the present Kingdom of Thailand. From the end of the 19th century to the beginning of the 20th century; there were some attacks by France and England, which resulted in loss of some territories such as Laos, Cambodia, and Malay. However, the nation maintained the independence. The bloodless revolution by the People's Party in 1932 changed the absolute monarchy to the constitutional monarchy. The nation cooperated with Japan during the World War II and extended the territory. After Japan was defeated, Thailand returned the extended territory and had only what the nation had before the War.

Since the War the people have made efforts to build the nation under the Royal Government. The growth of economy in Thailand had been dramatic until the financial and economic crisis was produced in 1997. It was called "Honor Student in Southeast Asia."

② Political system

The Kingdom of Thailand adopts the constitutional monarchy with the king as a sovereign. The present king is King Bhumibol Adulyades (RamaⅨ, Ascended the throne in 1946).

The National Assembly consists of two Houses, the Upper House and the Lower House. The New Constitution was established in September 1997 through due democratic formalities first in Thailand. According to the Constitution, the people directly elect the members of Upper and Lower Houses. (According to the Old Constitution, both Houses are as follows:

The Upper House: 260 seats, 4-year term of membership, appointed by the King
The Lower House: 393 seats, 4-year term of membership, direct election)

According to the new Constitution, both Houses are as follows:

The Upper House: 200 seats, 6-year term of membership, direct election
(Election executed in March, 2000)
The Lower House: 500 seats, 4-year term of membership, direct election
(Election executed in January, 2001)

In November 1997; Mr. Chuang Leek Pai (Democratic Party) organized the coalition cabinet (mainly consisting of Democratic Party, National Development Party, and Thai Nationalist Party), which stayed in power until the first general election was executed in January 2001 according to the new Constitution. As the result of the election; Thai Patriotic Party headed by Mr. Thaksin, captain of industry and communication magnate, became the leading party. In early February, Mr. Thaksin took office as Prime Minister. His financial problem arose, but it may take time to settle. Anyway; the coalition cabinet led by Mr. Thaksin, Thai Patriotic party, started to improve the Thai economy. (The National Corruption Prevention and Control Committee have been investigating if the report of his property which was submitted when he was engaged in politics is false. If it is judged to be false, he cannot take part in politics for five years.)

There are 73 prefectures for local administration. Each of them contains counties, districts, and villages. However, the nation was tinged with centralization and each local government could decide only few. According to the new Constitution, the range of local autonomy is extended.

(3) Economic relation with Japan

a. Trade

Japan is No.1 exporter to Thailand and No.2 (next to USA) importer from Thailand. Computers and the parts, rubber, fresh fishes and shellfishes, furniture, home electric appliances, and clothing are exported to Japan. Capital goods and raw materials are imported from Japan, which reflects the activities of Japanese companies that directly invest in Thailand. Japan is constantly in black in the trade between Thailand and Japan, but it is reducing with the peak in 1995.

b. Investment

Major investments are in manufacturing industries such as electric machines, automobile parts, and metal processing. Lately there are some investments in small-to-medium sized enterprises of various parts. Since 1997; the condition of Japanese economy and the actual results of various companies in Japan have been lowered, and the exchange rate has been unfavorable. Accordingly the number and the amount of investments have been reducing. Japan was No.2 in investment (next to Netherlands) in 1998, though No.1 before.

Investment by Japan in Thailand (total at 1997 financial year end): 1,560.9 billions yen

(Source: Statistics by Ministry of Finance)

c. Economic cooperation

Thailand is given the highest priority in economic cooperation by Japan. 60 - 70% of the total economic cooperation in Thailand is from Japan. Economic Cooperation in Japan puts emphasis on infra structural preparation, protection of environment, local development, and education and training. Credits in yen and technical assistance are the nuclei of the economic cooperation. The total credits in yen is 1,782.986 billions yen (Exchange of notes basis)(Total at March end in 2000: up to 1999 financial year).

(4) Political and social conditions

Thai Baht was keenly depreciated several times in 1997. In July of 1997, the exchange control system was moved from the dollar peg system to the managed float system. No economic stabilization was seen yet, and in November of 1997 the Chuang Cabinet led by Democratic Party succeeded the Chavalit Cabinet. The Chuang Cabinet took the strong initiative in carrying out the economic reconstruction actions agreed with IMF.

As the result, the unemployment rate, which had been lowering a little, rose suddenly from 1.5% in 1996 to 3.5% in 1997. The number of the unemployed reached 2.6 millions. The sudden poor employment condition caused the people to criticize and disaffect to the Chuang Cabinet, though it had been strongly supported by the people with the high support rate of 80% or more. It developed into a severe political issue. After that, the Government made their efforts to reconstruct the economy according to the agreement with IMF. The economic dislocation in Thailand reached the bottom and the people have calmed down gradually. The 13th Asian Athletic Meeting was held in December of 1998 and resulted in success.

According to the new Constitution, the first Upper House election was conducted on the 4th March 2000. Due to many election irregularities, the reelections were repeatedly held. All the members were finally elected in the fifth reelection at the end of July. For the Lower House, the term of membership expires on the 17th November. The People kept a watch on Prime Minister Chuang's right to dissolve with seeing the tendency of the actual economy improved. The general election was conducted on the 3rd January 2001 after expiration.

As the result, Democratic Party led by Prime Minister Chuang failed to be supported by the People and Thai Patriotic Party led by Mr. Thaksin, businessman, became No.1 party. Accordingly, the coalition cabinet headed by Mr. Thaksin, Prime Minister, was newly at the helm of the Thai politics and economy.

(5) Economic conditions

1) Change of economic growth rate

The Thailand's economic growth rate kept being high for a long time. The economic development plans mainly led by state enterprizes in 1950s were at deadlocks, but in 1960s the economic development plans were carried out by private enterprizes. The mean real economic growth rate in 1960s is 8.0%; but the mean real economic growth rate in 1970s is lower, 6.8%, due to the floating exchange rate system changed in 1971, cloudy future caused by the global inflation, sudden rise in crude oil price caused by the first Oil Shock, and tie-up of investments from foreign countries caused by the increased country risks of the three Indo-Chinese socialist states.

In 1980s, the mean real GDP growth rate of the first half is 5.4% due to the second Oil Shock and the subsequent worldwide depression. However, after the Plaza Agreement in 1985 there were so many investments from Japan, Korea, Taiwan, NIES, and other Asian countries with a favorable wind of strong yen and weak dollar. The super high economic growth days had come. Especially in the three years of 1988 - 1990, the high growth of two figures was attained consecutively: 13.3%, 12.2%, and 11.2%. In 1990s, the high economic growth kept the 8% level (Table 1.1.1).

Table 1.1.1 Change of Thai GDP and economic growth rate

(Unit: Billion Bahts, %)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Real GDP	913.7	967.7	1,019.5	1,076.4	1,138.4	1,191.3	1,257.2	1,376.8	1,559.8	1,750.0
(Growth rate)	-	5.9	5.4	5.6	5.8	4.6	5.5	9.5	13.3	12.2

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Real GDP	1,945.4	2,111.9	2,282.6	2,473.9	2,695.4	2,935.3	3,109.3	3,057.0	2,746.1	2,861.0
(Growth rate)	11.2	8.6	8.1	8.4	9.0	8.9	5.9	▲1.7	▲10.2	4.2

(Note) 1998 and 1999: Prompt report

Source: National Economic and Society Development Bureau (NESDB)

2) Economic trend before and after financial and economic crisis

In 1996 the export growth rate sharply slowed down. Private investment also gradually slowed down under the influence of high interest rates. In the middle of the year the future prospect was cloudy. Accordingly, the real GDP growth rate in 1996 is 5.9%, which is the lowest level since 1986 (Table 1.1.2)

Table 1.1.2 Latest real GDP growth rate, consumer price index (CPI)

(Unit: %)

	1996	1997	1998	1999	2000	1999				2000		
						IQ	IIQ	IIIQ	IVQ	IQ	IIQ	IIIQ
Real GDP growth rate	5.9	▲1.7	▲10.2	4.2	5.0	0.2	2.5	7.8	6.5	5.3	6.6	
CPI rise rate	5.9	5.6	8.1	0.3	2.0	2.7	▲ 0.4	▲ 1.0	0.1	0.8	1.6	2.2

(Note) ①GDP in 1998, 1999, 2000 I - II Q: Prompt report, 2000: Forecast ②CPI: Yearly mean

Source: National Economic and Society Development Bureau (NESDB)

This business downturn was caused by the two intended and unintended factors, which occurred simultaneously: the intended business downturn due to the control of the domestic demand by tightening the money market and the unintended great decrease of export growth. It was beyond the government's view. There was a large gap between demand and supply caused by the large estate investments in the latter half of 1980s. The Bubble was broken. The financial unrest and instability including bad bonds was also a background of the business downturn.

In 1997 the business downturn did not stop. Baht was much weaker due to the bad economic fundamentals such as extended red-ink balance of current account and bad financial balance. At last, the Thai Government decided to move the Thai Baht exchange control system to the managed float system on the 2nd July 1997; and started to reform the structure of the Thai economy radically by accepting the IMF financing conditions on the 5th August. For example, reduction of the budget, increase of Value Added Tax (VAT), and business suspension orders to 42 financing companies.

The real GDP growth rates in 1997 and 1998 were estimated to be 2.5% and 3.5% respectively based on the above economic reconstruction measures, but Baht was much weaker and the business downturn did not stop. In November 1997, the real GDP growth rates in 1997 and 1998 were changed to 0.6% and 0 - 1% respectively.

With taking off the restrictions on exchange to non-residents in 1998 as a turning point, the exchange rate gradually advanced. However, the Thai economy was still sluggish due to the domestic factors such as the low domestic demand caused by the reduced budget and banks not willing to finance and the overseas factors such as recessions in Asian countries. Finally, the real GDP growth rate in 1998 (prompt report) is sharply decreased to ▲10.2%.

The Thai economy touched the bottom from the fourth quarter of 1998 to the beginning of 1999, and it is now under recovery. The real GDP growth rate in the fourth quarter of 1999 is increased by 6.5%. The growth continues for four quarters. The manufacturing industry and the service industry show high growth rates in the production field. The Government supported the demand to increase individual consumption and private investment. As the result, the real GDP growth rate in 1999 is 4.2%, which is the plus after three years' minus.

It is generally expected that the future business will be continuously improved as some Government economic measures including low interest and tax reduction. However, many banks still have bad bonds at the high level with the peak in May 1999 (22.8%, 1115.4 billion Bahts as of September end, 2000). It is necessary to rebuild the financial system by increasing the owned capital of each bank and reorganizing the enterprise debts. The real GDP growth rate in 2000 is estimated to be 5.0% (by NESDB) or 4.5% - 5.0% (by Central Bank).

As the trend of the industries, the production index in the manufacturing industry in 1998 is 10.0% lower than the previous year, greatly 12.5% higher in 1999 (Table 1.1.3), and also decreases in 2000. The private equipment investment is at low level due to excess equipment and poor demand in the construction field. The domestic cement consumption reached at the bottom, but is unable to move upward. The real capital goods imported keeps growing greatly.

The main industries are roughly outlined as follows:

Foods: Processed foodstuffs such as tuna cans for exports increases in output. The production index in 1999 is 16.0% higher than the previous year.

Textiles: With the Baht exchange rate improved, the industry must compete with the peripheral countries in price. The export is unable to move upward. The production index in 1999 is 1.2% lower than the previous year.

Petroleum products: The output for exports increased, and the working ratio of oil factories in 1999 keeps the high level of 85.7%. The production index in 1999 is 2.2% higher than the previous year.

Table 1.1.3 Changes of the latest indexes relating to production, equipment, and investment

(Unit: %)

	1997	1998	1999	1999	2000			2000					
				IVQ	IQ	IIQ	IIIQ	Apr.	May	Jun.	Jul.	Aug.	Sep.
Production index in manufacturing field	▲0.5	▲10.0	12.5	17.6	9.6	3.4	P▲0.5	3.7	5.2	1.5	▲1.3	▲2.3	P2.0
Working ratio of equipment	65.5	52.0	60.1	63.3	57.3	54.1	55.7	51.1	54.8	56.5	54.2	55.0	P57.9
Domestic cement consumption	▲16.3	▲39.8	▲2.4	▲0.7	1.9	1.2	▲11.2	1.9	8.3	▲6.6	▲16.8	▲11.1	P▲5.9
Real capital goods imported	▲23.0	▲39.7	3.7	14.2	23.0	24.2	P31.4	24.7	35.8	14.7	2.6	34.1	P30.3

(Note) ①Growth rate compared to previous year, same period of previous year ②P: Prompt report

Source: Thai Central Bank

Construction materials: As domestic and overseas demands increased, the production index in 1999 is 14.5% higher than the previous year.

Steel: As the demand for steel for automobile parts and electric appliances increased, the outputs of bar steel and plate steel increased. The production index in 1999 is 14.5% higher than the previous year.

Automobiles: With supported by the increased output for export and the improved domestic demand thanks to the decreased VAT and interests, the output in 1999 is 327,233 automobiles or 106.9% more than the previous year and the domestic sales is 218,330 automobiles or 51.5% more than the previous year. However, the equipment-operating ratio of the year is only 35.5%. The output from January to August in 2000 is 262,069 automobiles (34.1% more than previous year). The domestic sales in the same period are 165,254 automobiles (136.3% more than the same period of the previous year). The domestic sales in 2000 are estimated to be 280,000 automobiles approximately, but it is unable to move upward as the gasoline cost is high lately.

(6) Trade balance and trend of international payments

The trade balance of Thailand was constantly in red because the increase of capital goods with the direct investment extended and materials imported were greatly higher than the increase of exports. In 1996 the export trade was inactive and the highest trade deficit of 16.1 billion dollars was recorded (Table 1.1.4). The balance of current account in red is 7.9% to nominal GDP.

Since the latter half of 1980s, the international payments balance of Thailand had a structure to be continuously in black in total by compensating the black-ink capital for the constant red-ink current account. Since the third quarter in 1996, the private loans in the balance of capital account are rapidly reduced to result in the red-ink total balance since the time continuously from the first to the last quarter. In 1997 the import was sharply reduced and the export was increased with Baht devaluated. Accordingly, The red-ink current account was greatly reduced to 4.6 billion dollars and the capital balance in red was 4.3 billion dollars. The total balance shows 10.6 billion dollars in red.

Table 1.1.4 International balance of payments of Thailand

(Unit: Million dollars)

	1994	1995	1996	1997	1998	1999	2000
Balance of current account	▲7,737	▲13,206	▲14,350	▲3,110	14,291	12,465	8,300
Trade balance	▲8,730	▲14,652	▲16,148	▲4,624	12,235	9,271	6,300
Export (FOB)	44,649	55,731	54,667	56,725	52,878	56,800	60,000
Import (CIF)	53,379	70,383	70,815	61,349	40,643	47,529	53,700
Invisible trade	993	1,446	1,798	1,514	2,056	3,194	2,000
Balance of capital account	12,183	21,921	19,504	▲4,324	▲9,742	▲7,907	
Private	12,025	20,821	18,201	▲7,623	▲14,652	▲13,836	
Government	158	1,100	1,303	1,550	1,805	1,909	
Thai Central Bank	0	0	0	1,730	3,936	4,020	
Error, Mistake	▲271	▲1,479	▲2,985	▲3,196	▲2,815	26	
Total balance	4,175	7,236	2,169	▲10,649	1,734	4,584	

Source: 1996-1999: Thai Central Bank. 2000: Estimate by NESDB

The trade balance and the current account balance have been in black since the fourth quarter of 1997, but the black figure has a tendency of reduction. On the contrary, the capital balance has been in red since the second quarter of 1997.

The cement industry and other industries are also required to export, as the domestic demand is sluggish. From the view point that overseas capital is necessary to recover the economy after the financial and economic crisis, the Foreign Enterprises Control Act (Note) was amended to open the cement industry and other manufacturing industries. Accordingly, it is an urgent problem for the cement industry and others to strengthen the cost competitive power.

(Note) The Foreign Enterprises Control Act established in 1972 places various restrictions on the foreign enterprises in Thailand (50% or more foreign capital) such as business type, capital ratio, business decision, and business enlargement. As the Act was amended (established on 20th Oct., 1999; enforced on 3rd March, 2000), the number of the restricted business types is reduced from 63 to 43.

(7) Financial conditions

Thanks to the developing business for the past several years, the balance of finance had been in black.

Table 1.1.5 Financial conditions in Thailand

One billion bahts	1982	1985	1987	1990	1993	1994	1995	1996
Revenue	116.2	160.6	202.4	411.7	574.9	680.3	777.3	853.2
Annual expenditure	157.1	199.5	211.2	304.7	521.1	579.2	642.3	819.1
Balance of finance	-41.0	-38.9	-8.8	107.0	53.8	101.1	135.0	34.1

Source: EIU Country Profile

The balance of finance turned to be in red in 1997. It was the first time since1988. With the recession, there was a drop in revenue (import tax, tax on value added, and corporation tax) unexpectedly. In spite of having tried to reduce the annual expenditure, the balance of finance in 1997 turned to be in red (1.3%compared to GDP) from 1.9% in black in 1996. According to the financial reconstruction plan agreed with IMF, the balance of finance in 1998 was aimed to be 2.0% in red compared to GDP at first. In consideration of the bad economic condition, however, the figure was increased to 3.0%.

IMF admitted that the Thai Government took the financial policy for economic rehabilitation on the financing condition that the financial deficit in 1999 (October, 1998 to September, 1999) should be within 10 billion bahts. Accordingly, the real revenue in the year was only 822.6 billion bahts. However, in March of 1999, the budget was revised to add 53 billion bahts. Additional 33 billion bahts were paid to support the socially weak persons in 1999. The financial plan in 2000 contains 860 billion bahts, but IMF admits additional expenditure of 110 billion bahts, which is the unpaid budget in 1999. In addition, another 20 billion bahts can be put out according to the new MIYAZAWA plan.

(8) Environment

1) Environmental policy

As the environmental problems have become more severe with the rapid industrialization and advanced urbanization, the National Environment Act was established in 1975 and started protecting the environment nationally and systematically as follows:

- Making conservation plans
- Establishing environmental standards
- Preparing environmental monitoring systems

However, the expected results could not be attained due to the short budget and short talents.

In 1981 the national environmental policies were announced. Some policies were set force to conserve the natural resources and to harmonize economic development with the environment, but the environmental problems became more acute with the growing economy and the accelerated industrialization in 1980s.

In 1990s there were many social requests for the protection of the environment. The 7th Plan (1991 - 1996) was worked out in August 1990 to develop the economy continuously, to protect the environment and natural resources, and to improve the quality of the living environment. The Government declared to take measures for preservation of the environment.

Therefore, in 1992, the National Environmental Preservation Act 1975 was abolished and the Enhancement and Conservation of National Environment Quality Act, A.D. 1992 was newly established. In addition, the following laws relating to the environmental actions were amended.

- Factory Act, A.D., 1992
- Public Health Act, B.E., 2535, A.D., 1992
- Hazardous Substance Act, A.D., 1992

- Energy Conservation Promotion Act, B.E., 2535, A.D., 1992

2) Environment administrative organization

As the Enhancement and Conservation of National Environment Quality Act, A.D.1992 was established; the environmental administrative organization was greatly reformed.

(a) Ministry of Science, Technology and Environment

The conventional functions belonging to the National Environment Committee Secretariat were included in the Ministry of Science, Technology and Environment. The national environment administrative organization was reformed as shown in Fig.1.1.1.

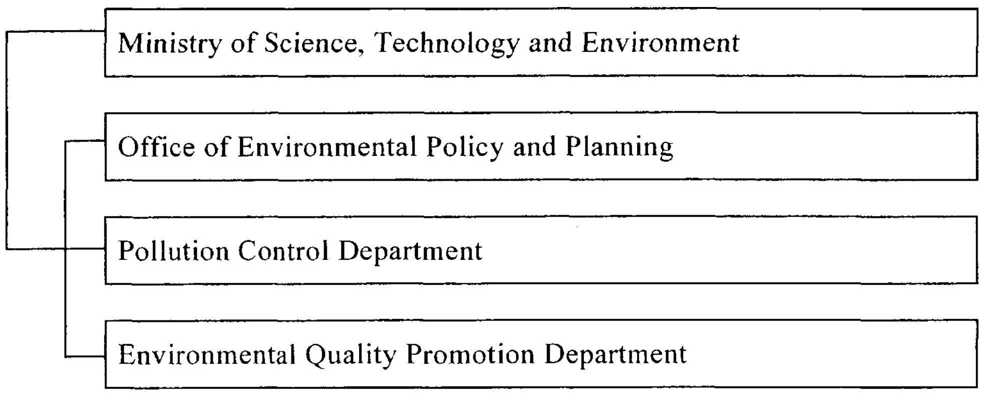


Fig.1.1.1 Organization in charge of environment in Ministry of Science, Technology and Environment

Source: Environmental Measures for Japanese enterprises abroad (Earth and Human Environment Forum, March 1999)

Each Office or Department is mainly in charge of the following works.

Office of Environmental Policy and Planning

The Office adjusts the national policies, prepares environmental master plans, evaluates the environmental projects by investigating the influence on the environment, and sets up local offices (at present 12 local offices including Ayutthaya and Saraburi).

Pollution Control Department

The Department administers the pollution control, which consists of sections of air, water, noise, solid and harmful waste. The pollution grievance section is also set up.

Environmental Quality Promotion Department

The Department publicizes the environmental administration activities, collects and controls the environmental information, studies and educates on the environment, and arranges with NGOs and the Ministry of Science, Technology and Environment.

(b) Government agencies relating to environment

According to the Enhancement and Conservation of National Environment Quality Act, A.D. 1992, the environmental administrative organization was tried to be reformed. However, the longtime administrative centralization of power had an influence and made it difficult to unify the various authorities concerned in the environmental administration and control immediately. At present, 20 or more Government agencies still engage in the environmental control.

The major Government agencies are Ministry of Industry (MOI), Ministry of Interior (MOI), Ministry of Agricultural Cooperative Association, and others.

The local government of Bangkok City, Capital, also controls the environment.

The Ministry of Industry has the strongest influence of all to control wastewater and air pollution in relation to the approval of plant installation and operation. (Nearly the same standards as those by the Ministry of Science, Technology and Environment) In addition, the Ministry of Industry requests the plants to submit quarterly report of water and air measurements.

(c) Environmental administration by local governments

The local governments relating to environmental administration are Bangkok Capital, prefectures, and cities. Only the Bangkok government executes the original environmental actions and controls.

3) Environmental laws and regulations and standards

(a) Environmental laws and regulations

In 1992 the Enhancement and Conservation of National Environment Quality Act was established as an environmental law in Thailand. Various

Government agencies have relations to the environmental problems and control them according to each laws and regulations. The following are the major laws and regulations relating to industrial pollution preventives.

Enhancement and Conservation of National Environment Quality Act:

Basic and general law to control the environment. Basic regulations for protection of environment are contained to preserve natural resources and to control pollution.

Factory Act:

The Act controls the operation of the plant under the control of the Ministry of Industry. The Minister is given an authority to control complementarily.

Plants are classified into three groups according to business types and sizes to be controlled.

Public Health Act, A.D.1992:

The Act provides the articles regarding the people's health and sound lives and the quality of life. Local governments are responsible to enforce the Act.

Navigation in Thai Water Act, B.E.2535, A.D.1992:

The Act aims to prevent actions influencing on and interfering water-borne traffic. It has a relation to prevention of water pollution.

Hazardous Substance Act, A.D.1992:

The Act provides the articles regarding the proper control of hazardous substances and the procedures.

Energy Conservation Promotion Act, A.D.1992:

The Act aims to promote manufacturing high-efficiency machines and equipment to support energy conservation and energy saving. The plants, which have and carry out the countermeasures against the environmental problems regarding energy conservation, are granted special favors such as exception of fees or subsidies.

(b) Environmental quality standard

Tables 1.1.6 and 1.1.7 show the typical examples of the environmental quality standards for rivers and the air.

Table 1.1.6 Environmental quality standards for rivers and lakes (Abstract)

(mg/liter)

Item	Statistics	Reference by classes				
		Class 1	Class 2	Class 3	Class 4	Class 5
Color, Odor, Taste	-	n	n	n	n	-
Temperature	-	n	n'	n'	n'	-
pH	-	n	5 - 9	5 - 9	5 - 9	-
DO	20%	n	6	4	2	-
NO_3-H	Maximum allowable	n	5.0	5.0	5.0	-
Cu	ditto	n	0.1	0.1	0.1	-
Cd *	ditto	n	0.05	0.05	0.05	-
Cr^{6+}	ditto	n	0.05	0.05	0.05	-
Pb	ditto	n	0.05	0.05	0.05	-
As	ditto	n	0.01	0.01	0.01	-

Note: n = Natural condition

n' = Natural condition. Temperature fluctuation should not beyond 3°C.

* = Water hardness of more than 100 mg/liter of $CaCO_3$

Source: Materials from Khao Wong Plant

Table 1.1.7 Environmental quality standards for the air (Abstract)

Item	1-hour mean value		8-hour mean value		24-hour mean value		1-month mean value		Yearly mean value	
	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm
CO	34.2	30	10.26	9						
NO_2	0.32	0.17								
SO_2	0.78	0.30			0.30	0.12			0.10	0.04
TSP					0.33				0.10	

Source: Materials from Khao Wong Plant

(c) Discharge standard

Tables 1.1.8 and 1.1.9 show typical examples of the standard for plant drain water and the standard for emission into the air (including reference by Siam Cement Group)

Table 1.1.8 Standard for plant drain water (Abstract)

Item	Reference by Ministry of Industry	Reference by Ministry of Science, Technology and Environment	Reference by Siam Cement
Temperature	40°C or less	40°C or less	According to the reference specified by public agency
pH	5.5 - 9.0	5.5 - 9.0	6.0 - 8.0
SS	50 mg/liter or less	50 mg/liter or less	30 mg/liter or less
Cu	2.0 mg/liter or less	2.0 mg/liter or less	According to the reference specified by public agency
Cd	0.03 mg/liter or less	0.03 mg/liter or less	
Cr^{6+}	0.25 mg/liter or less	0.25 mg/liter or less	
Pb	0.2 mg/liter or less	0.2 mg/liter or less	
As	0.25 mg/liter or less	0.25 mg/liter or less	

Source: Materials from Khao Wong Plant

Table 1.1.9 Standard for emission into the air (Abstract)

Item	Source of emission	Reference by Ministry of Industry	Reference by Ministry of Interior	Reference by Siam Cement
CO	All sources	1,000 mg/Nm^3 or 870 ppm or less	-	According to the reference specified by public agency
SO^2	Petroleum fuel	1,250 ppm or less	-	
NOx	Boiler - Coal fuel - Other fuel	 940 mg/Nm^3 or 500 ppm 470 mg/Nm^3 or 250 ppm	-	600 mg/Nm^3 or 300 ppm
Dust	Boiler and furnace - Heavy oil fuel - Coal fuel	 300 mg/Nm^3 or less 400 mg/Nm^3 or less	-	According to the reference specified by public agency

Source: Materials from Khao Wong Plant

1.1.2 Energy conditions

(1) General

Table 1.1.10 shows the economic indicator of energy in Thailand.

The total supply of the primary energy in Thailand increases at high growth rate of 7.68% (mean) in proportion to the high economic growth rate for 7 years of 1990 - 1997. With advancement of economy, the mean growth rate of energy imported (mainly oil and coal) is 10.2% though the mean growth rate of energy produced is 5.67%. The Thailand depends chiefly on imports for energy. After the financial and economic crisis in 1997, the total supply of primary energy is reduced to 70.87 Mtoe in 1998 though it reaches the peak of 75.36 Mtoe in 1997. In 1999 it increases only a little to 74.80 Mtoe. Since 1997 home-produced natural gas increases and oil import decreases, which results in lower dependence on imported energy. However, Thailand still depends chiefly on the imported oil as major energy.

Table 1.1.10 Economic indicator of energy in Thailand

		Unit	1990	1992	1994	1996	1997	1999	Growth rate 97/90	Growth rate 99/96
Energy production		Mtoe	27.21	31.15	31.89	36.33	40.33	41.03	5.67	4.14
Net import		Mtoe	17.98	21.20	27.02	37.23	35.45	33.14	10.2	-3.81
Total supply of primary energy (TPES)		Mtoe	45.10	52.00	59.34	72.44	75.36	74.80	7.68	1.08
Oil net import		Mtoe	18.47	21.66	26.87	35.80	34.52	31.64	9.35	-4.03
Oil supply		Mtoe	19.67	22.98	28.20	37.12	37.82	33.33	9.79	-3.53
Power consumption		TWh	38.34	49.30	62.51	77.35	82.43	81.45	11.6	1.74
GDP	One hundred million bahts '88		19,454	22,826	26,954	31,093	30,570	28,603	6.67	-2.74
	One hundred million dollars '88		769.8	897.9	1,070.9	1,226.1	974.5	756.9	3.43	-14.9
Population		One million	56.3	57.8	59.1	60.1	60.8	61.7	1.10	0.88
Energy production/ TPES			0.60	0.60	0.54	0.50	0.53	0.55	-1.76	3.23
Oil net import/GDP		t/100,000 Bahts	0.95	0.95	1.00	1.15	1.19	1.11	3.27	-1.17
TPES/GDP		t/100,000 Bahts	2.32	2.28	2.20	2.33	2.47	2.62	0.89	3.99
TPES/Population		toe/man	0.80	0.90	1.00	1.21	1.24	1.21	6.46	0.28
Oil supply/GDP		t/100,000 Bahts	1.01	1.01	1.05	1.19	1.24	1.17	2.97	-0.56
Oil supply/man		toe/man	0.35	0.40	0.48	0.62	0.62	0.54	8.51	-4.50
Power consumption/ GDP		kWh/1,000 Bahts	19.7	21.6	23.2	24.9	27.0	28.5	4.61	4.60
Power consumption/ person		kWh/ man	681	853	1,058	1,287	1,356	1,320	10.3	0.85

Source: THILAND ENERGY SITUATION 1999, DEPARTMENT OF ENERGY DEVELOPMENT AND PROMOTION, MINISTRY OF SCIENCE, TCHNOLOGY AND ENVIRONMENT

Table 1.1.11 shows the Thai primary energy supply growth to the rate of economic growth (elasticity to GDP). The improving life level, spreading motorization, developing industrialization, and especially expanding energy-consuming industries have influenced on the increasing figures until 1996.

Table 1.1.11 Primary energy supply growth to the rate of economic growth (elasticity to GDP)

	1990 - 1995	1991 - 1996	1992 - 1997	1996 - 1999
Primary energy supply growth	10.04%	10.62%	9.27%	1.08%
Rate of economic growth	8.6%	7.9%	6.3%	-2.74
Energy growth/ rate of economic growth	1.17	1.34	1.48	-0.39

Due to the financial and economic crisis in 1997, the rate of economic growth turned to be on the minus side as shown in Table 1.1.11. There was a large drop in 1998 (-10.2%), but it improved to 4.2% in 1999. The rate is expected to be on the plus side in 2000. This tendency of increasing will be continued in the future. Accordingly, from the viewpoints of the economic development and highly competitive power in Thailand and the global environment, the problem of energy saving will be more important in the future.

Table 1.1.12 shows the energy balance in Thailand.

The energy supply in 1999 is 74,800,000 tons in oil equivalent. The modern energy (coal, oil, gas, and electricity) supply is 60,840,000 tons and the traditional energy (wood, charcoal, chaff, and bagasse) is 13,960,000 tons. Each supply is 81.3% and 18.7% respectively. As modern energy, the following are included: petroleum (55.7%), natural gas (10.7%), and lignite and coal (13.0%). Natural gas and lignite are home-produced energy, but 95% of oil is imported.

The energy consumption in 1999 is 47,700,000 tons in oil equivalent. The modern energy (coal, oil, gas, and electricity) consumption is 38,810,000 tons and the traditional energy (wood, charcoal, chaff, and bagasse) is 8,890,000 tons. Each consumption is 81.4% and 18.6% respectively, which shows that the modernization has been relatively advanced compared to 70.8% and 29.2% in 1990. The annual mean growth of the modern energy final consumption is 6.7% for 9 years from 1990 to 1999, and that of the traditional energy consumption is nearly 0%. The total power generation (main fuels: natural gas, oil (heavy and light), lignite, water power) efficiency is 34.72% - 37.53% from 1990 to 1999.

Table 1.1.12 Energy balance in Thailand, 1999

(Unit: ktoe)

	Coal	Lignite	Crude oil	Petroleum products	Conden-sate	Natural gas	Electricity		Renew-able energy*	Total
							Water power	Thermal power		
Production		5,699	1,694		2,225	16,655	783		13,975	41,031
Import	2,029		34,860					192	9	38,966
Export				-5,072	-569	-152		-15	-21	-5,829
Primary supply	2,031	5,884	37,274	-3,381	1,542	16,530	783	177	13,963	74,803
Oil refining			-37,130	32,499	-401	-21				-5,053
Natural gas process plant				1,543		144				1,687
Power generation	-293	-3,746		-3,692		-12,150	-783	7675	-247	
Others				116					-4,824	-4,708
Total of conversion	-293	-3,746	-37,130	30,466	-401	-12,027	-783	7675	-5,071	-21,310
Total of final consumption	1,738	2,138		27,085	1,141	1,250		6941	8,892	49,185
Non-energy consumption				212	1,141	133				1,486
Final energy Consumption	1,738	2,138		26,873		1,117		6,941	8,892	47,699
Agriculture				2,146				14		2,160
Mining				68						68
Industry	1,738	2,138		3,971		1,112		3,083	4,087	16,129
Construction				237						237
Housing・Commercial				1,465				3,844	4,805	10,114
Transportation				18,946		5				18,991
Road				15,277		5				15,282
Rail road				103						103
Air traffic				2,696						2,696
Water traffic				910						910

* Wood, Charcoal, Chaff, Bagasse, etc.

The errors in total primary supply are caused by stock changes and statistic errors.

The difference between the total from the primary supply to the conversion and the final consumption is caused by self-consumption and loss.

Source: THILAND ENERGY SITUATION 1999, DEPARTMENT OF ENERGY DEVELOPMENT AND PROMOTION, MINISTRY OF SCIENCE, TCHNOLOGY AND ENVIRONMENT

(2) Fuels and energy

① Oil, Natural gas

The crude oil produced in 1999 is only 33,953 bpd; while the crude oil imported is 698,496 bpd, of which 79.7% is from the Middle East. Due to the financial and economic crisis, the import in 1999 is reduced compared to the import in 1997 of 729,700 bpd. However, Thailand still depends chiefly on crude oil imported. The condensate of 48,982 bpd is added. The total capacity of seven oil refiners is 862,500 bpd. The daily mean output of natural gas is 1,857 MMscf, and the annual total output reaches 677,866 MMscf of which 92% is from the gas well developed inside the Bay of Thailand. Natural gas is approximately 44.8% of crude oil in oil equivalent. Natural gas and lignite are the important home-produced energy resources in Thailand.

Fig.1.1.2 shows the flow chart of supply, conversion, and consumption of oil and gas.

Total consumption of oil products are made up as follows: Transportation: 62.4%, Industries: 13.0%, Agriculture: 6.8%, Housing/commercial: 6.2%, Power generation: 10.6%, Mining: 0.2%, Construction: 0.7%, Non-energy consumption: 0.8%. Total consumption of natural gas are made up as follows: Power generation: 92.71%, Industries: 7.25%, Transportation: 0.04%

As shown in Table 1.1.13, oil product consumption had a tendency of sharp increasing before economic crisis in 1997. Reduction continuously lasted for three years of 1997, 1998, and 1999. Gas oil (41.4%) and gasoline (19.0%) are high. Heavy oil is over 20%, but it is a little reduced as natural gas takes the place of heavy oil for power generation.

Table 1.1.13 Final consumption of oil products

Unit: 1,000 kl

Year	1990	1993	1996	1997	1999	Growth rate 1990 - 1996 (%)	Growth rate 1996 - 1999 (%)
Liquefied petroleum gas	1,743.7	2,265.9	3,200.2	3,310.3	3,370.1	10.6	1.7
Gasoline	3,686.2	4,707.6	6,918.1	7,355.3	7,023.4	11.1	0.50
Aviation fuel	2,361.7	2,855.0	3,311.3	3,542.7	3,297.7	5.8	-0.14
Kerosene	123.6	109.8	98.9	86.2	51.9	-3.7	-19.3
Gas oil	9,810.2	12,016.4	17,801.5	17,553.0	15,302.9	10.4	-4.9
Heavy oil	5,314.4	8,033.6	9,677.2	9,107.4	7,960.6	10.5	-6.3
Total	23,039.8	30,199.8	41,007.2	40,954.9	37,006.6	10.1	-3.4

Source: OIL AND THAILAND 1999, DEDP, MOSTE

② Coal

The coal produced in 1999 is 18,270,000 tons (5,700,000 tons in oil equivalent), which is mostly lignite of low quality (Calorific value: 2,500 - 4,400 kcal/kg). The entire quantity of lignite is consumed in Thailand for power generation (74.0%), cement production (20.3%), tabacco drying (0.24%), and others (5.4%). The largest Mae Moh Coalfield locates 650 km to the north of Bangkok, Capital. The Coalfield produces 70 -

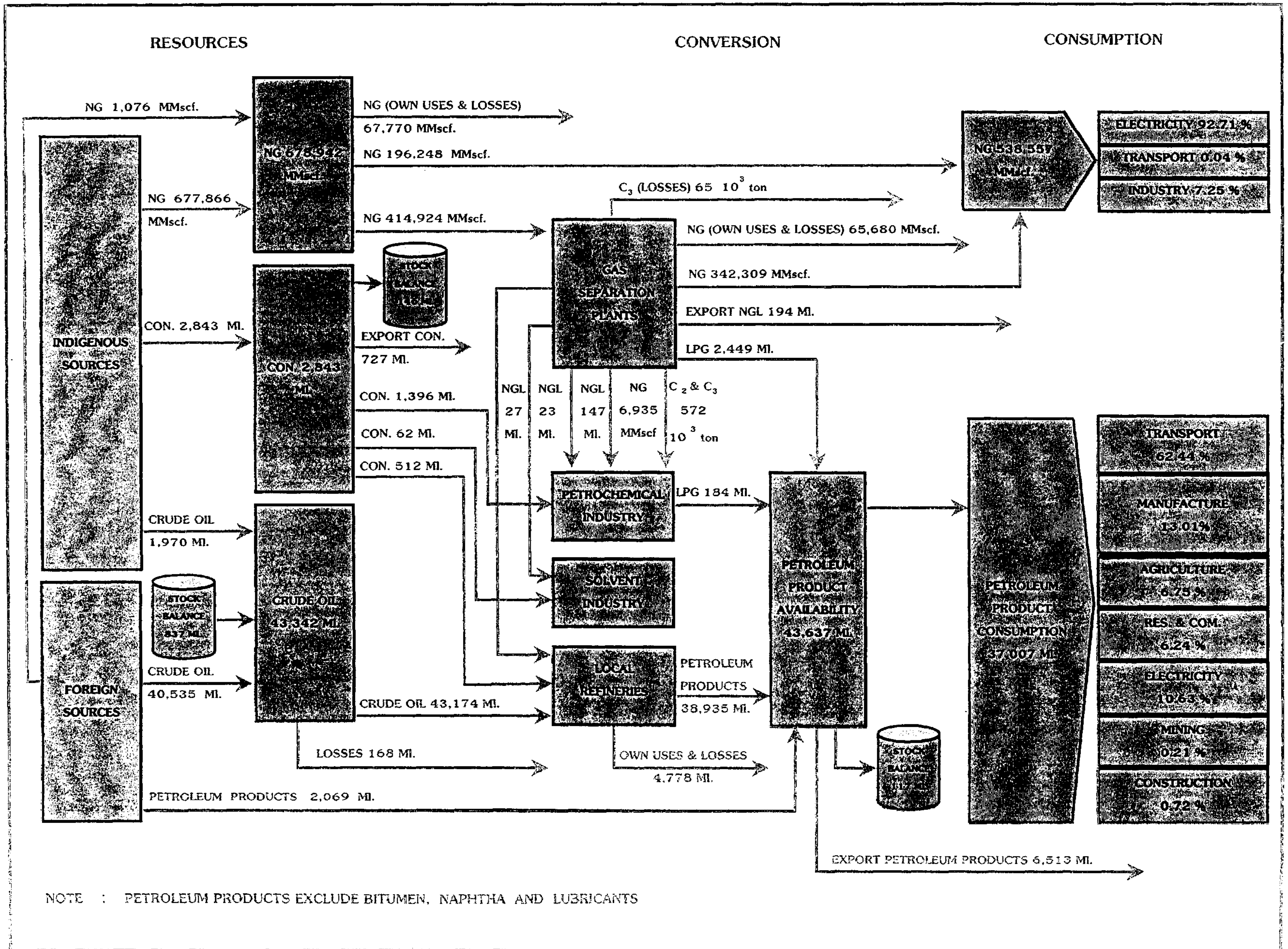


Fig.1-1-2 Oil and gas flow chart

(Source: Oil and Thailand 1999, DEDP, MOSTE)

80% of the total output with the confirmed coal reserves of 1.29 billion tons, which is 55.6% of the entire reserves in Thailand (2.312 billion tons). However, the sulfur content is very high (3.1 - 6.6%).

The quantity of coal imported had been greatly increased from 348,000 tons in 1990 to 3.964 million tons in 1996. Since 1997, it was reduced to 3.283 million tons (1997), 1.624 million tons (1998), and 3.225 million tons (1999) due to the economic crises. The mean calorific value of the coal is 6,600 kcal/kg, and it is used in the manufacturing field.

③ Electricity

The total power generating installation capacity in 1999 is 20.22 million kW, and the total electricity generated is 90,067GWH. Power consumption in 1990 - 1997 is greatly increased every year with the rapid economic development.

The annual mean growth rate reaches 11.6%, but it is reduced to 1.7% in 1996 - 1999.

The percentage of each fuel for power generation in 1999 is as follows:

Natural gas: 57.6%, Lignite and coal: 18.7%, Heavy oil: 18.8%, Diesel oil: 0.6%, Water power: 4.3%

Until 1989 the Government had a policy not to depend on oil and to utilize the domestic resources (water, natural gas, lignite) effectively, and the percentage of the oil power generation is only 13% of the total generation in 1989. Since 1990, the relation between the demand and the supply has been very tight. More thermal generation plants started to run. Then, the percentage of oil thermal generation is high, or around 25% of the total power generated. Since 1997, it is reduced to nearly 20%.

The percentages of each applied power consumption (1999) is as follows:

Industrial use: 44.4%, Commercial use: 32.4%, Housing use: 22.4 %, Agricultural use: 0.2%, others: 0.6%

The power generated in 1999 is 7,675 million tons in oil equivalent. The total energy input is 20.911 million tons in oil equivalent, and the power generation efficiency is 36.70% which is a little lower than the mean power generation efficiency in Japan (Generation end: 39.98%, Transmission end: 38.22%, 1998).

Percentage of power generated by power generation plants and generation efficiency (data in 1999) are as follows:

Generation type	Percentage of power generated (%)	Generation efficiency (%)*	Fuel
Water	3.9%		
Thermal (steam)	42.5%	35.1%	Natural gas, Lignite, Light oil
Gas turbine	1.3%	22.2%	Natural gas, Light oil
Combined cycle	43.8%	41.3%	Natural gas, Light oil
Diesel	0.1%	35.6%	Light oil
Co-generation (SPP)	8.4%		Natural gas, Lignite, Coal, Traditional fuel

* EGAT and IPP (Steady operation data), 1999

④ Renewable energy

The traditional renewable energy (wood, charcoal, chaff, bagasse) supply is 13.96 Mtoe in 1999, which is 34.1% of the domestic energy and 18.7% of the total energy supply. In 1988, it reaches 36.1% of the total energy supply. The consumption is 8.89 Mtoe (as 3/4 of wood is converted to charcoal), which is 18.6% of the final energy consumption. It is mostly for housing use and industrial use (most of them are for food processing). 66.3% of the energy for housing use is renewable energy.

Mostly the energy is not used in Bangkok, or Capital, and towns and cities, but in the countries and agricultural districts.

(3) Energy reserves, development, and demand-supply forecast

① Petroleum

Thailand has poor petroleum reserves only with approx. 0.4 billion bbl crude oil and 0.51 billion bbl condensate. 34,000 bpd crude oil was produced in 1999 and 698,000 bpd was imported in 1999. Thailand will also have to depend on importing crude oil for the future. 49,000 bpd condensate was produced.

The Government appears to reduce importing fuels including petroleum, though highly depending on the import, and shift to domestic natural gas.

Table 1.1.14 shows an example of the demand-supply forecast for oil products in Thailand.

Since 2004, as shown in the table, the fuel oil consumption is expected to grow at high rate again as the consumption will increase in the traffic and industrial fields.

Table 1.1.14 Demand-supply forecast for oil products in Thailand

(ktoe)

Oil products	1998	2004	2008	2010	Annual mean growth rate			
					2004/ 1998	2008/ 2004	2010/ 2008	2010/ 1998
Products total	30,595	34,920	41,960	46,086	2.2	4.7	4.8	3.5
Gasoline	5,452	6,396	7,791	8,568	2.7	5.1	4.9	3.8
Aviation fuel	2,647	3,480	4,091	4,425	4.7	4.1	4.0	4.4
Kerosene	45	50	58	64	1.8	3.9	4.5	3.0
Light oil	13,315	14,525	17,344	18,926	1.5	4.5	4.5	3.0
Heavy oil	7,562	8,471	10,015	11,038	1.9	4.3	5.0	3.2
Fuel oil total	29,021	32,922	39,300	43,020	2.1	4.5	4.6	3.3
LPG	952	1,271	1,782	2,103	4.9	8.8	8.6	6.8
Others	622	728	878	963	2.6	4.8	4.8	3.7
Share (%)								
Products total	100.0	100.0	100.0	100.0				
Gasoline	17.8	18.3	18.6	18.6				
Aviation fuel	8.7	10.0	9.7	9.6				
Kerosene	0.1	0.1	0.1	0.1				
Light oil	43.5	41.6	41.3	41.1				
Heavy oil	24.7	24.3	23.9	24.0				
Fuel oil total	94.7	94.3	93.7	93.3				
LPG	3.1	3.6	4.2	4.6				
Others	2.0	2.1	2.1	2.1				

Source: Japan Energy Economy Research Institute

② Natural gas

The natural gas reserves in Thailand are estimated to be 20.4 trillion scf. Most of the deposits (approx. 90%) are far out at the Bay of Thailand. Natural gas produced from the gas fields (Erawan, Bangkot) are delivered to the Ban Pak Chon Plant and the South Bangkok Plant (EGAT) and the Rayong Plant (EGCO) through the pipeline of approx. 524 km. Another pipe line of 330km connects the gas fields at Erawan and Bangkot delivers gas to the Khanom Power Plant (EGCO) located in the south of the peninsula. The natural gas output in 1997 is 677.9 billion scf. If the conditions keep on, it is expected to be exhausted in approx. 30 years or less if the demand increases.

Accordingly, until the currency and economic crisis was caused, the Government had prepared the satisfactory supply plan including imports as follows:

a. Importing LNG from Oman and importing natural gas via pipe line from the Natuna gas field in Indonesia

   This plan was postponed from 2007 on. It may be stopped in certain circumstances.

b. Project to import from Myanmar via two pipelines (Yadana and Yetagun gas fields)

The import contract has been made, and construction has been started. The project may be continued, but the import plan is behind. It is now under negotiation.

c. Withdrawal from the joint development area (JDA) with Malaysia

The import contract has been made and construction has started. The project maybe continued, but operation may be started from 2003 on (or it may not be included in the plan until 2008.)

The structure of natural gas consumption in Thailand has not changed and will not change. The high percentage of 70 - 80% is for power generation use. Since the currency and economic crisis, the long-term forecast of electricity repeatedly changed downward. The planned generation installed capacity from 2000 to 2010 will be reduced by 25 - 30% compared to that before the crisis. IPP may not be much expected (Table 1.1.15). The forecast of the demand for natural gas was reduced by 30% (Table 1.1.16), and the past supply plan was thoroughly changed.

Accordingly, the chances of starting a new import plan before 2010 appear slim.

Table 1.1.15 Prospect of demand for natural gas:
Comparison between before and after crisis

(Unit: million cfd)

	1995	1998	2000	2005
Before	900	2,000	3,000	4,400
After	900	1,600	2,100	2,800

Source: PetroTech, Vol.22, No.4, 16 (1999) by Japan Energy Research Institute

Table 1.1.16 Long-term plan of power development in Thailand (Governmental)

(Unit: MW)

	October, 1996	September, 1997	August, 1998	Percentage of natural gas
1998	16,455	14,975	14,180	86.2%
2001	21,423	19,049	15,900	74.2%
2002	23,131	20,566	16,933	73.2%
2004	26,645	23,685	19,193	72.0%
2006	30,464	27,076	22,182	72.8%
2007	32,536	28,918	23,760	73.0%
2009	36,914	32,809	26,755	72.5%
2011	41,683	37,047	29,955	71.9%
Annual mean growth rate				
1997 - 2001	8.16 %	7.43 %	3.62 %	
2002 - 2006	7.30 %	7.29 %	6.89 %	
2007 - 2011	5.06 %	6.47 %	6.19 %	

Source: PetroTech, Vol.22, No.4, 16 (1999) by Institute of Energy Economics Japan based on EGAT materials

③ Coal

Thailand produces little high quality coal but lignite. The confirmed reserves of lignite is said to be 2.3 billion tons. Most of them are produced in the north district. 55.6% of the lignite reserves in Thailand are at the Mae Moh Coalfield. The output of lignite has been increasing year after year with 7.259 million tons in 1988 and 23.393 million tons in 1997. Since the financial and economic crisis, it is reduced to 20.163 million tons (1998) and 18.266 million tons (1999).

The coal imported has been sharply increasing since 1993 with approx. 4 million tons in 1996, but 3.283 million tons in 1997 due to the currency crisis. It drops to 1.625 million tons in 1998, but increases to 3.225 million tons in 1999. The increase has not yet reached the level before the financial and economic crisis.

According to the longterm demand-supply prospect, it is estimated that the great amount of imported coal would be utilized for power generation. The power outputs by natural gas in 2010 is estimated to drop from 58.0% (2004) to 42.2% according to the Government policy to utilize various fuels. On the contrary, the power output by coal, which is 21.0% in 1998, is estimated to reach 33% (Table 1.1.17).

Table 1.1.17 Power source construction (Primary input)

(Unit: ktoe)

	1998	2004	2008	2010
Power generated	7,746	8,964	11,083	12,355
Primary input	19,152 (100.0)	21,596 (100.0)	26,240 (100.0)	29,019 (100.0)
Lignite, Coal	4,013 (21.0%)	3,705 (17.2%)	7,304 (27.8%)	9,590 (33.0%)
Oil	4,372 (22.7%)	4,904 (22.7%)	5,965 (22.7%)	6,604 (22.8%)
Natural gas	10,352 (54.1%)	12,520 (58.0%)	12,432 (47.4%)	12,259 (42.2%)
Water power	445 (2.3%)	467 (2.2%)	539 (2.1%)	565 (1.9%)

Source: Institute of Energy Economics, Japan

④ Water power

The contained waterpower that can be developed is 7.007 million kW. 6.648 million kW can be added by pumping-up power plants. Only approx. 30% (3.874 million kW) was started to be developed before September in 1997. It may be environmentally difficult to develop the rest part. The future waterpower development will be limited to the small-scale, environmentally friendly, and economical projects.

Waterpower has been increasingly imported from neighboring countries, especially from Laos. Lately, in addition to purchasing electricity from the existing water power plant, EGAT and other private enterprises in Thailand took part in the power generation business in Laos for the purpose of importing electricity to Thailand.

(4) Energy policy

The energy policy guideline was indicated in the 8th economic and social development 5-year plan (1997 - 2001) as follows:

① Supplying the correct energy to meet the demand and assuring the quality of supply and the appropriate price, with including the following.

(1) Rapidly prospecting and developing oil and coal resources (Promoting the Thailand-Malaysia joint petroleum development)

(2) Rapidly negotiating for joint energy developments with neighboring countries (Plan to purchase electricity from Laos, Studies of water power generation projects in Thailand and other neighboring countries, Plan to purchase natural gas from Myanmar, Plan to purchase electricity/natural gas from Malaysia)

② Promoting to utilize energy efficiently and economically

According to the Energy-Saving Promotion Act, the electricity demand management (DSM) and energy-saving plans are to be carried out rapidly.

③ Promoting competitions among energy departments and strengthening non-governmental parts

The petroleum and electricity businesses are to be committed to private hands.
The Governmental PTT (petroleum) and the Governmental EGAT (electricity) should be promoted to come under private management. Electricity should be purchased from IPP and SPP.

④ Preventing environmental problems from being caused by energy development and utilization and improving the safety of the energy departments

Heavy oil containing low sulfur and diesel light oil should be used. Application of natural gas fuel should be extended to commercial cars and trucks in Bangkok, or the Metropolitan area.

⑤ Making laws relating to energy and energy management

The guideline also aims to carry out as follows:

- Increasing to generate energy for commercial use by 5% a year during the plan.
- Reducing the energy import depending on foreign countries to 70% or less toward the final year (2000)
- Delivering electricity to all the family houses until the final year

(5) National plan to save energy

① Establishment of NEPC and NEPO (National Energy Policy Office)

During the period of the 5th National Economic and Social Development Plan, especially before 1987, each Government energy relating policy or management was presented in its own way and no unity was attained among the departments. Therefore, the 6th National Economic and Social Development Plan suggested that a committee should be established to adjust and coordinate the Governmental general energy plans and policies by various departments/committees/WGs.

In September and October of 1986, the Government established NEPC and its subordinate executive organ NEPO under the Prime Minister Office.

NEPC and NEPO were established at the same time when the Regulations on the National Energy Administration, B.E. 2529 (1986) were established by the Prime Minister.

The name of the National Energy Office (handling only at the feasible level including studies) under MOSTE was changed to the Department of Energy Development and Promotion. The head office is the executive office without handling policies to avoid overlapping with NEPO.

② Role and responsibility of NEPO

According to the National Energy Policy Council, B.E. 2535 (1992), NEPC consists of Prime Minister as Chair and the ministers of the relating Departments and the heads of the official agencies as committee members.

The director of NEPC is a member of the committee and the executive office.

According to the law, NEPO as an executive office of NEPC executes the following tasks.

- According to the National Energy Policy Council, B.E.2535, NEPO reviews and analyzes the National energy policy, management, and development plan to be submitted to NEPC.
- The Energy-Saving Promotion, B.E. 2535 (1992) describes the authority and the responsibility regarding energy saving given to NEPC. NEPO recommends and adjusts the tasks as an executive office or an executing agency according to the law.

○ Recommending policies, projects, and means to execute regarding energy-saving

○ Management of the energy-saving promotion fund

The purposes of the fund are as follows:

- Promotion of more efficient and economic utilization of energy
- Promotion of manufacturing high energy-efficient equipment/machines
- Promotion of studies and developments related to energy saving
- Reduction of impacts on environment caused by energy development and utilization
- Promotion of producing and utilizing renewable energy and new energy

③ Program of energy-saving promotion

According to the Energy-Saving Promotion, B.E. 2535 (1992), the energy-saving program is executed. The program is divided into the three subprograms: compulsory program, voluntary program, and supplementary program. The executing fund is given from the energy-saving promotion fund, which is applied from the oil tax.

a. Compulsory program

This program is applied to the specified factories and buildings of which operating power capacity is 1MW or more and power consumption of 20 TJ/year or more. The total number of applicable factories and buildings is approx. 3,500.

- Execution according to the law of buildings specified, B.E. 2538 (1995) and the related regulations

  These were enforced on the 12th of December in 1995, and have been already executed mainly in the Governmental buildings. The energy consumption in the specified building, coefficient of general thermal conductivity, and standard lightings and air conditioners are specified.

- Execution according to the law of factories specified, B.E. 2540 (1997) and the related regulations

  The law was issued by the DEDP/MOSTE in 1997. The law has an influence on the energy consumption at the specified factory and compulsorily places an owner of the specified factory under an obligation to carry out energy-saving actions as follows:

  - Creating the energy-saving target value and preparing the plan
  - Auditing and analyzing the energy utilization
  - Recording and submitting the data on energy generation and utilization

  This compulsory program is executed by DEDP/MOSTE.

National Petroleum Chemical (NPC), a subject of this survey, has already started to find out the energy-saving problems in the factories and review the energy-saving plan jointly with the consultants. As the result of the review, NPC requested the Japanese side for further investigation and review.

b. Voluntary program

This program supports and helps governmental agencies and private facilities for energy-saving activities. The following effects are expected.

- More efficient and economical utilization of energy
- Spreading utilization of environmentally-friendly renewable energy
- Promotion of energy-saving products and services
- Promotion of studies, research projects, and developments related to energy saving

NEPO is in charge of this program. In the energy-saving program 1995 - 1999, the following programs were put in practice.

- Renewable energy and local industrial program
  - Biogas power generation in stock farming
  - Energy-saving at tabacco factories
  - Ceramic Kiln of high efficiency
- Industrial related program (Supporting existing small types)
  - Solar water heater
  - Solar herbicide extract system
  - Roof solar energy system demonstration program (Selling extra electricity)
  - Delivering water to villages by solar generation
  - Energy park (Utilization and spreading of solar heat systems and solar batteries)
- Research and development program (Support/publicity activities for small-scale demonstration projects)
  - Vegetable dryer with solar condenser
  - Study of non-crystalline silicon PV for tropical climate
  - Hybrid power generation system in national parks and wildlife sanctuaries
  - Development of electric automobile with solar battery
  - Green briquette fuel (Utilization of agricultural/agricultural processing secondary products and waste matters)

The next (2000 - 2004) program will start with the following two subprograms.

- Promotion of SPP (small power plant) with renewable energy
- Promotion of energy-saving activities at non-specified medium to small sized factories/buildings

c. Supplementary program

- Training and education program of energy saving

- Publicity of energy-saving information and activities
- Management and monitoring program

NEPO is in charge of the programs.

④ Energy-saving promotion fund

As mentioned before, it is the fund specified in the law to execute energy-saving programs. The source of the fund is the oil tax*. The total budget for the following 5-year program (2000 - 2004) is 29.11 billion bahts (approx. 80 billion yen). 58.5% of them are allowed to Compulsory Program made up as follows:

Government buildings:	10.0%
Buildings + Factories:	46.5%
Design・Construction:	0.5%
Publicity activities:	1.6%

* Oil tax: 4 satang/liter (1 baht = 100 satang)

⑤ DSM program

The DSM program formally started in September of 1993 to promote power energy-saving activities and efficient utilization on the customer side. The DSM bureau at EGAT (Thai power generation public corporation) carried out the 5-year DSM Master Plan (1993 - 1997) in corporation with MEA (power distribution in the Capital) and PEA (power distribution in local districts).

At the beginning, the goals were 238 MW reductions in peak demand and 427 GWh reductions in power consumption. Finally, however, they exceeded the target values to attain 311 MW reductions in peak demand and 1,826 GWh reductions in power consumption.

The DSM program consists of the following six subprograms.

- Residence program
- Industrial sector program
- Energy-saving attitude promotion program
- Commercial/Governmental building program
- Load management program
- Program monitoring and evaluation

The first three programs aim at equipment of high-energy efficiency, especially lighting apparatus, highly efficient refrigerator/air conditioner, and highly efficient motor.

The following are the programs concretely executed.

a. Lighting apparatus

In September of 1993, EGAT suggested five major manufacturers, who have a 95% market share in manufacturing and supplying fluorescent lights, to negotiate and make a voluntary agreement to change from the conventional lamps to new thin tubes (18W and 36W).

b. Refrigerator

The energy efficiency label system was introduced to refrigerators in January of 1995 under the cooperation of major manufacturers. It was started with the refrigerators of

5 - 6 ft^3 capacity.

c. Air conditioner

The above labeling system was introduced at the beginning of 1996. All of the 55 air conditioner manufacturers took part in the program.

d. "Green building" program

EGAT started the "Green building" program in September of 1995.

The program put emphasis on energy saving and energy improvement in buildings. 180 buildings and more took part in the program. EGAT introduced the loan system free of interest with the term of repayment of 3 - 5 years for the owners of buildings to promote installing equipment of higher efficiency.

e. Highly efficient motor program

This program started at the beginning of 1996. When a factory purchases highly efficient motors, the factory can receive a reduction incentive pay of US$440/kW.

1.1.3 Needs for CDM project

The industries in Thailand have inclined to export as the domestic demand has reduced since the financial and economic crisis in 1997. It is important for them to improve the cost competitive power to win in the cost competition abroad. Energy and production goods are the major cost, and they must be reduced for the purpose of cost reduction. Namely, energy saving and resources saving are required, and which result in prevention of environmental pollution and satisfy the social request for environmental integrity.

It is one of the methods in providing capital for the energy saving and resources saving cost to raise funds from the inside and the outside of Thailand. Judging from the present circumstances in Thailand, it is more necessary to introduce the capital with advantageous conditions from the outside. One of the choices is the funds and technology by CDM (Clean Development Mechanism).

The COP6 meeting was held in The Hague in November 2000, but no final agreement was made regarding the Kyoto Mechanism. We must wait for the final conclusion until the COP6 meeting is restarted in Bonn in July 2001. However, there is a good possibility for utilization of ODA to CDM if it is additional to the conventional international cooperation. According to the existing circumstances in the Thai industries, it must be considered as an inevitable consequence in case of some large investments to rely on the advantageous loans from the outside. If the financing condition is good, the environmental credit in yen may be considered.

Judging from the existing business circumstances, Siam Cement (SCI) would like to utilize such an advantageous credit to a large-scale investment from the inside or the outside of Thailand.

Section 2. Necessity to introduce energy-saving technology into cement production process

Thailand has been escaping from the one-time slack in the domestic economy, but has still taken measures for the strong promotion of export. Especially the cement industry with the capacity of 55 million tons, including the capacity by Siam Cement of 23 million tons (42%), has been much expected of as a support and driving force for promoting the Thai economy. In the export market there is a severe cost competition. The Thai cement industry must try to do best in reducing the cost greatly to win the competition in the global market.

The cement production process requires a very large quantity of heat energy. Utilization of domestic natural gas with taking energy-saving measures is very useful to improve the international competitive power, and additionally it is very effective in reducing CO_2 gas. DEDP of the Ministry of Science, Technology and Environment responsible to develop and spread the energy-saving technology has strongly guided to introduce the energy-saving technology, and Siam Cement wants to introduce the technology immediately.

The cement industry in Japan has come to grips with the energy-saving measures as the most important subject, and developed and introduced various technologies.

In the cement industry, fossil fuel is used as the energy for burning and electricity is used as the energy for pulverization of raw materials and burned clinker. To reduce the fossil fuel consumption, petroleum coke, waste tire, waste oil, and other industrial wastes are utilized largely and widely. The fossil fuel reduction of $8,539 \times 10^9$ kcal or 1.40 million tons in coal equivalent was attained in 1995.

To reduce electricity consumption, it is aimed to spread the waste heat generation system. The electricity generated by the system reached $2,969 \times 10^9$ kcal or 490,000 tons in coal equivalent in 1995.

For the physical unit of clinker burning, it reached 700×10^3 kcal/t-clinker in 1987 and after, which is much less than the level in U.S.A. and Europe (U.S.A.: $1,300 \times 10^3$kcal/t-clinker, France: 890×10^3 kcal/t-clinker).

Accordingly, it is very significant to cooperate and promote the energy-saving activities in the Thai cement industry based on the advanced energy-saving technology in Japan.

Section 3. Meaning, need, and effect of this project and influence on and spreading to the similar industries

(1) Meaning

Siam Cement (SCI) chosen as a subject is a large company, which represents the Thai cement industry. The SCI plants consume much energy. Therefore, the energy-saving project at SCI is very significant.

The purpose of this project is to reduce the fuel consumption unit to improve the energy utilization in efficiency by introducing the gas turbine generation system into the white cement plant to utilize both of electricity and waste gas heat. A large energy-saving effect and a greenhouse effect gas reduction can be expected.

The high-efficient generation system and the waste heat recovery technology can be applied not only to the cement industry but also to various fields of industries.

(2) Need

The reduction of production cost is the most important subject for the Thai cement industry due to the greatly decreased domestic demand for cement after the financial and economic crisis and the necessity for increasing the export. The industry consumes much energy, and especially the reduction of energy cost is the top target.

(3) Effect

A large energy-saving effect and a greenhouse effect gas reduction can be attained when the cement industry of much energy consuming type adopts this project. It can be also applied to other industries variously and widely.

(4) Influence on and spreading to similar industries

Siam Cement (SCI), a leading company in the Thai cement industry, has a 42% share of the gray cement capacity in Thailand. It is useful to spread the project to other gray and white cement companies. This project is a good proposal for the white cement industry from the viewpoints of energy-saving effect and reduction of CO_2 gas, because such industry suffers high cost due to high amount of fuel consumption. As soon as the good result is verified, the project may spread over the white cement industry. However, it is necessary to choose the regions, capable of supplying material gas and paying based on the purchased electricity charge and the gas turbine fuel cost.

This project includes some general technologies such as high-efficient generation system and waste heat recovery, which are the problems to be solved common to many industries. Such technologies can be applied not only to the cement industry but also to others.

Chapter 2. Implementation of the Project

This chapter contains an outline of the project, a profile of Siam Cement Industry, the financing plan and the CDM conditions.

This project aims to introduce advanced technologies from Japan to the Khao Wong White Cement Plant of Siam White Cement Company. These technologies are intended to conserve energy and reduce the emission of greenhouse gases. Specifically, the following approaches will contribute to reduced fuel consumption.

1. Gas turbine generating equipment will be introduced so that the waste heat from the exhaust gas can be utilized in the white cement manufacturing process.
2. The manufacturing process will be modified to enhance the thermal efficiency of the clinker baking department.

Siam Cement Industry (SCI) is a core company of the Siam Cement group, the largest industrial conglomerate in Thailand. SCI is a leading company in that field, as it accounts for 42% of gray cement production in Thailand. Siam White Cement Company (SWCC) is one of the group companies. Since the financial crisis of 1997, SWCC has been making a significant effort to reduce its production costs and improve its competitiveness. Consequently, they have a strong interest in this project. We have also determined that they have the organizational and financial capacity to carry out the project.

The white cement manufacturing process differs from that of gray cement. The unit energy requirement is twice that of gray cement due to the smaller production scale. SWCC had been considering a fuel shift from expensive heavy oil to petroleum coke and cracker bottom (cracked heavy oil) in an effort to reduce fuel costs. We proposed this project as an energy saving approach in addition to the fuel shift.

In this project, the introduction of the steam injection gas turbine generating equipment and modification of the material preheater will provide the required power, reduce energy consumption by 91 kcal/kg-cl (clinker) by utilizing the waste heat from the exhaust gas, and produce surplus energy for increasing production by about 18%. The cost of the project is about 315 million baht.

This project is too small to qualify for a loan from the Japanese government. We suggest that the ideal approach would be to raise funds through export credits.

Although the Ministry of Scientific Technology and Environment (MOSTE) and the Office of Environmental Policy and Planning (OEPP) have not clearly committed to it because of the uncertainty of the CDM scheme, the possibility exists that this project may be considered a CDM project if other conditions are satisfied. This is because the funds would be from an additional budget and not in competition with the original ODA.

Section 1. Project Planning

2-1-1 Outline of the Province of Saraburi

The province of Saraburi is located in the center of Thailand. It is the heart of the cement manufacturing industry in Thailand because it is rich in limestone and other resources and is fairly close to large markets including the capital of Bangkok and the eastern coastal industrial zone.

A series of cement factories was constructed beginning in the 1970s, with the pace increasing in the late 1980s and beyond. Saraburi now houses six factories of the four major companies. These factories — three of which belong to SCI — are concentrated in the province. This congregation of factories contributes about 80% of the 55 million metric tons of cement produced annually in Thailand (Figure 2-1-1. Distribution and Production Capacities of Cement Factories in Thailand).

Figure 2-1-1 shows that, outside the Saraburi region, only two large cement manufacturing plants exist in Thailand — Lampang and Nakornsrithammarat. These two plants, which belong to SCI, supply northern and southern Thailand, respectively.

Most of the cement produced in Thailand is ordinary gray cement. The white cement that is the subject of this project is a high-quality cement. The Khao Wong Plant of SWCC accounts for almost 80% of white cement production.

Figure 2-1-2 shows a map of central Thailand. Natural gas from the Gulf of Thailand is supplied via a pipeline extending from about 100 kilometers north-northeast of Bangkok to the province of Saraburi, which is 120 kilometers from the capital. Figure 2-1-3 shows the distribution of major cement factories and industrial complexes in the Saraburi region. These industrial complexes are located along the path of the natural gas pipeline. The only cement factory with access to the pipeline is the Ta Luang Plant of Siam Cement Inc. It is about 15 to 17 kilometers from the target of this project, the Khao Wong Plant.

The following industrial complexes are located in Saraburi (Figure 2-1-3):

- Saraburi Industrial Complex (Keang Khoi Area)
- Siam Cement Industrial Complex (Nong Khae Area)
- Nong Khae Industrial Complex (Nong Khae Area)

Several member companies of the Siam Cement group operate in the Siam Cement Industrial Complex.

On the other hand, the province has several national parks with outstanding scenic beauty. The Khao Wong Plant is also surrounded by forests. Preservation of the natural environment is also a key issue.

2-1-2 Details of the Project

This project is intended to conserve energy and reduce emission of greenhouse gases at SWCC's Khao Wong Plant by introducing advanced energy-saving technologies from Japan for the white cement production process.

Section 2-2-4 presents details of the technologies applied to energy conservation. This project will reduce fuel consumption through the following approaches:

1. Gas turbine generating equipment will be introduced to utilize the waste heat from the exhaust gas in the white cement manufacturing process.
2. The manufacturing process will be modified to enhance the heat efficiency of the clinker baking department.

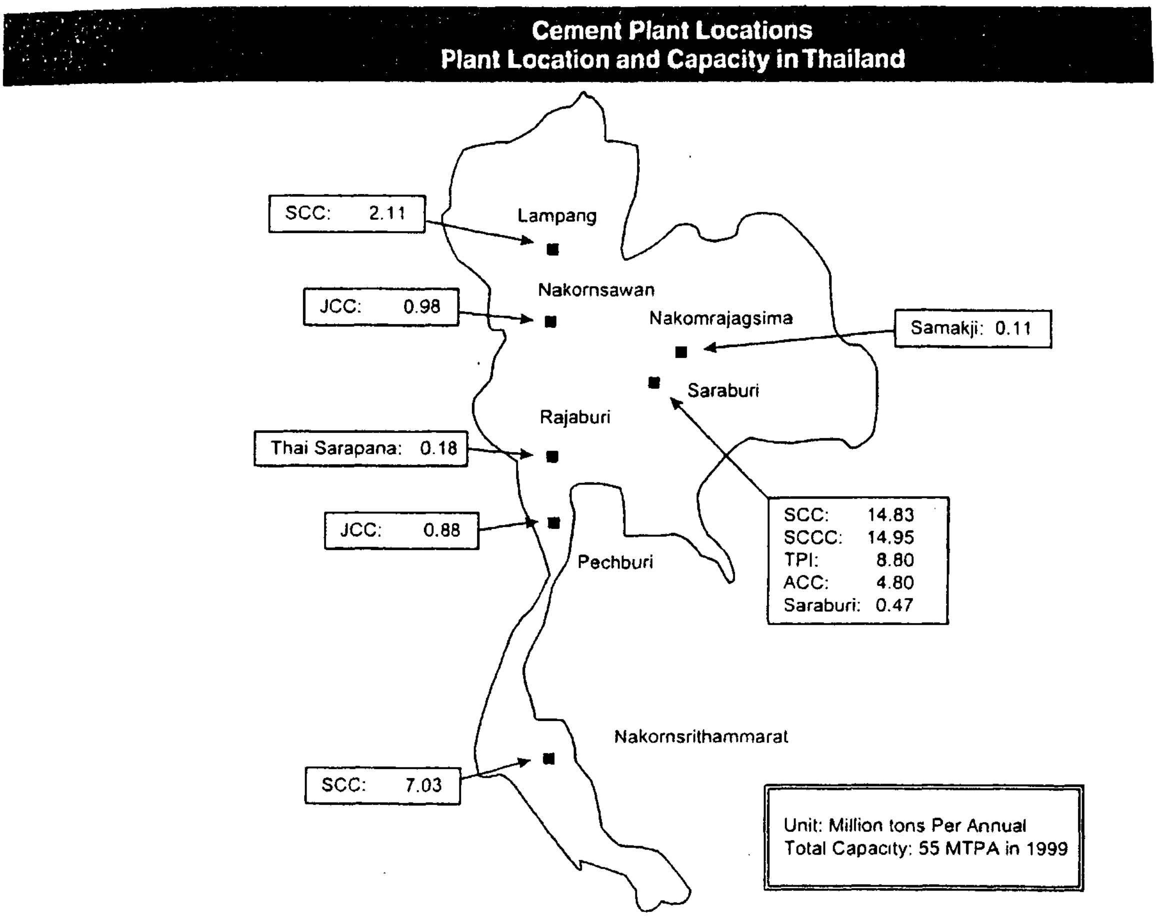
In addition, this project reduces electricity costs by replacing power purchased from a supplier with power from the generating equipment to be introduced. The modification of the process also increases cement production and enhances productivity.

2-1-3 Reduction in Greenhouse Gas Emissions

This project conserves energy by decreasing the fuel consumption of the cement production factory, as mentioned in section 2-1-2.

Consequently, consumption of fuels at SWCC (heavy oil and petroleum coke) is reduced, which results in a proportional reduction in carbon dioxide emissions. Carbon dioxide emissions are further reduced due to the use of low-carbon natural gas for fueling the gas turbine power generation equipment. The power from this unit replaces the power purchased from an electric power company, which uses mainly natural gas, brown coal and heavy oil as fuels.

Therefore, this project reduces overall emissions of carbon dioxide, a greenhouse gas.



SCC:Siam Cement Public Co..Ltd.
SCCC: Siam City Cement Public Co.,Ltd.
TPI:TPI Polene Public Co..Ltd.
ACC:Asia Cement Public Co., Ltd.
JCC:Jalaprathan Cement Public Co.,Ltd.
Saraburi: Saraburi Cement Co.,Ltd.
Samakji: Samakji Cement Co.,Ltd.

Fig. 2-1-1 Cement plant locations and capacity in Thailand
(Source: The Siam Cement Public Co. Ltd.)

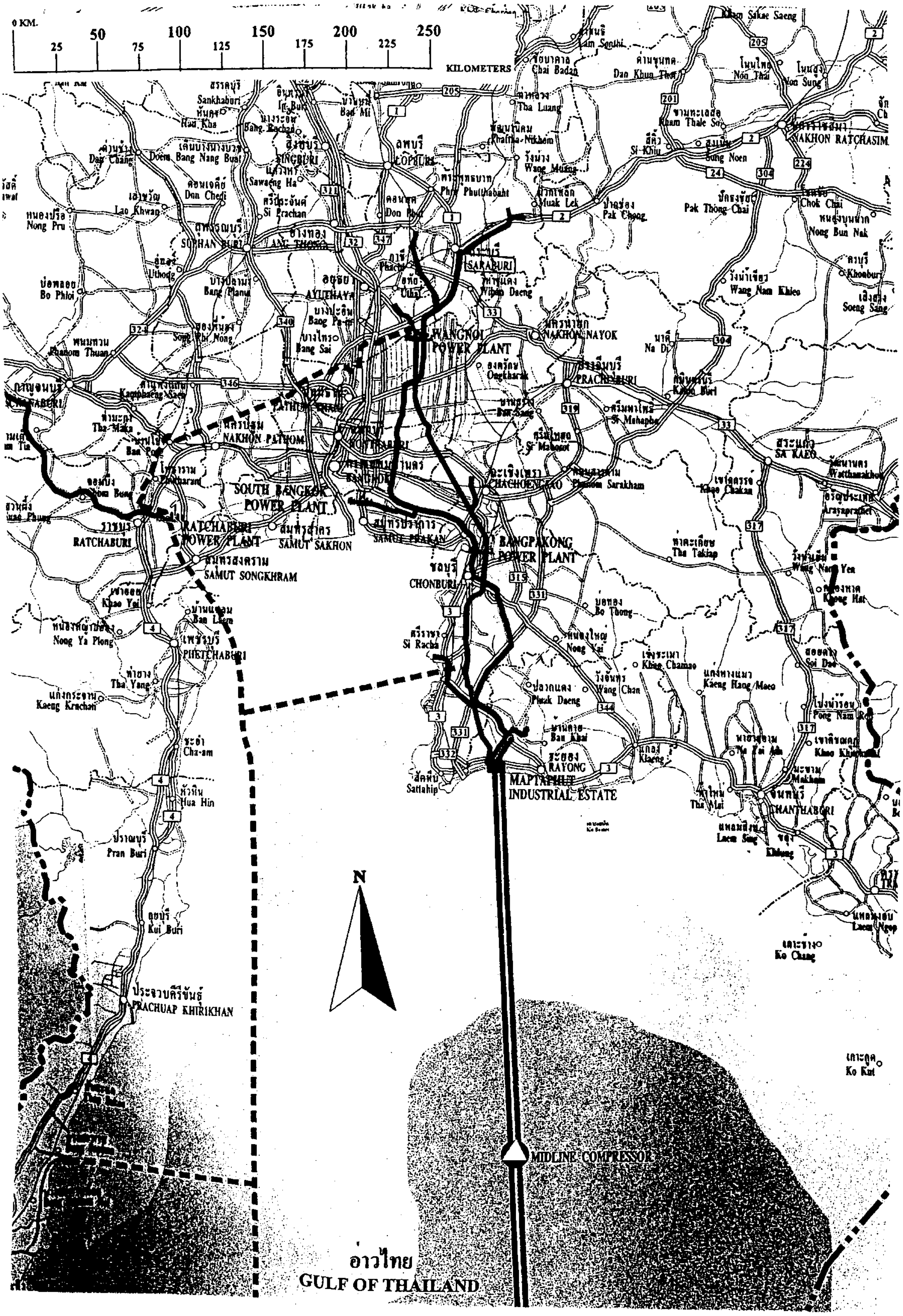


Fig.2-1-2 Cement plant and industrial park locations in Sara Buri area
(Source: made based on the PTT Gas pipeline network map)

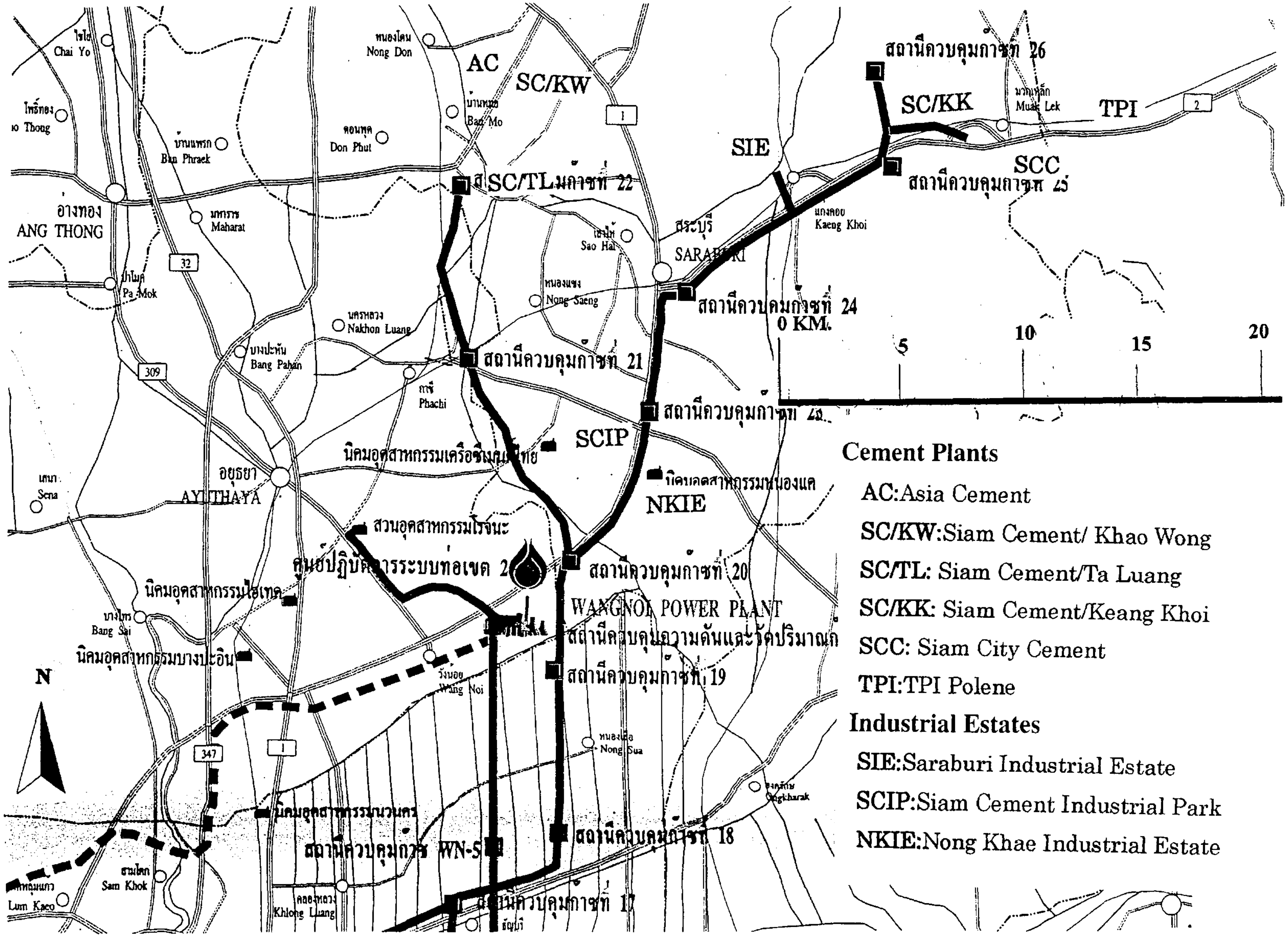


Fig.2-1-3 Cement plant and industrial park locations in Sara Buri area

(Source: made based on the PTT Gas pipeline network map)

Section 2 Outline of Siam Cement Industry

• Siam Cement Public Company (SCC)

SCC was established in 1913 by an Imperial edict issued by Rama VI in order to ease the country's dependence on imported cement, one of the fundamental construction materials, and to effectively utilize domestic resources.

Today, as the largest conglomerate in Thailand, SCC deals in more than 20,000 types of products and has over 27,000 employees under nine intermediate holding companies.

Intermediate Holding Companies:

①. Cement (SCI: Siam Cement Industry Co., Ltd.),
②. Petrochemicals,
③. Pulp and paper manufacturing,
④. Roofing and concrete,
⑤. Ceramics,
⑥. Gypsum boards,
⑦. Sales and import of construction materials,
⑧. Tires,
⑨. Holding companies (more than 50 subsidiary companies, including steel, auto parts, electrical products (CRT, etc.), construction and agricultural machinery, etc.)

Among these companies, SCC regards the three industries comprising cement, petrochemicals and pulp and paper manufacturing as its core businesses.

• Siam Cement Industry (SCI)

As the core company of SCC, SCI accounted for 24.8% of SCC's turnover in 1997, and 24.1% of its profit (EBITDA). The leading company in the Thai cement industry, it produces 23 million metric tons of gray cement per year, or 42% of the gray cement production capacity in Thailand, which stood at 55 million metric tons in 1999.

After the currency and economic crisis, the entire company was restructured to reinforce its competitiveness by dividing its cement manufacturing department into five companies.

①. Siam Cement (Ta Luang): Ta Luang Factory and Khao Wong Factory
②. Siam Cement (Keang Khoi)
③. Siam Cement (Tung Song)
④. Siam Cement (Lampang)
⑤. Siam White Cement (SWCC)

① and ②, which are located in Saraburi Province, supply cement to the large consumer cities in the central part of Thailand. 3 is located in Nakornsrithammarat Province and targets the southern part of Thailand; 4, located in Lampang Province, targets the northern part. 5, the subject of the present research, is attached to the Khao Wong Factory of Siam Cement (Ta Luang), and produces white cement, a high-quality product.

Table 2-2-1 shows the production capacities of SCI companies.

Table 2-2-1 Production Capacities of SCI Companies

Company	Location	Clinker production capacity (T/D)	Annual production (1999) (Million T/year)
Siam Cement (Ta Luang)	Ta Luang, Saraburi Province	2 × 4,000	7.00 G
	Khao Wong, Saraburi Province	1 × 10,000	
Siam Cement (Keang Khoi)	Keang Khoi, Saraburi Province	2 × 4,000 2 × 5,500	7.26 G
Siam Cement (Tung Song)	Tung Song, Nakornsrithammarat Province	2 × 500 1 × 1,000 1 × 3,000 1 × 5,500 1 × 7,500	6.33 G
Siam Cement (Lampang)	Lampang, Lampang Province	1 × 5,500	2.04 G
Siam White Cement	Khao Wong, Saraburi Province	2 × 220	0.15 W
計	—	—	22.72

Note 1: indicates the plant researched here.

Note 2: G means gray cement (ordinary cement), while W means white cement.

Source: data supplied by SCI

• Khao Wong Factory of Siam White Cement (SWCC)

The Khao Wong Factory of SWCC is on the same premises as the Khao Wong Factory of Siam Cement (Ta Luang). There are two lines of white cement manufacturing systems. Its clinker production capacity of 140,000 T/Y and cement production capacity of 150,000 T/Y are the largest in Thailand.

Figure 2-2-1 illustrates the corporate structure. The company has 73 employees. Siam Cement (Ta Luang) has 701 employees comprising Ta Luang Factory and Khao Wong Factory.

Among them, 104 workers are assigned to the ordinary cement manufacturing department of Khao Wong Factory.

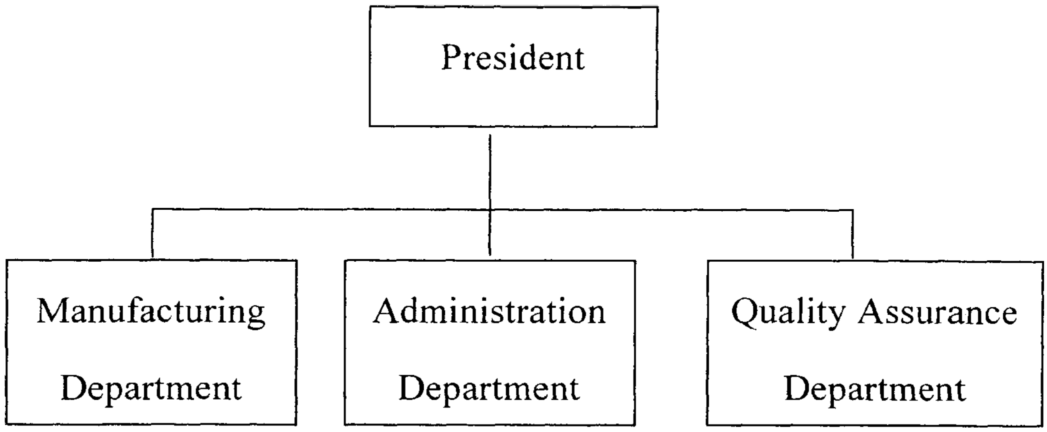


Figure 2-2-1 Organization Chart of Khao Wong Factory of Siam White Cement Company (SWCC)

2-2-1 Issues and plans of Siam Cement Industry

In and after the financial crisis in 1997, the cement industry in Thailand suffered from a drastic fall in demand. Siam Cement Industry was not excepted. It has been making every effort to reduce production costs to reinforce its corporate competitiveness. Particularly among high energy consuming companies in the cement industry, reduction of energy costs is a priority issue.

SCI has already taken the following measures to cut energy costs.

1. Measures to reduce electric charges:
   - Electric charges are cut by introducing the "Time of Use" system
   - Receiving Voltage was changed to 115KV (Lower charges are applied to higher voltages)
2. Measures to reduce fuel costs
   - Inexpensive petroleum coke has been used instead of heavy oil (HFO) (since 1999)
   - Attempts are made to use waste engine oil and waste tires
   - Inexpensive imported coal is used instead of lignite

SCI has organized a system to examine its energy saving strategies, mainly at the Energy Section, Engineering Division. A new company related to energy conservation has also been established. SCI has shown great interest in Japanese waste recycling and zero emission practices. Following from this, we have researched the suggestions proposed by SCI, and SCI in turn will be highly interested in verifying the results of our research.

2-2-2 Related Facilities at Siam Cement Industry

(1) History of the White Cement Plant

SCI has been manufacturing white cement since 1971. In this phase of the project, part of the ordinary cement manufacturing system in the Bangsue Factory was switched to white cement production. As a result, its capacity was around 25,000 metric tons/year.

The white cement plant was built in the Khao Wong Factory and began operation in 1982. Later, the facilities for white cement production at the Bangsue Factory were gradually closed down, with the Khao Wong Factory taking over exclusive production. The plant has been modified and expanded as follows (Photo 2-2-1):

1982: The first white cement plant system is built and begins operation at its full capacity of 50,000 metric tons/year.

1990: A preheater is introduced for a modification from the wet style to the dry style, increasing capacity to 70,000 metric tons/year.

1992: A second white cement plant system is added and begins operation at its capacity of 70,000 metric tons/year.

The plant's current official production capacity is 140,000 metric tons/year of clinker and 150,000 metric tons/year of cement. SCI supplies two kinds of white cement to the domestic market: “Elephant” brand, which meets the Thai standard, and “Tiger” brand, for universal application. These two brands and clinker are exported mainly to Asian nations. Although the exported quantity fluctuates annually in relation to domestic demand, exports account for about 20%–50% of production.

(2) Operation at the White Cement Plant

1) General operating conditions

The plant is properly managed in accordance with the rules for production line operation and maintenance. As Table 2-2-2 shows, its operation rate is high.

In addition, the plant is appropriately swept and everything is in order. It is clean for a cement factory.

The plant has two production systems, each of which has a daily production capacity of 220 metric tons. Both systems are normally in operation. However, only one system is used for production adjustment according to the cement demand.

To reduce production costs, the factory is examining two drafts: the energy-saving approach proposed in this project, and a fuel shift approach away from the heavy oil (the main fuel used at present) to inexpensive alternatives. This year they started examining the former approach seriously, in expectation of the results of this report. In the latter, they tried mixing petroleum coke, cracker bottom (cracked heavy oil) and other alternatives with heavy oil and have been examining the results since last year. Currently, they are under pressure to consider implementing the shift to petroleum coke that was examined.

In addition, they are willing to utilize waste as fuel. They have already begun to examine whether waste can be supplied in quantity from areas around the factory.

The standards established at this plant have been authorized as compliant with ISO 9002 and ISO 14001, international standards for quality and environmental management, respectively. Recently, Total Productive Maintenance (TPM) activity has been initiated. Various improvement activities have been implemented in line with these initiatives.

2) Features of White Cement Manufacturing

The main feature that gives white cement commercial value is its whiteness. Ensuring whiteness is the most important factor in its manufacture. Therefore, it is essential to minimize the content of metals such as iron oxide (Fe_2O_3), as these are the cause of the coloring of the product. It is also necessary to prevent their oxidation and coloring during the manufacturing process.

Elimination of the Cause of Coloring

At the plant, they are making a great effort to prevent coloring during manufacture of the white cement; they select and use raw materials with a low iron content; adopt special materials for the cement mill crushing liner and bowl to prevent metal ingredients from contaminating the material; and have replaced the air cooling used in the ordinary gray cement production process with rapid cooling measures such as direct water spraying and water soaking in the clinker cooling process in order to prevent oxidation of the metal content.

Cooling of Clinker

Raw materials with a low iron content are hard to bake. Clinker baking requires a high temperature, which results in increased calorie consumption. Unlike the gray cement manufacturing process, the direct cooling approach with water produces a loss in that generated heat retained by the clinker cannot be recovered with cooling air. In addition, cement made from hard-baked crushed clinker and clinker cooled with water require pulverizing to ensure strength. Consequently, the fuel and the power consumed in the manufacture of white cement are much greater than those consumed in the production of regular cement.

As shown in Table 2-2-2. Five-Year Trend of Operations, the fuel consumption is approximately 1,420 kcal/kg of clinker, and the power consumption is approximately 176kWh/t of cement. Compared with the energy consumption of the regular (gray) cement process (700-800 kcal/kg-clinker and

100-120kWh/t-cement), the values of white cement are significantly larger even when one allows for the higher costs of manufacturing white cement due to its small production scale. White cement manufacturers have strong expectations for reducing these values.

3) Operation Achievements

Table 2-2-2 shows data indicating the operation achievements, the production, running achievements, the fuel consumption and other elements during the past five years.

Excluding the adjustment due to stagnant demand, production has been stable. Compared with the roughly 300 days of operation per year of ordinary cement factories, this plant's 322 days in 1995 is a significant improvement. This implies that the potential capacity is great.

Cement production for 1995 and 1999 was less than clinker production because of the export of clinker. The usage of petroleum coke and clinker bottom presented in "Fuel Consumption" in 1999 indicates that mixed burning was partially carried out in the effort to shift fuel.

Table 2-2-2. Five-Year Trend of Operations

<table>
<tr><th>Year</th><th>Cement production (t/y)</th><th>Clinker production (t/y)</th><th>Rate of operation (% ; t/y)</th><th>Fuel consumption (t/y)</th><th>Power consumption (kWh/t-opc)</th></tr>
<tr><td>1995</td><td>126,854</td><td>150,648</td><td>88.35; 322</td><td>21,107</td><td>174.80</td></tr>
<tr><td>1996</td><td>135,899</td><td>115,723</td><td>67.54; 247</td><td>16,165</td><td>178.17</td></tr>
<tr><td>1997</td><td>145,604</td><td>138,040</td><td>81.50; 297</td><td>19,690</td><td>174.14</td></tr>
<tr><td>1998</td><td>108,473</td><td>98,728</td><td>65.74; 240</td><td>14,851</td><td>180.01</td></tr>
<tr><td>1999</td><td>109,465</td><td>117,251</td><td>70.92; 259</td><td rowspan="3">17,030
P.C.; 199
C.B.; 214</td><td>172.66</td></tr>
<tr><td>Total</td><td>626,295(t)</td><td>620,390(t)</td><td>1,365(d)</td><td rowspan="2">5-year average: 175.9</td></tr>
<tr><td>Average</td><td colspan="3">Cement: 459 metric tons/day,
Clinker: 454 metric tons/day</td></tr>
</table>

HFO: Heavy oil; P.C: Petroleum coke; C.B: Cracker bottom; opc: Cement

4) Unit Requirements of Raw Material and Energy

Table 2-2-3 shows the achievements for unit requirements of raw material, fuel, and power per kilogram of clinker. As for the fuel unit requirement, the value calculated based on the fuel consumption at the operation room during the survey is indicated as the achievement in the survey.

Table 2-2-3. Unit Requirements Achieved

		In 1999	In the survey
Raw material unit requirement	Kg/kg-clinker	1.56	—
Fuel unit requirement	Kcal/kg-clinker	1,431.46	1,420
Power unit requirement	KWh/t-cement	172.66	—

(3) White Cement Manufacturing Process and Specifications of Major Equipment

Figure 2-2-2 illustrates the flowchart of the existing white cement plant. The manufacturing process and major equipment are outlined as follows.

1) Raw Material Receiving Department

The raw materials used in the manufacture of white cement clinker are limestone, pyrophyllite and white sand. They are individually delivered to the plant by truck, dumped into the receiving hoppers, and immediately supplied to the raw mill storage silos or the outdoor storage yards.

Gypsum is also used in a mixture with clinker and is crushed in the cement mill in order to adjust the cement hardening time.

Table 2-2-4 shows the types of storage and amounts of raw materials.

Table 2-2-4. Raw Material Storage Facilities

	Limestone	Pyrophyllite	White sand	Gypsum
Storage	Silo outdoor yard	Silo outdoor yard	Silo outdoor yard	Hopper
Amount (metric tons)	2000	2000	600	140

Due to its large grain size, limestone is coarsely crushed with the crusher in the plant prior to storage. The specifications of the limestone crusher are as follows.

Limestone Crusher

Purpose:	Primary crushing	Secondary crushing
Type:	Jaw type	Impact type
Capacity:	50t/h	50t/h
Motor:	90kW	110kW

All the materials contain relatively small amounts of water, and no equipment is available for drying after crushing. A common receiving department is provided for Lines No. 1 and No. 2. The two lines start at the outlet of the storage silo.

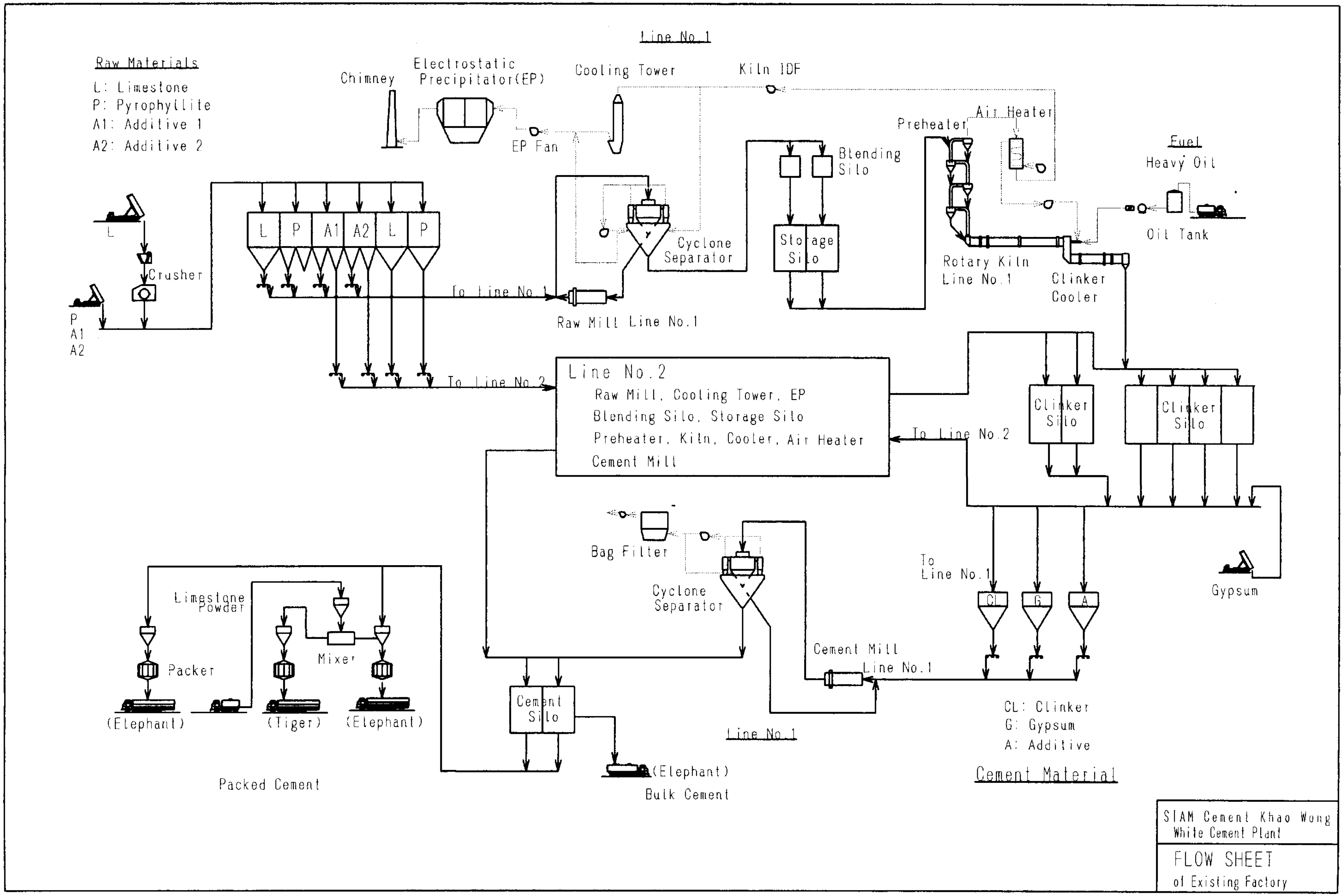


Fig. 2-2- 2 Process flow before modification

2) Raw Mill and Exhaust Gas Treatment Department

For drying, raw materials are fed from the storage silo in the raw material mixture management ratios by a feeder equipped with a belt-style meter. They are then sent to the cyclone separator together with the circulating material from the mill outlet. The kiln exhaust gas is supplied to the separator, which sorts the air as a drying heat source. The flue gas is treated with an electric precipitator and released into the atmosphere from the stack after being used for drying.

A closed-circuit crushing system with a ball mill is arranged for crushing of the raw materials. The system manufactures products with a wide variety of grain sizes by using a sorting separator.

Refined powder sorted by the separator is fed as kiln feed material to the raw material mixing silo in the next process. On the other hand, the rough powder is returned to the mill for re-crushing. Here, a circulating flow is established.

Generally, the drying system using the gas for sorting in the separator as a heat source has simpler equipment than does the conventional system using the dryer. It is more efficient in terms of labor saving and maintenance owing to its lower water content.

The dust collected by the electric precipitator is fed to the cyclone separator along with the materials supplied and circulated. Dust is transferred to the mixing silo in Line No. 1, and can be switched to feed to the next step after the kiln supply meter in Line No. 2.

The processes of the two systems in this department, Line No. 1 and Line No. 2, are the same. The main specifications of the raw material crushing equipment and the exhaust gas treatment equipment are as follows.

Raw Material Crushing Equipment

Line:	No.1	No.2
Crushing type:	Closed circuit/exhaust gas drying	Closed circuit/exhaust gas drying
Capacity:	14t/h (4% on 88μ screen)	21.5t/h (4% on 88μ screen)
Mill type:	Dual-chamber tube mill	Dual-chamber tube mill
Mill dimensions:	2.1mD x 7.8mL	2.6mD x 11.3mL
Drive:	Side, 365kW x 1	Side, 900kW x 1
Separator:	Cyclone separator	Cyclone separator

Exhaust Gas Treatment Equipment

Line:	No.1	No.2
Type:	Electric precipitator	Electric precipitator
Treatment capacity:	620 Nm^3/min.	896 Nm^3/min.
Gas temperature:	130°C	127°C
Dust content (inlet/outlet):	-/-	80/0.06g/Nm^3 (dry)
EP fan:	1300 Nm^3/min x 150 mmAq	1550 Nm^3/min x 150 mmAq
Motor:	65kW x 4P	75kW x 4P

3) Raw Meal Mixing and Storage Department

The crushed materials are sent to two mixing silos, where the constituents are made uniform.

The materials are mixed with low-pressure compressed air blown from the silo bottom. The materials are added, mixed and discharged in batch style, in other words, in each silo in turn.

The mixed raw meal is stored in the storage silos below each mixture silo. At the same time, the set quantity is apportioned in response to kiln operation by the belt-type meter for supply to the next process.

This department has two systems, Line No. 1 and Line No. 2, both of which have the same processes. The major specifications of the raw meal mixing equipment and the raw meal storage facility are outlined below.

Line:	No.1	No.2
Raw Meal Mixing Equipment		
Type:	Batch type/Manufactured by RC	Batch type/Manufactured by RC
Capacity:	75t x 2	200t x 2
Mixing air:	Roots blower x 2	Roots blower x 2

Raw Meal Storage Facility		
Line:	No.1	No.2
Type:	Manufactured by RC	Manufactured by RC
Capacity:	675t x 2	675t x 2

4) Clinker Manufacturing Department

The white cement clinker manufacturing system consists of a preheater, rotary kiln, air heater, combustor, clinker cooler and other components.

Figure 2-2-3 is a flowchart of the Clinker Manufacturing Department. This department also has two lines, No. 1 and No. 2, featuring the same processes.

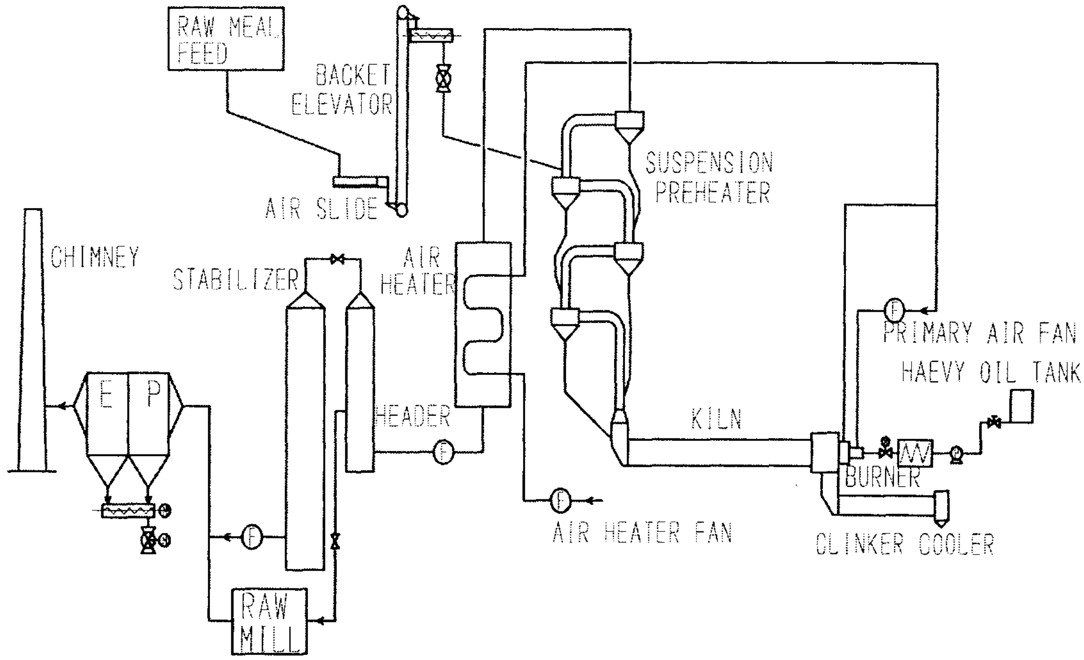


Figure 2-2-3. Flow chart of the Clinker Manufacturing Department

The preheater is a suspension preheater (SP), which comprises four stages of air heat exchangers (cyclones) connected longitudinally.

The suction of the exhauster following the preheater draws the flue gas from the kiln flow from the lower stage to the upper stage of the cyclone. By this arrangement, the raw meal supplied to the front of the top-stage cyclone is carried in the flue gas, and exchanges heat efficiently as it falls and is recovered by the cyclone. The raw meal is heated (preheated) to around 800°C at the kiln inlet.

The main specifications of the preheater are indicated below, and the appearances of the preheater, the air heater, the electric precipitator and the chimney are shown in Photo 2-2-2.

Preheater

Line:	No.1	No.2
Type:	4-stage SP (Suspension preheater)	4-stage SP
Capacity:	240t/h-clinker	240t/h-clinker
Diameter of the cyclone (mm):	1st/2nd/3rd/4th/stages 2410/2540/2660/2660	1st/2nd/3rd/4th/stages 2410/2540/2660/2660
Dimensions of the tower:	8.5mW x 8.5mL x 34.4mH	8.5mW x 8.5mL x 34.4mH
Exhauster:	1000 Nm^3/min x 1050 mmAq	1000 Nm^3/min x 1050 mmAq
Motor:	280kW x 4P	280kW x 4P

The heated powder is transferred from the preheater to the rotary kiln, where it is calcinated and baked into clinker. The red-hot clinker is put into the clinker cooler, which has a reduced atmosphere. After being cooled to around 130°C with a water spray, it is sent to the clinker silo and stored there.

The major specifications of the rotary kiln and the cooler are indicated below, and the appearance of the kiln is shown in Photo 2-2-3.

Rotary Kiln

Line:	No.1	No.2
Type:	SP kiln	SP kiln
Capacity:	240t/h-clinker	240t/h-clinker
Dimensions:	2.5mD x 89.6mL	2.5mD x 89.6mL
Number of supporting points:	3	3
Slope:	3.5/100	3.5/100
Number of revolutions:	Max. 1.8rpm	Max. 1.8rpm
Motor:	30kW-DC	30kW-DC

Cooler

Line:	No.1	No.2
Type:	Rotary cooler	Rotary cooler
Capacity:	240t/h-clinker	240t/h-clinker
Dimensions:	1.8mD x 18.2mL	1.8mD x 18.2mL
Outlet temperature:	80°C	80°C

Heavy oil is the main fuel used to bake the clinker. The heavy oil is pressurized and heated to a pressure and temperature suitable for combustion by the pump/heating unit and sent to the kiln burner. Combustion air for the kiln is heated by the air heater with the flue gas from the preheater and is sent to the burner.

The kiln (preheater) flue gas used for drying in the Raw Mill Department mentioned in 2) is the gas that has passed through the air heater mentioned above. When the raw mill is not operating, the air is routed to the damper after the air heater. It goes to the stabilizer, not to the raw mill. After being cooled with water spray, it is sent directly to the electric precipitator for treatment. It is released into the atmosphere from the stack.

5) Clinker Storage Department

This department, with six clinker silos, is common to both Lines No. 1 and No. 2 in the preprocess and the post-process. For the clinker from Line No. 1, four silos can be selected for storage, while six silos can be selected for the clinker from Line No. 2. With both lines, the clinker can be taken out to allow for removal of defective clinker from the system before storage in the silo or outdoor storage. The main specifications of the clinker silo are as follows.

Clinker Silo

Number:	6 units
Type:	Manufactured by RC
Capacity:	1,150 metric tons (per unit)

The clinker removed from the silo is sent to the cement mill feed hopper for supply. It can also be taken out of the course for loading onto the truck in bulk and transportation out of the factory.

Gypsum is delivered from outside and dumped into the receiving hopper. It is then supplied to the mill feed hopper by the clinker carrier.

From the cement mill feed hopper, the next process is divided for Line No. 1 and Line No. 2.

6) Cement Mill Department

Cement is crushed in a closed circuit with a dual-chamber ball mill equipped with a cyclone separator. The mill liner and the bowl are made of special materials to prevent contamination by iron and chrome from the crushing media.

Clinker, gypsum and a small amount of limestone added as an admixture are measured out from the material feed hoppers in specified ratios by the belt meters. They are supplied to the cement mill inlet.

The refined powder sorted by the cyclone separator is sent to the cement silo as a product, while the rough materials are returned to the mill for re-crushing. This is a circulating system. In addition, to prevent the cement temperature from rising, outside air is introduced to the cyclone separator for cooling and a cooling water spray is provided in the cement mill. Part of the sorting air is recycled, while the hot air not recycled is treated for dust removal by a bag filter before being released into the atmosphere.

This department has two lines, Lines No. 1 and No. 2, which have the same processes. The main specifications of the cement crushing equipment are shown below.

Cement Crushing Equipment

Line:	No.1	No.2
Crushing style:	Closed circuit style	Closed circuit style
Capacity:	11t/h-clinker (3600cm^2/g)	11t/h-clinker (3600cm^2/g)
Type of mill:	Dual-chamber tube mill	Dual-chamber tube mill
Dimensions of mill:	3mD x 10mL	3mD x 10mL
Drive:	Side drive, 550kW x 1	Side drive, 550kW x 1
Separator:	Cyclone separator	Cyclone separator

7) Cement Storage and Shipment Department

The cement sent from the cement mill is stored in two cement silos. The major specifications of the cement silo are as follows.

Cement Silos

Number:	2 units
Type:	Manufactured by RC
Capacity:	2,000 metric tons (per unit)

The cement taken out of the silo is shipped in bags or in bulk as "Elephant" brand white Portland cement. Part of the cement from the silo is mixed with about 30% limestone for shipment in bags as "Tiger" brand white mixed cement.

One 100 metric ton hopper is provided for storage of the "Tiger" brand white cement, and one 120 metric ton hopper is provided for limestone powder.

Three bagging devices are installed: two for the "Elephant" brand, and the other in combination with a mixer to mix limestone for the "Tiger" brand. Each bag weighs 40 kg. One bulk loader is provided for the "Elephant" brand.

8) Electricity and Control Department

Power is supplied directly to the white cement plant from the Provincial Electrical Authority (PEA) in the Khao Wong area of Saraburi. It is not connected to the gray cement plant, which has another system on the same premises as the Khao Wong Factory. The specifications of the power supply and the power in the plant are as follows.

Power Supply

Power specifications:	22kV, 3 phases, 3 lines, 50Hz
Number of power supply lines:	1 line
Capacity of receiving transformer:	2500KVA + 2000KVA x 3

Power in the Plant

High-voltage power supply:	22kV, 3 phases, 3 lines, 50Hz
Intermediate-voltage power supply:	3.3kV, 3 phases, 3 lines, 50Hz
Low-voltage power supply:	380kV, 3 phases, 3 lines, 50Hz
Emergency power supply:	210kW, 380V AC (Diesel generator)
	110V DC (NiCad battery)
AC motor (Greater than 200kW)	3.3kV, 3 phases
AC motor (Less than 200kW)	380kV, 3 phases
DC motor	400V
Lighting	220V, 1 phase
Control (MCC)	380V
Control (Relay panel)	220V
Instrumentation	100V AC/48V DC

Power Supply System

The power received by the 22 kV switch in the plant from the PEA network is supplied to the transformers of Lines No. 1 and No. 2 in the cement manufacturing facility.

Each line has a high-voltage/intermediate-voltage (22 kV/3.3 kV) transformer and a high-voltage/low-voltage (22 kV/400-230 V) transformer. The former supplies intermediate voltage to the intermediate-voltage motors of the raw mill, the kiln draft fan and the cement mill. The latter supplies low-voltage power to the low-voltage motors, control panel, lighting panel, and other various loads.

The plant has a diesel generator and an emergency private power source using batteries from which power is supplied as necessary in case of emergency such as a blackout, security concern, or avoidance of breakage.

Figure 2-2-4 illustrates the power supply system.

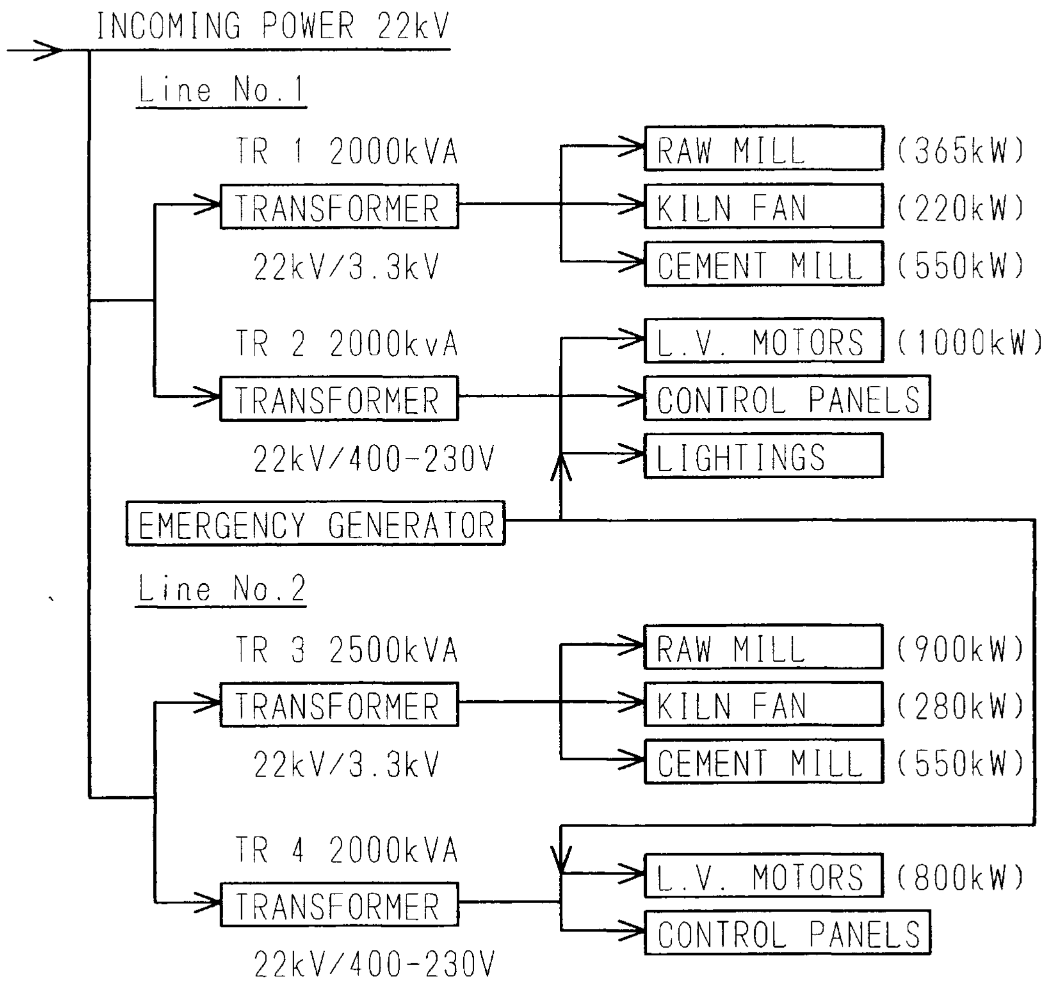


Figure 2-2-4. Power Supply System

Electricity Room

The following common electricity room contains the electrical equipment for Lines No. 1 and No. 2.

- Substation
- Raw material receiving/raw mill
- Clinker manufacturing
- Cement mill/shipping
- Electric precipitator

Operation Room

The following common operation room contains the controllers and instrumentation for Lines No. 1

and No. 2. The standalone control panel is equipped with a controller, instrumentation, a mimic panel and others, as well as independent lines.

- Raw material receiving/raw mill
- Clinker Manufacturing
- Cement mill/shipping

(4) Factory Layout

Besides its white cement plant, the Khao Wong Factory of Siam Cement Industry has a large standard cement plant with official production of 10,000 metric tons/day of clinker. This large plant dominates most of the premises of the Khao Wong Factory. The layout of the white cement plant alone is illustrated in Figure 2-2-5, as the layout of the entire factory is complex.

In the white cement plant, Line No. 1 is on the east side and Line No. 2 on the west side. In the center of the plant are two systems of rotary kilns, preheaters, and coolers of the clinker baking department arranged in parallel in a north-south orientation. On the south side between the two systems is provided the upstream process department with material crushing, mixing and storing processes. The downstream department is located on the north side, with its clinker storage and cement crushing processes. The manufacturing process, from raw materials to products, flows from south to north.

The air heater for recovering heat from the kiln flue gas, a feature of this factory, is installed beside the preheater on each line. The high-temperature kiln flue gas duct is minimized, and the heated combustion air at a lower temperature is transferred to the burner through insulated ducts.

An electric precipitator for final treatment of the exhaust gas is installed in parallel with the raw mill on each line. The layout easily accommodates either of two cases: treatment with drying kiln flue gas and treatment without drying.

The material receiving/rough crushing department and the cement storage/shipping department, which require access to the outside of the plant, are arranged as projections at the south and north ends on the east side of the plant. Access to the outside road is easy from both locations.

The white cement plant was built before the ordinary cement plant. Although it is small in scale, it is independent and compact having no materials, fuel, power or water in common with the other plant.

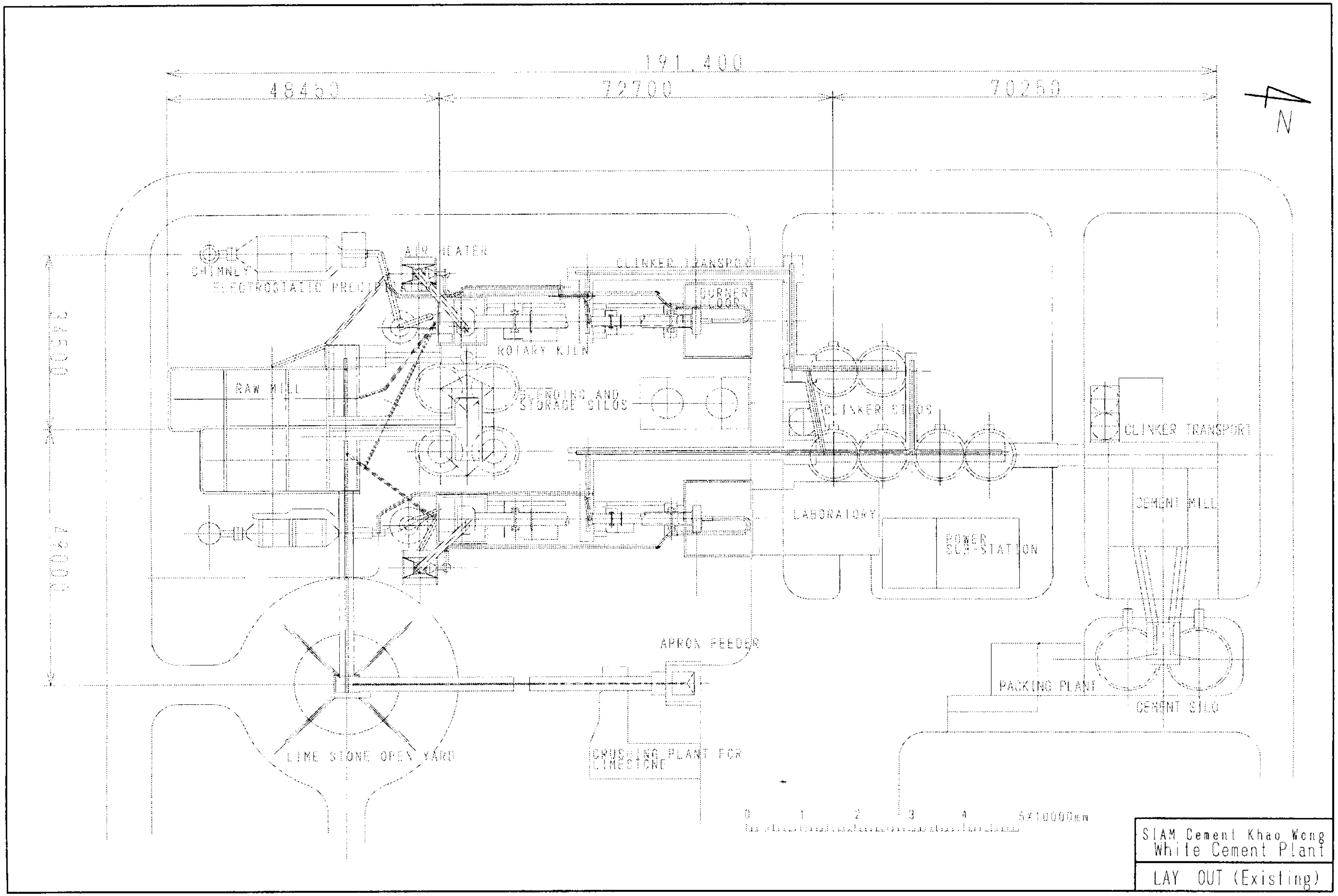


Fig. 2-2-5 Plant layout before modification

(5) Raw Materials for White Cement

1) Properties of Raw Materials

Table 2-2-5 shows the properties of the raw materials used in the manufacture of white cement — pyrophyllite, white sand and gypsum.

Table 2-2-5. Properties of Raw Materials for White Cement

		Limestone	Pyrophyllite	White sand	Gypsum
Grain size (maximum mm)		300	20	5	25
Moisture	Maximum (%)	1.50	3.15	8.38	4.50
	Average (%)	0.10	0.36	6.06	1.50
	Minimum (%)	0.04	0.12	4.31	1.00
Appearance		Gray	Gray	White	White
Supply (area)		From own mine (Saraburi)	Purchased (Saraburi)	Purchased (Rayong)	Purchased (Nakhon Sawan)

a) Among the above-mentioned materials, limestone, pyrophyllite and white sand are crushed by the raw mill. The powdered materials are supplied to the rotary kiln, where they are baked to become clinker.

Only gypsum is directly supplied to the cement mill, where it is mixed with clinker and crushed to become product.

b) In both mills, the standard grain size of the materials received is around 25 mm maximum. Limestone from the company's own mine is coarsely crushed to a maximum of 25 mm by the crushing equipment and is stored after being received. Other materials are purchased in small grain sizes, and they are supplied and stored as received.

c) In general, the water content of each material is low. Although white sand has a relatively high water content, no special devices are required for drying because of its low blending ratio. The sorting process of the separator, which uses kiln exhaust gas as a heat source, dries the material sufficiently.

2) Constituents and Blending of Materials

Table 2-2-6 illustrates the constituents of each material for white cement and its blending ratio.

Table 2-2-6. Constituents of Each Material and Blending Ratio

Constituent	Limestone	Pyrophyllite	White sand	Blended material	Gypsum
L.O.I	ッ	—	—	36.09	—
SiO_2	0.34	78.69	98.44	16.55	0.62
Al_2O_3	0.27	15.21	0.55	3.15	0.09
Fe_2O_3	0.03	0.14	0.02	0.08	0.03
CaO	54.85	0.37	0.00	44.35	32.04
MgO	0.65	0.05	0.01	0.59	0.13
SO_3	0.09		—		($CaSO_4$) (98.00)
Na_2O	0.05		—		
K_2O	0.05		0.04		
Cl					
Blending ratio	80.0	18.5	1.5	—	Approximately. 4% of clinker
			L.S.F.	88.7	
			S.M.	5.10	
			88μ on screen	3.65	

L.O.I: Loss of ignition
L.S.F: Lime saturation factor
S.M: Silica modulus

a) The most important issue for ensuring the whiteness of white cement is maintaining a low content of metal constituents (iron, etc.), which develop color through oxidation. Therefore, it is necessary to reduce the presence of Fe_2O_3 in the raw materials.

As Table 2-2-6 shows, the iron content (Fe_2O_3) of the raw material is 0.08%, while it is 0.12% in the clinker shown in Table 2-2-7. In ordinary gray cement, it is 2-3%. Compared with this value, this material is of sufficient quality for good whiteness of the white cement.

b) Raw materials containing little iron are difficult to bake in the clinker baking step. The result is high-temperature baking, which is one reason white cement manufacturing consumes more fuel than gray cement manufacturing.

As Table 2-2-6 also shows, the silica modulus (S.M.) is 5.1. The higher this value, the more difficult it is to bake the material. In ordinary gray cement, it is around 2.5. Compared with this, the material for white cement is harder to bake. (The silica modulus is calculated with a formula having the constituent value of Fe_2O_3 as a denominator. As the value of Fe_2O_3 becomes smaller, the silica modulus rises.)

c) About 4% gypsum is added to clinker in order to control the hardening reaction of cement before mixing and crushing by the cement mill. As the above table shows, gypsum with high purity and a low iron content is supplied.

(6) Constituents and Properties of White Cement and Clinker

Table 2-2-7 shows the chemical composition and nature of the products and clinker produced by this plant.

Table 2-2-7. Chemical Compositions and Properties of Cement and Clinker

Constituent		Clinker	Cement	
			Elephant	Tiger
L.O.I	%	0.64	1.83	
SiO_2	%	25.25	24.00	
Al_2O_3	%	4.67	—	
Fe_2O_3	%	0.12	0.08	
CaO	%	67.92	66.77	
MgO	%	0.03	0.82	
SO_3	%	0.44	2.09	1.50
Na_2O	%	0.01	0.04	
K_2O	%	0.02	0.09	
Cl	%	—	—	
L.S.F.		88.6	—	
S.M.		5.3	—	
Free lime		1.66	—	
Fineness: Blain (cm^2/g)			3640	3680
Pressure strength (kg/cm^2)		3 days	203	132
		7 days	287	178
		28 days	444	284
Whiteness		Hunter scale index	93	94-95

In this plant, two kinds of products are manufactured.

a) White Portland Cement: "White Elephant Brand"

This product, in which clinker is mixed with approximately 4% finely ground gypsum, conforms to the Thai standard, TIS 133-2518. Its strength is equivalent to that of ordinary Portland cement of the JIS standard, and its whiteness has commercial value.

This is the main product, which accounts for more than 80% of shipments. It is mainly used for terrazzo-finish panels and scrubbed-finish panels of sand/stone. It is also mixed with pigments for color-finishing.

b) White Mixed Cement: "White Tiger Brand"

This product, in which approximately 30% of finely ground limestone is mixed with the "Elephant" brand, is out of standard. Although its whiteness has sufficient commercial value, it is used mainly to embed ceramic tiles and finish joints.

(7) Utilities

1) Fuels

Tables 2-2-8 and 2-2-9 indicate the properties of the heavy oil currently used as the main fuel and the occasionally used petroleum coke.

Table 2-2-8. Properties of Heavy Oil

Type		ST.933	ST.934
Higher calorific value		10,385	10,322
Lower calorific value		9,650	—
Sulfur content		2.7	2.2
Density		0.9535	0.9425
Viscosity		204	180
Element analysis	C	84.6	84.5
	H	11.2	11.5
	N	0.17	0.23
	O	1.3	1.5

Table 2-2-9. Properties of Petroleum Coke

Type		4.5%S	Element analysis	
Total moisture upon receipt		9.00	C	87.42
Adhering moisture upon receipt		9.00	H	3.93
Higher calorific value		8547	O	0.61
Lower calorific value		8332	N	1.50
Industrial analysis	Internal moisture	0	S	4.60
	Ash content	1.60	Ash	1.50
	Volatile components	13.27		
	Fixed carbon	86.08		
Fuel ratio (fixed carbon/volatile components)		6.49		
Hard grove index (H.G.I.)		46-85		

In this plant, heavy oil has been used to achieve the whiteness of the product, unlike general gray cement factories that use coal and lignite.

Recently, however, the shift from heavy oil to inexpensive substitutes has become an issue. Since

Recently, however, the shift from heavy oil to inexpensive substitutes has become an issue. Since 1999, petroleum coke and cracker bottom have been partially mixed for burning in actual operation. At present, petroleum coke is being closely examined.

The issues related to a shift to petroleum coke include the effect on product whiteness, stability of supply and pricing, and technological issues for burning including storage, crushing, fine powder transport, and burner type. To solve these problems one by one and achieve implementation, Siam Cement Industry is also investigating white cement plants in Japan that use similar fuels.

2) Power

Table 2-2-10 shows the electric power specifications in the white cement plant.

Table 2-2-10. Power Specifications

Receiving power	22kV, 3 phases, 3 lines, 50Hz
Receiving (transformer) capacity	8500KVA
Drive power	380V (<200kW) 3300V (>200kW)
Emergency power	380V AC & 110V DC
Control (MMC) power	380V
Control (relay panel) power	220V
Instrumentation power	100V AC/48V DC

a) Power is directly supplied to the white cement plant from the network of PEA, the Provincial Electrical Authority, in the Khao Wong area of Saraburi. The power supply system is independent, and is not connected to the gray cement plant also on the premises of the Khao Wong Factory.

b) Power supply has been stable without a lack of quantity and fluctuating quality. That is proved by the fact that the modern gray cement plant operates smoothly at its official production capacity of 10,000 metric tons/day of clinker.

c) A 210kW diesel generator is provided for private power generation. This is for lighting and powering the motor to avoid damage in the event of an emergency.

d) For other electrical items, see 2.2.2 (3) 8) Electricity and Control Department.

3) Cooling Water

Table 2-2-11 shows the quality of groundwater for cooling.

Table 2-2-11 Properties of Cooling Water

PH	8.1
Total hardness (ppm)	74
Chlorine ions (ppm)	—
Sulfide ions (ppm)	—
Suspended solids (ppm)	92
Turbidity (NTU)	2.23
Total dissolved matter (ppm)	380

a) The source is groundwater, which is stored in a reservoir. No water quality problem was indicated by the factory. As the above table shows, it is good quality water.

b) Cooling water is circulated at a rate of approximately 80 metric tons/hour.

4) Compressed Air

Table 2-2-12 shows the specifications of compressed air. Compressors that supply compressed air to the plant are centralized for bug filters and general cleaning.

Table 2-2-12. Specifications of Compressed Air

Compressor	Capacity (m^3)	33.4
	Pressure (kg/cm^2G)	6.0
	Temperature (after drying) (°C)	40.0
Receiver	Capacity (m^3)	7.0

(8) Quality Control

A test room for white cement manufacturing is located in the center of the plant for quality control according to the ASTM standard. Table 2-2-13 indicates the sampling methods for materials and product cement.

Table 2-2-13. Sampling Methods for Quality Control

Sample name	Materials received	Crushed material	Material added	Cement
Sampling spot	Receiving hopper	Mill product outlet carrier	Kiln inlet carrier	Mill product outlet carrier
Sampling frequency	Frequency of receipt	Every hour	Every hour	Every 2 hours

Quality control standard: ASTM Standard

Daily analysis: Fluorescent X-ray spectroscopy

(9) Environmental Conditions Surrounding the Khao Wong Factory

To monitor the atmospheric conditions around the factory, the Quality Control Division of the Technological Bureau of Siam Company measures the ambient air quality regularly at six specified measuring spots. The data are released publicly. Measurement results in recent years are indicated in Table 2-2-14. The table shows that the atmospheric conditions around the factory largely satisfy the environmental standard.

Table 2-2-14. Results of the Measured Ambient Air Quality

around Khao Wong Factory

mg/m³

Measuring location	Location from the factory	Item measured	First half of 1999	Latter half of 1999	First half of 2000	Environmental standard (average of 24 hours)
Ban-Nong Pa-pong	1 km east	TSP	0.098	0.254	0.176	TSP 0.33
		SO_2	0.031	ND	ND	
Ban Woung	2 km west northwest	TSP	0.209	0.253	0.328	
		SO_2	0.031	ND	ND	SO_2 0.30
Ban-Khao Wong	3 km southwest	TSP	0.106	0.227	0.215	
		SO_2	0.026	ND	ND	
Ban-Mong Fay	3 km south	TSP	0.098	0.085	0.123	
		SO_2	0.037	0.036	ND	
Ban-Na-Pra-Lan	3 km northeast	TSP	0.329	0.462	0.198	
		SO_2	0.027	ND	ND	
KW Employee's House	1 km east southeast	TSP	0.074	0.148	0.090	
		SO_2	0.047	0.002	0.002	

Note 1: Measured values are the average of values measured seven times.

Note 2: NOx is not measured.

Source: Khao Wong Factory records

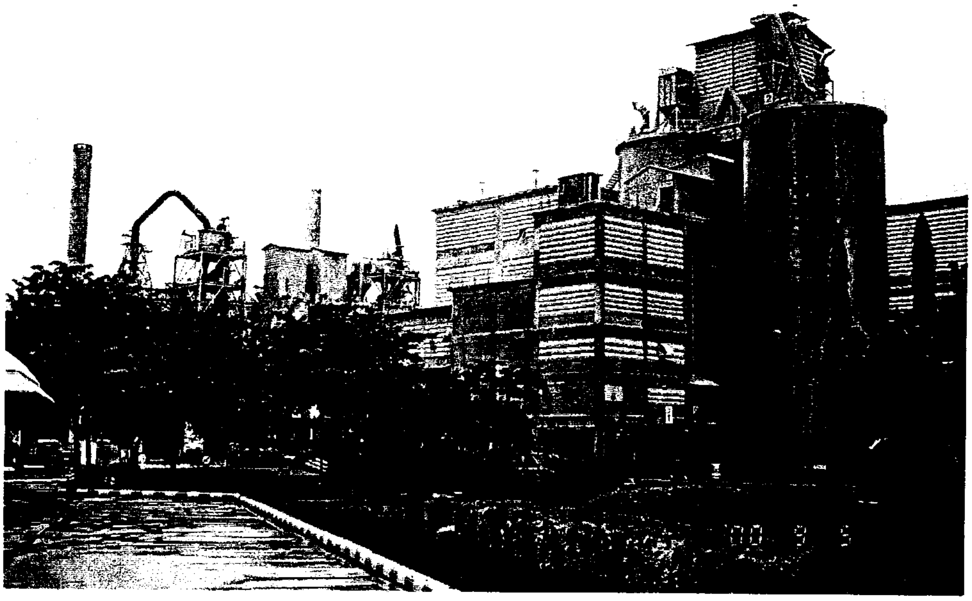


Photo 2-2-1 Whole view of White cement plant

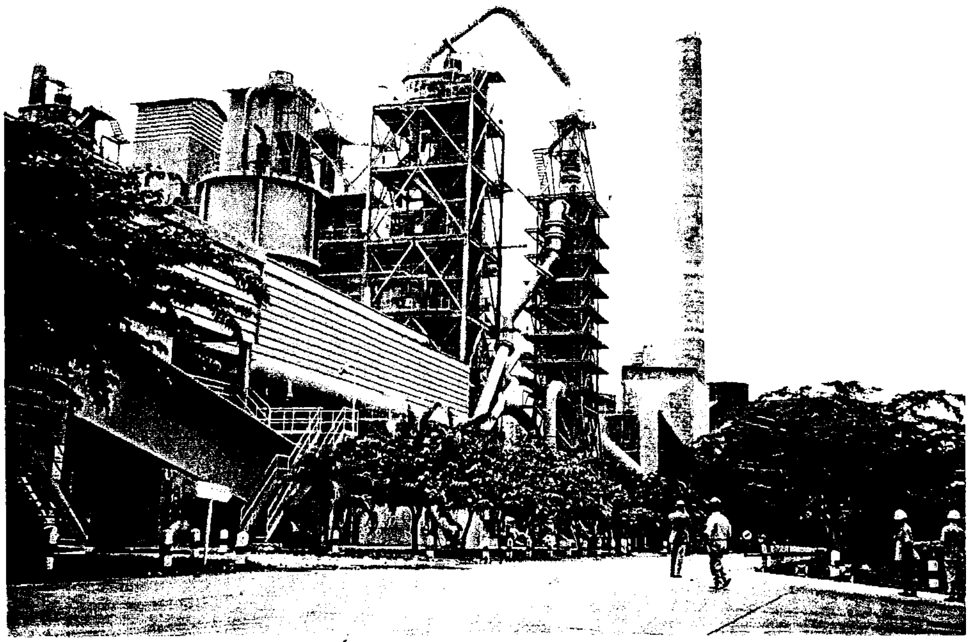


Photo 2-2-2 Preheater, Air Heater, EP and Stack(LineNo.2)

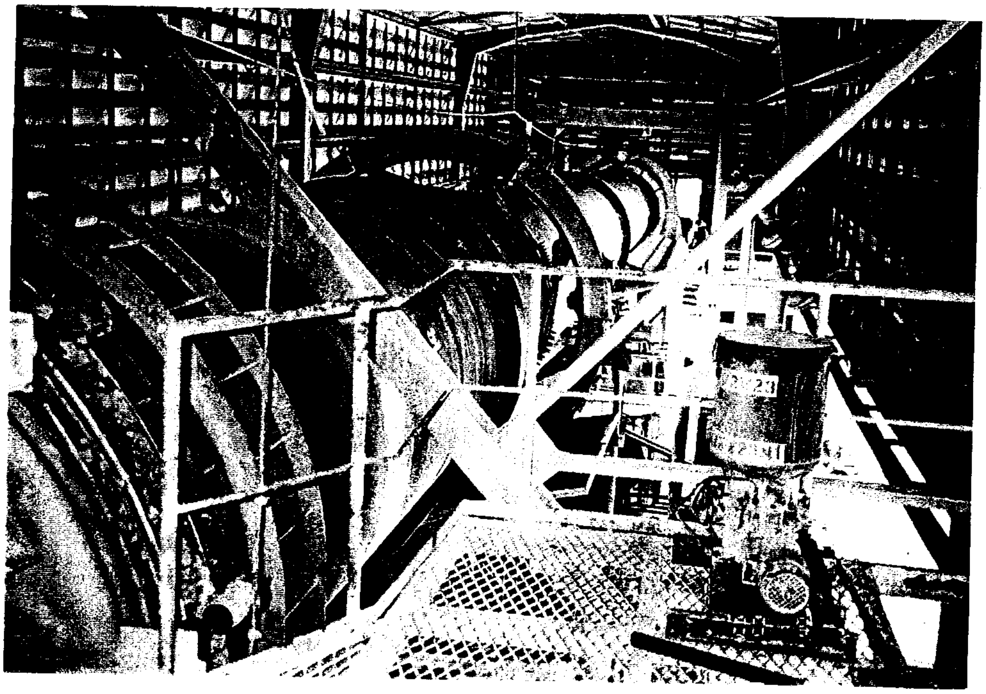


Photo **2-2-3** Rotary kiln

2-2-3 SCI's Capability to Fulfill the Project

(1) Technological Capability

Siam Cement Industry (SCI) is a leader in the Thai cement industry. The company demonstrates excellent plant management and operation control.

The second white cement manufacturing process (which began operation in December 1992) was organized by SCI according to drawings provided by a Japanese manufacturer. Their capabilities are sufficient to handle a project in which an overseas engineering company provides a master plan and engineering work. They are capable of designing equipment and having it manufactured in Thailand if it does not require advanced technologies.

Electric power companies in Thailand Gas introduced gas turbine generation more than 10 years ago. The country maintains a technological background in the operation and maintenance of the necessary equipment.

As mentioned in 2-2-1, SCI has been working hard to reduce energy costs and conserve energy in production, and they have made good progress in this area.

The following external awards and certificates prove that the entire company has been eagerly addressing plant management, product quality and environmental issues, and that their efforts have borne fruit.

Awards and Certificates from the Ministry of Industry (1999)

- Ta Luang Factory, Siam Cement Industry (Ta Luang)
  - Award of Excellence in Industrial Management and Exporting
  - Certified as compliant with ISO 14001, the standard for environmental management systems (May 1997)
  - TIS18000-Certified (April 2000)
- Khao Wong Factory, Siam Cement Industry (Ta Luang)
  - Honorary Award for Most Excellent Factory (Grade AA)
  - Certified as compliant with ISO 14001, the standard for environmental management systems (April 1999)
  - TIS18000-Certified (December 2000 expected)
- Siam Cement Industry (Keang Khoi)
  - Honorary Award for Most Excellent Factory (Grade AA)
  - Certified as compliant with ISO 14001, the standard for environmental management systems
  - Certified as compliant with ISO 14001, the standard for environmental management systems, by LMPA Sachsen, Germany

- Siam Cement Industry (Keang Khoi)
  - Certification of the German Cement Quality Standard (for four products)

From these facts, we have determined that SCI is technologically capable of carrying out this project.

(2) Management System

The energy conservation project will be managed by the engineering department of Siam Cement Industry (SCI), the parent company of Siam White Cement Company (SWCC). Figure 2-2-6 illustrates its organizational chart. Under this organization, the Energy Section will undertake management, the Quality Control Section will cooperate in environmental and safety areas, the Plant Engineering Section will oversee the manufacturing process, and the Civil Engineering and Construction Section will undertake civil engineering.

In the Khao Wong Factory of SWCC, the managers of the manufacturing department will manage the project, while the production staff of SWCC and the SCI (Ta Luang) Factory will cooperate with them.

This indicates that a management system is in place for the implementation of the project.

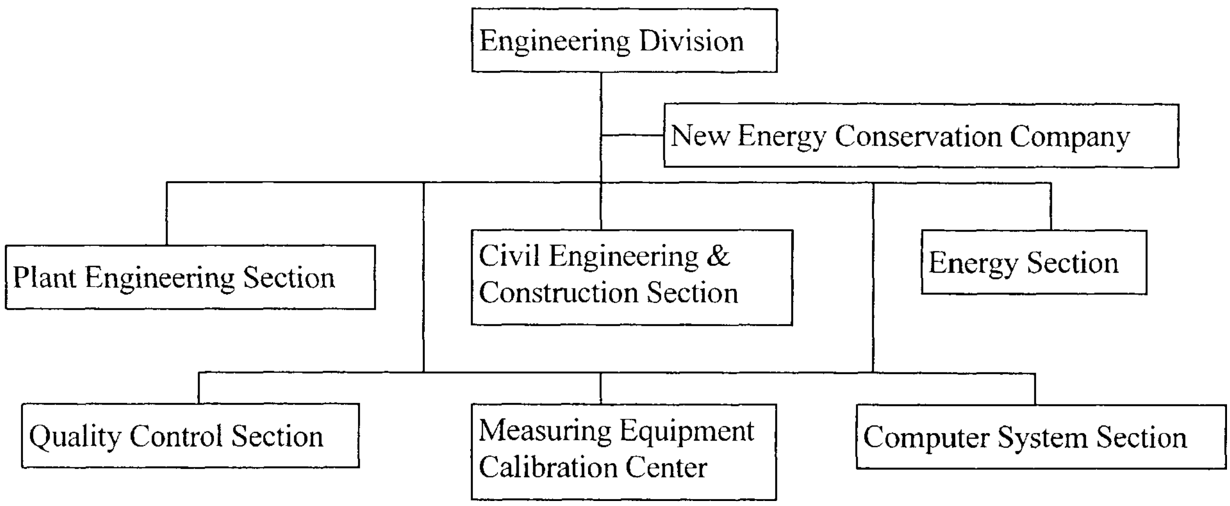


Figure 2-2-6. Engineering Organization Chart of Siam Cement Industry (SCI)

(3) Management Foundation and Policies

As mentioned earlier, the Siam Cement Group is the largest conglomerate in Thailand. It has nine intermediate holding companies, which cover a variety of areas. Here, we refer to its cement business.

The company recently spun off its cement business completely in order to enhance its corporate transparency and facilitate equity participation from strategic partners abroad. SCI believes that this integrates national corporations and supports their participation in both global and regional markets.

Table 2-2-5 shows the financial state and managerial achievements of SCI. In 1997 and 1999, they suffered losses from exchange-rate fluctuations, an external event. Excluding the resultant depreciation of the baht, the company maintained surpluses in 1998 and 1999, although sales fell greatly and profits decreased.

In 1999, Thailand's production of gray cement (ordinary cement) totaled 55 million metric tons. Domestic demand, however, totaled only 18 million metric tons (peaking at 37.4 million metric tons in 1996), and SCI's national sales dropped 11% from the preceding year.

SCI has been focusing its efforts on exporting to Asian nations. In 1999, SCI exported 4.8 million metric tons, an increase of 71% over the total for the preceding year. Exports of white cement, the focus of this project, also increased 33%, but domestic sales fell 16% from the preceding year. SCI has been actively taking steps to reduce energy costs by shutting down its old plants, raising the efficiency of its existing plants, and utilizing industrial waste as fuel.

Clearly, the company has the stable management foundation required to handle the project, and it has the appropriate management policies required of a counterpart.

Table 2-2-15. Management Conditions of Siam Cement Industry (SCI)

Millions of baht

	· 1999	1998	1997	1996	1995
Financial statement					
Floating assets	3,351	4,055	4,946	4,396	5,425
Gross assets	68,692	66,277	83,340	37,569	31,211
Gross debt	56,670	47,170	65,052	24,370	19,781
Net assets*	12,022	19,174	18,288	13,199	11,430
Performance					
Gross revenue	22,847	25,507	31,328	35,701	31,287
Unit costs and expenses	22,184	24,734	27,631	31,569	26,872
Profit (Loss)**	302	529	3,227	3,584	3,615
Net profit (Loss)	(1,358)	9,342	(5,832)	4,166	3,120
Investments	897	2,507	9,505	9,026	6,250
EBITDA	9,298	8,839	10,517	8,375	7,855

*Gross assets − Gross debts

**Excluding exchange-rate fluctuations

***Earnings before interest, taxes, depreciation and currency exchange gains (losses)

(4) Funding Capacity

The Siam Cement Group is the largest conglomerate in Thailand. Cement is a leading industry in

Thailand, and obtaining bank loans is not a problem. Large Japanese city banks have also dealt with the company. We believe that SCI is capable of raising the funds required for the project.

(5) Personnel

As indicated in the discussion of the management system, the company's organization includes many young yet excellent managers who cooperated with us in this basic research as well as technical staff. Therefore, the personnel and their technological abilities are adequate for implementing the project.

(6) Implementation System

The Engineering Division of the SCI Head Office will be in charge of this project. Its Energy Section will take the lead in implementing the project. The effects of the project on the environment and safety issues will be examined by the Quality Management Section and the Energy Section. The Plant Engineering Section will study the effects on the manufacturing process. Any civil engineering work required will be carried out by the Civil Engineering and Construction Section (see Figure 2-2-6).

At the Khao Wong Factory, the managers and engineers of the manufacturing departments of SWCC and Siam Cement (Ta Luang) will take charge of this project. They will undertake the project in cooperation with the Head Office.

(7) Environmental Issues

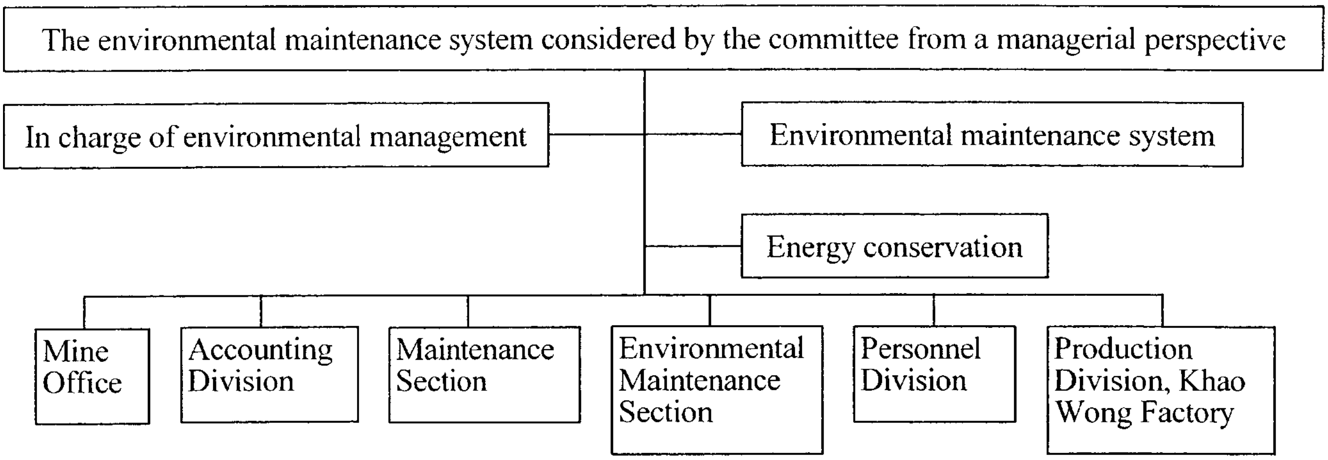
1) Environmental Strategies

The Siam Cement Group has four managerial principles, one of which is "fulfilling their social obligations."

Under this principle, the Khao Wong Factory has prescribed the following basic concept regarding environmental improvement: "Continuous improvement of factory environments will be undertaken in order to meet the environmental standards specified by public institutions with responsibilities for employees and community residents."

The strategies for improving the factory environment are specified in writing, and concrete targets for environmental maintenance and improvement measures are continuously systemized. They are disclosed to all employees and public institutions. At the factory, emission criteria for air, wastewater and other products are established voluntarily and strictly observed. In addition, environmental maintenance activities and conservation of resources and energy are developed actively. The factory received ISO 9002 certification in 1994 and ISO 14001 certification in 1999.

Figure 2-2-7 shows the management organization chart of the factory's environmental maintenance system.



Source: Khao Wong Factory data

Figure 2-2-7. Management Organization Chart for the Environmental Maintenance System

2) Environmental Conservation Measures

(a) Dust Control Equipment

High-performance dust collecting equipment (with an efficiency of 99.9%) has been installed in combination with bag filters and electrostatic precipitators to control dust discharged into the atmosphere. Smoke at the stack outlet is measured every quarter to determine whether it satisfies the factory emission standard.

Table 2-2-16 shows the results of recent smoke measurements. Table 2-2-17 outlines the specifications of the dust collecting equipment. Photo 2-2-4 shows the dust collecting equipment, and Photo 2-2-5 shows the smoke from the stack outlet.

Table 2-2-16. Example of Measured Smoke

Location of measurement		4^{th} quarter of 1999	1^{st} quarter of 2000	2^{nd} quarter of 2000
Stack I	Dust	Operation suspended	62	23
	SOx (ppm)	Operation suspended	339	71
	Nox (mg/m^3)	Operation suspended	1,711	1,299
Stack II	Dust	17	62	26
	SOx (ppm)	557	60	22
	NOx (mg/m^3)	102	1,050	1,100

Note: The indicated value is the average of three measurements.

Source: Khao Wong Factory data

Table 2-2-17. Specifications of the Dust Collecting Equipment

	Line 1	Line 2
Treatment capacity	620 Nm^3/h	896 Nm^3/h
Concentration at inlet	$80g/Nm^3$	$80g/Nm^3$
Concentration at outlet	$0.06g/Nm^3$	$0.06g/Nm^3$

Source: Khao Wong Factory data

(b) Wastewater Treatment Equipment

Equipment cooling water is used in the cement production plant. A closed circuit system is adopted for the cooling water so that it is not discharged from the factory. The water is pumped up from a reservoir (Photo 2-2-6) maintained on the factory premises. The pH and hardness of the reservoir water are regularly monitored. Table 2-2-18 shows the water quality.

Table 2-2-18. Quality of the Cooling Water

	PH	Hardness
Before reservoir	7.73	344 ppm
After reservoir	8.67	91 ppm

Source: Khao Wong Factory data

Before being released, the effluents from the office, dining hall and other areas are treated by effluent treatment equipment containing a filtration tank and absorption tank.

(c) Other issues

Noisy manufacturing machinery such as crushers and blowers is housed indoors to minimize outdoor noise pollution. As well, various types of waste are collected and sorted into four categories for recycling or treatment and disposal by outside consignees.

Many trees are planted on the factory premises to beautify the surroundings with the goal of creating a green factory.

3) Disclosure of Environmental Reports

The factory prepares environmental reports covering its environmental conservation measures and various measurement data. These reports are submitted to the national government (the Ministry of Industry, the Ministry of Agriculture & Co-operatives) and disclosed to the public after environmental audits (surveys) by outside institutions.

- Environmental report: Prepared by the company semiannually

- Environmental auditing report: Prepared by the auditor designated by the national government every three or four years
- Consultant environmental report: Prepared by a consulting company designated by the national government every three or four years

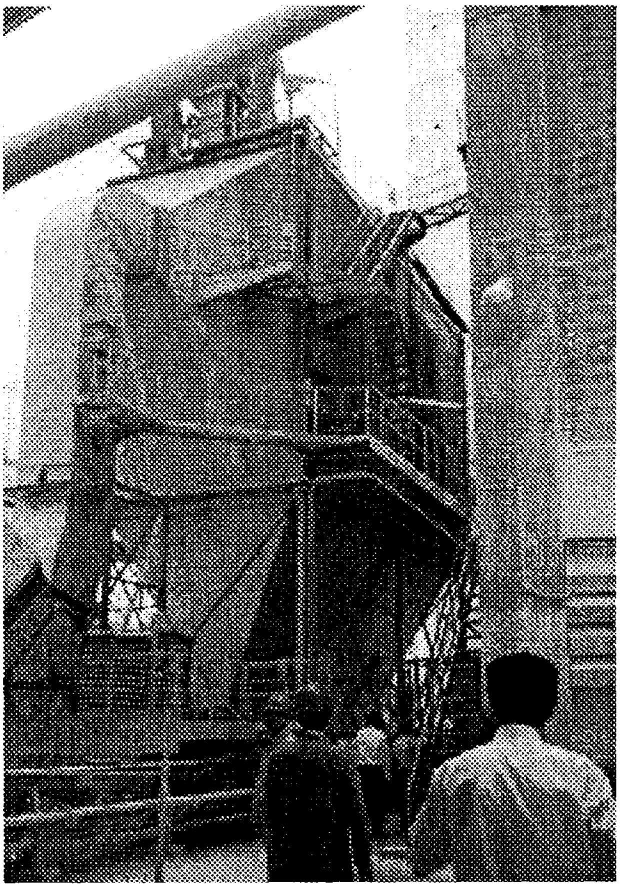


Photo **2-2-4** Electric Precipitator

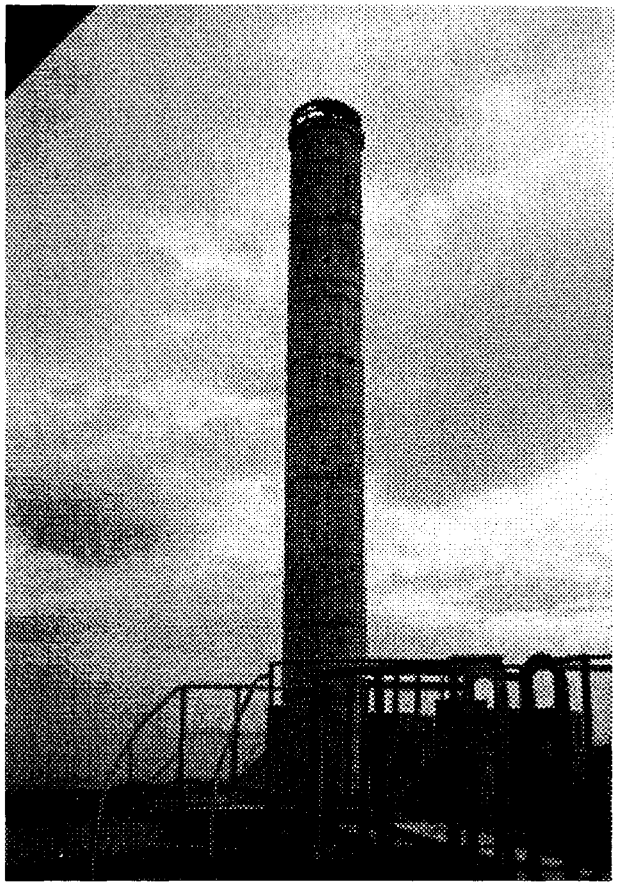


Photo **2-2-5** Smoke stack

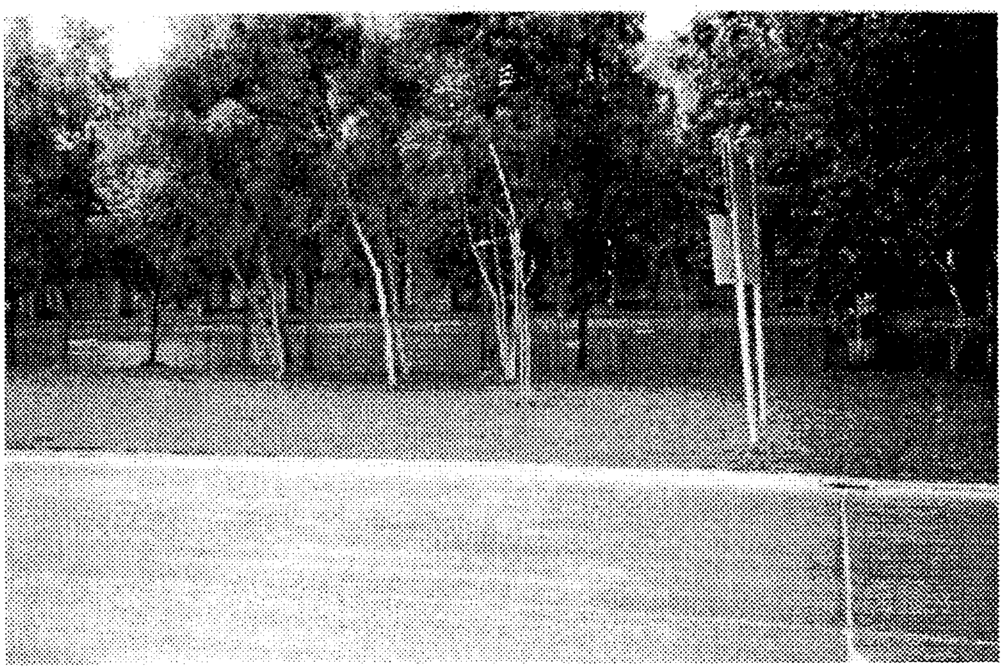


Photo **2-2-6** Reservoir

2-2-4. Details of the project and specifications of related equipment after the modification

(1) Scope of the project

This project aims to reduce the energy consumption without affecting the characteristics of the white cement. Therefore, energy will be saved by enhancing the kiln combustion air temperature and improving the thermal efficiency of the clinker baking process without changing the conventional raw materials, cement mill, or clinker cooling process.

2) Reducing energy consumption

This project aims to reduce the energy consumed in the manufacture of white cement through the following measures.

1. Enhancing the temperature of the kiln combustion air by using the waste heat from the exhaust gas of the gas turbine generating equipment introduced.
2. Improving the thermal efficiency of the clinker baking process by modifying the clinker baking department and introducing a swirl calciner.

These modifications will enhance productivity as well as increase production.

3) CO_2

The above measures to reduce energy consumption will also reduce CO_2 gas emissions as follows.

1. decreasing fuel consumption;
2. shifting the power generation fuel (from natural gas, heavy oil, and coal) to natural gas through the introduction of a gas turbine. (The three fuels have a different carbon content.)

(2) Outline of the project

1) Details

The following introductions and modifications will be undertaken to accomplish the aims of the project.

a) Steam injection gas turbine generating equipment will be introduced to provide the power currently being purchased.

b) A kiln combustion air heater will be introduced to provide additional heating from the exhaust gas of the gas turbine.

c) The raw material preheater will be modified through the introduction of a swirl calciner to promote calcination ahead of the kiln.

Figure 2-2-8 shows the positions of these innovations in the process flow and how they are interrelated.

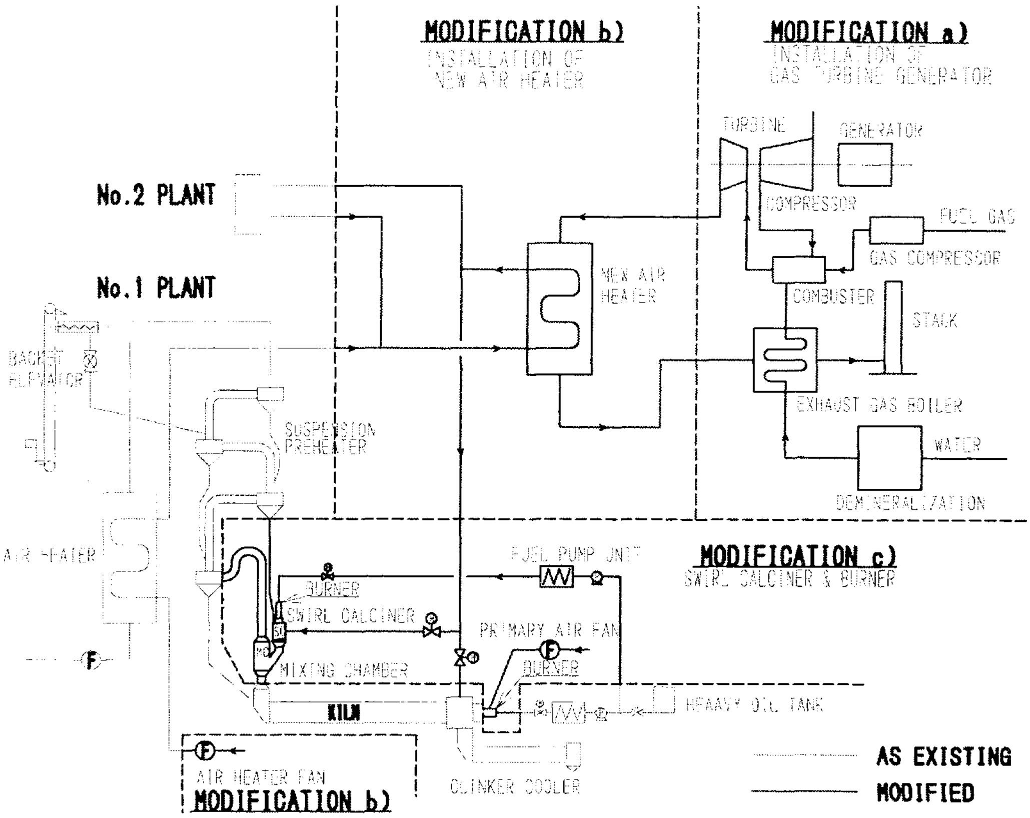


Figure 2-2-8. Details of the Project

To further utilize the waste heat of the gas turbine exhaust gas after heating of the combustion air, the following two drafts have been examined:

x) Heating of the raw materials

The raw meal is heated by the introduction of a cyclone heater.

y) Steam injection

The generation capacity is increased by injecting generated steam into the gas turbine.

Examining the features, generator specifications, energy consumption and construction cost of the two drafts, we have chosen to adopt draft y) and have decided to introduce steam injection gas turbine generating equipment. Table 2-2-18 shows the results of our examination.

Table 2-2-18. Comparison of Waste Heat Utilization

	Draft x)	Draft y)
Features	1) Reduction of fuel consumption by heating raw materials 2) New exhaust gas treatment equipment, such as an electronic dust collector, is required.	1) Increase in power generation by increasing generation efficiency 2) A boiler, a demineralizer and boiler water are required.
Plant power consumption (kW)	3,860	3,700
Type of gas turbine generator Power generated (kW) Heat consumption rate (Mj/kWh)	Simple cycle 3,400 13.39	Steam injection cycle 4,770 10.98
Power purchased (kW)	460	−1070
Results of energy consumption calculation (kcal/kg-cl)	Kiln fuel 1,240 Power generation fuel 554 Total fuel consumption 1,794	Kiln fuel 1,320 Power generation fuel 457 Total fuel consumption 1,777
Construction cost (Kbaht)	Approx. 420,000	Approx.320,000
Conclusion	Not adopted	Adopted

2) Manufacturing process and equipment after the modification

Table 2-2-19 summarizes the project goals to be implemented in the existing plant. Below is an outline of the production processes and equipment following the modification.

(a) Raw Material Receiving Department (not changed)

The kinds of raw materials and their properties will not be changed for the project. Their use for increasing production is limited to 20%. The existing storage facility of the Material Receiving Department and the limestone crusher have the capacity to cope with the changes introduced under the project.

(b) Raw Mill and Exhaust Gas Treatment Department (not changed)

The kinds of raw materials and their properties will not be changed for the project. Their use for increasing production is limited to 20%. The existing material crushing equipment has the capacity to cope with the changes introduced under the project.

The exhaust gas from the gas turbine generating equipment introduced, which does not contact the raw materials and is clean, does not require a dust collector. Only the kiln exhaust gas requires treatment, as usual. The existing equipment can cope with the changes introduced under the project.

Table 2-2-19 To Be Implemented in the Existing Plant

White Cement Manufacturing Department	State	Main points to be implemented
(a) Raw Material Receiving Department	No change	–
Raw Mill and Exhaust Gas Treatment Department	No change	–
Raw Meal Mixing and Storage Department	No change	–
(d) Clinker Manufacturing Department	Modification	Preheater: The unit will be modified and the following equipment installed: Swirl calciner with burner and mixing chamber Air heater: New heater is installed. Kiln combustor: The following updated systems will be introduced. Burner, primary air fan
(e) Clinker Storage Department	No change	–
(f) Cement Mill Department	No change	–
(g) Cement Storage and Shipping Department	No change	–
(h) Gas turbine generating equipment	New installation	The following will be introduced: Main unit of the gas turbine (GT) generator Exhaust boiler, water supply equipment, soundproofing facility, gas compressor, control panels, electrical equipment, instrumentation, auxiliary GT equipment
(i) Electricity and Control Department	Modification	Power supply: Changeover to the GT generator Power transmission system: Connection to the GT generator Addition of instrumentation and electrical and control equipment Electricity room: Arrangement of the new GT electricity room, and addition and connection to the existing electricity room Operation room: Common use of the GT electricity room, addition of and connection to the existing operation room

(c) Powder Mixing and Storage Department (not changed)

The kinds of raw materials and their properties will not be changed for the project. Their use for increasing production is limited to 20%. The existing powder mixing equipment and the powder storage facility have the capacity to cope with the changes introduced under the project.

(d) Clinker Production Department (modified)

The modifications to the Clinker Manufacturing Department are indicated below. The following

(d) Clinker Production Department (modified)

The modifications to the Clinker Manufacturing Department are indicated below. The following description is common to Lines No. 1 and No. 2 unless otherwise indicated.

The flow of this department after the modification is additionally illustrated in Figure 2-2-9.

Preheater

The swirl calciner, its burner, and the mixing chamber following the calciner will be introduced by modifying the existing preheater.

The swirl calciner is a cylindrical steel plate furnace lined with firebrick. The burner is installed on the top in a downward orientation. Figure 2-2-10 illustrates the swirl calciner to be introduced to the preheater. Below is an outline of its function and effects.

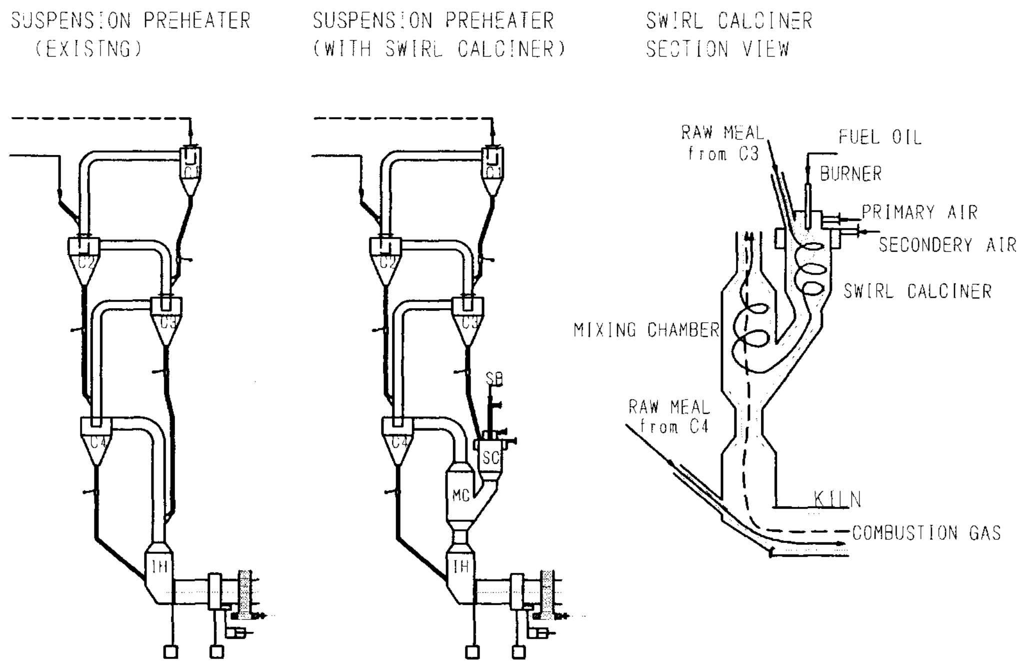


Figure 2-2-10. Introduction of the Swirl Calciner

The raw meal added to the top stage of the preheater fall downward, exchanging heat with the kiln exhaust gas in the preheater for preheating. After reaching the 3-stage cyclone (C3), they are introduced to the newly installed swirl calciner. Combustion equipment — including the burner, pump unit, heating unit and other units — is newly installed here along with the swirl calciner. About 35% of

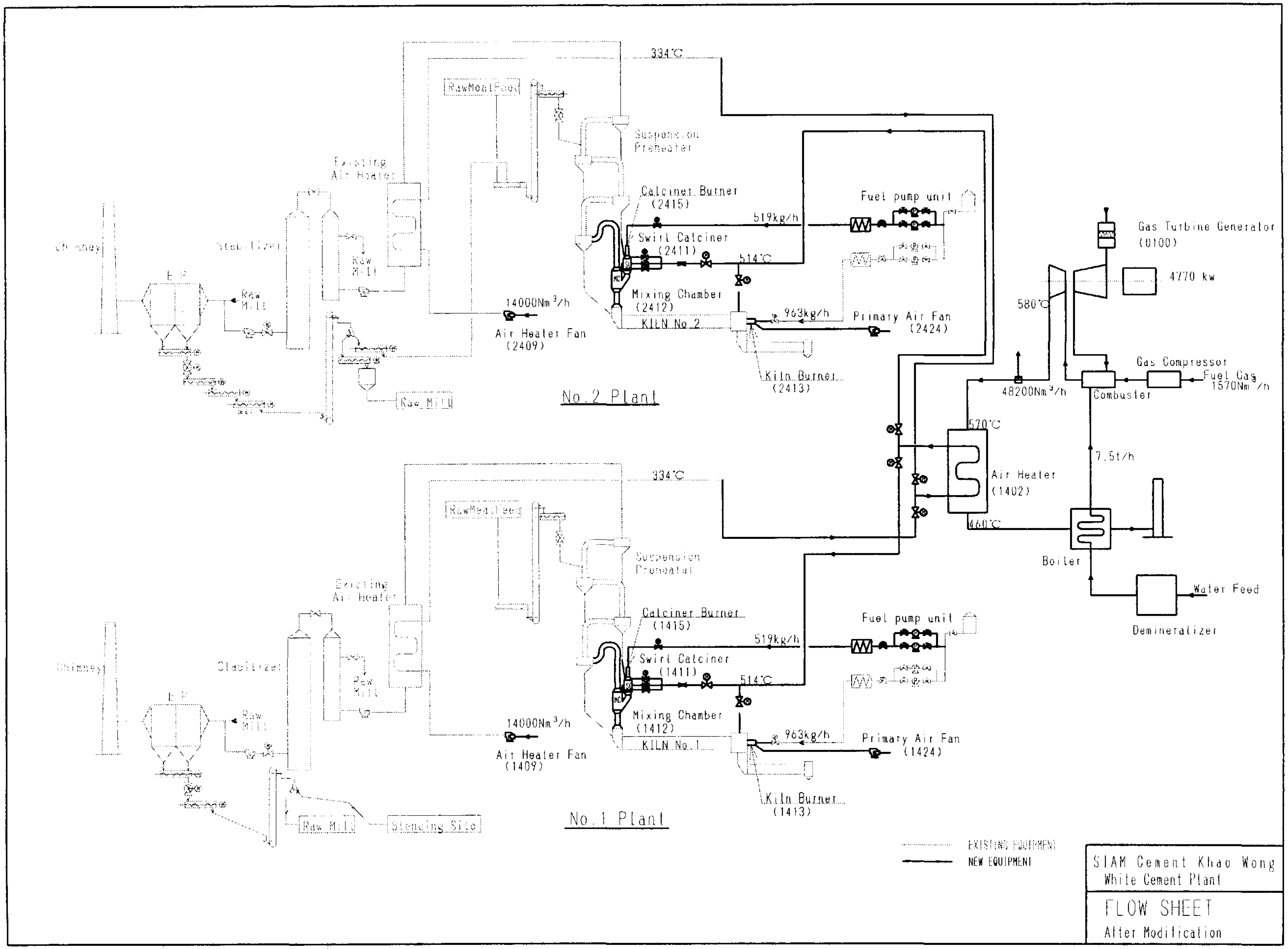


Fig. 2-2-9 Process flow after modification

the fuel required for clinker baking is burned in the swirl calciner. Most of the raw meal is calcinated there, after which it is carried down with the high-temperature gas through the duct below the swirl calciner. It is then mixed with the kiln gas in the mixing chamber and travels up in the duct to finally become calcinated. It is collected by the 4-stage cyclone (C4) and directed into the rotary kiln.

Thus, the calcination, which has been performed in the rotary kiln, is performed in the air flow heating zone with good heat exchange efficiency and ahead of the kiln, which results in enhanced thermal efficiency and productivity.

Air Heater

Although the kiln combustion air has already been heated in the existing heat exchanger, another heat exchanger is added to heat the air further with the gas turbine exhaust gas.

The new heat exchanger is used for both Line No. 1 and Line No. 2. After being divided for the two lines, the high-temperature air is further separated for transfer to the kiln burner and the swirl calciner burner.

The heating air fan, which blows air into the existing heat exchanger, requires higher pressure due to the new heat exchanger introduced. A new fan with high-pressure specifications is installed as a replacement.

Kiln burner

The heated kiln combustion air is more than 500°C in the kiln burner. With the conventional system, in which all the combustion air is sent to the kiln through the burner, a heat-resistance problem arises in the burner if additional heating takes place. Therefore, all the air heated with the new air heater is fed to the kiln from the kiln hood as secondary combustion air. The primary air fan is installed for the new kiln burner to allow only primary combustion air at normal temperatures to pass.

The specifications of the kiln burner capacity are determined according to a condition in which roughly 65% of the required fuel is combusted. The existing pump and heating unit can remain in use.

Other equipment

The rotary kiln and the clinker cooler will not be modified.

(e) Clinker Storage Department (not changed)

The increase in clinker production is limited to 20%. The existing clinker storage facility has the capacity to cope with the changes introduced under the project.

(f) Cement Mill Department (not changed)

The kinds and properties of the raw materials will not be changed for the project. It is estimated that the properties of the manufactured clinker will not be changed. The production increase in crushing capacity is limited to 20%. The existing material crushing equipment has the capacity to cope with the changes introduced under the project.

(g) Cement Storage and Shipment Department (not changed)

The increase in cement production is limited to 20%. The existing cement storage and shipment facilities have the capacity to cope with the changes introduced under the project.

(h) Gas turbine generating equipment (newly installed)

The new gas turbine generating equipment will be installed in the white cement plant for power generation. The steam injection type should be adopted considering its good thermal efficiency.

A flowchart of the steam injection gas turbine generating equipment is illustrated in Figure 2-2-11.

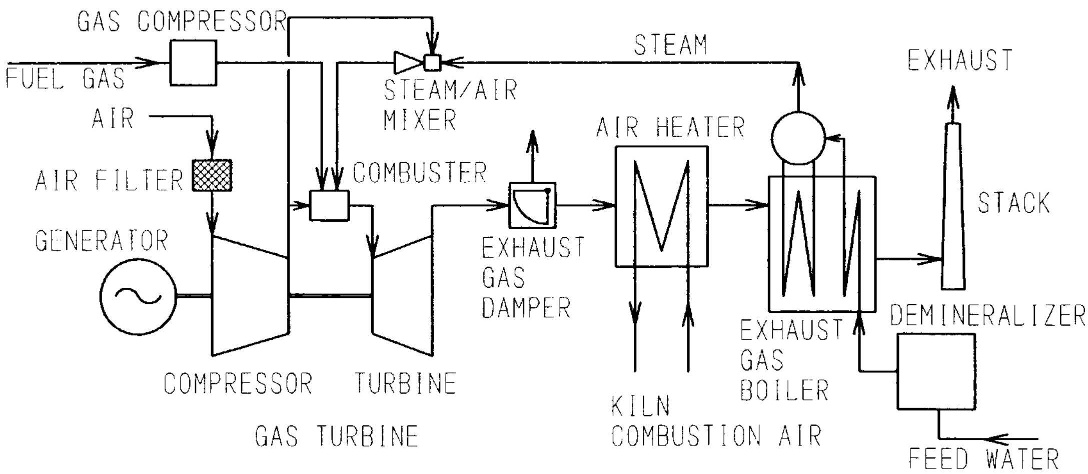


Figure 2-2-11. Flowchart of the Steam Injection Gas Turbine Generating Equipment

The generating equipment mainly comprises a compressor, combustor, turbine and generator. The exhaust gas heat is used as follows.

The exhaust gas used for heating of combustion air at the air heater is sent to the exhaust gas boiler, where it generates steam with its waste heat.

The generated steam is mixed with the high-temperature air from the turbine compressor outlet at the steam air mixer to make superheated steam. The air and steam mixture is transferred to the turbine combustor to be injected into the turbine.

This system, known as "steam injection," enhances the turbine output and the power generation capacity. It also allows for reduction of the nitrogen oxides contained in the gas turbine exhaust gas.

Soundproof facilities and other facilities

The gas turbine and the generator directly connected to the turbine through reduction gears are installed in a soundproof enclosure along with major auxiliaries. The intake air of the gas turbine is drawn into the gas turbine compressor through a high-performance filter. A fan ventilates the enclosure. In addition, an inflammable gas detection system is provided in the enclosure.

Exhaust damper

An exhaust damper is installed ahead of the kiln air heater. The damper is opened to release exhaust gas and enable operation with the gas turbine alone when the gas turbine is started, and the exhaust gas boiler and the heat exchanger are maintained.

Control room

Electric equipment including a gas turbine control panel, a generator control panel, an auxiliary panel, and a set-up transformer are installed in the newly provided electricity and control room (for common use).

Water supply and instrumentation air

The demineralizer, which supplies demineralized water to the exhaust gas boiler and the boiler for steam generation, is installed near the gas turbine generating equipment together with the boiler auxiliaries. Steam injection equipment for controlling the injection steam, an instrumentation air supply system, and a hydraulic starting system to control the gas turbine are also installed nearby.

Gas compressor

A gas compressor is arranged to increase pressure to the required level in case the terminal pressure of the gas fuel supplied to the gas turbine drops. The gas compressor is installed in the soundproof enclosure containing the inflammable gas detection system and an electric motor to provide drive power. The gas compressor is also installed near the gas turbine generating equipment.

(i) Electricity and Control Department (Modified)

The Electricity and Control Department after the project are shown below.

Power supply

Power, purchased from an external source, is supplied from the gas turbine generating equipment. The output specifications of the generator are 4,770kW, 6,600 V, 3-phase, 3-wire, and 50Hz. Enhanced to 22 kV with a step-up transformer, the power is connected to the 22 kV line of the existing equipment at the substation for distribution to the plant.

A power dispatching system should be maintained to draw power from the outside when the generating equipment is not operated, as in the case of gas turbine maintenance.

On the other hand, the gas turbine generating equipment should be operated fully to maintain good power generation efficiency. Power produced in excess of the demand of the white cement plant, as well as surplus power resulting from production adjustments, should be consumed by the adjacent gray cement plant. To achieve this project, coordination and the laying of the necessary wiring between the two plants is required.

Power dispatching system

The existing power dispatching system will be augmented, as follows:

1. a power dispatching line will be connected from the gas turbine generating equipment; and
2. necessary electric, control and instrumentation equipment will be added for the newly installed or modified equipment.

Figure 2-2-12. shows the power dispatching system after the additions.

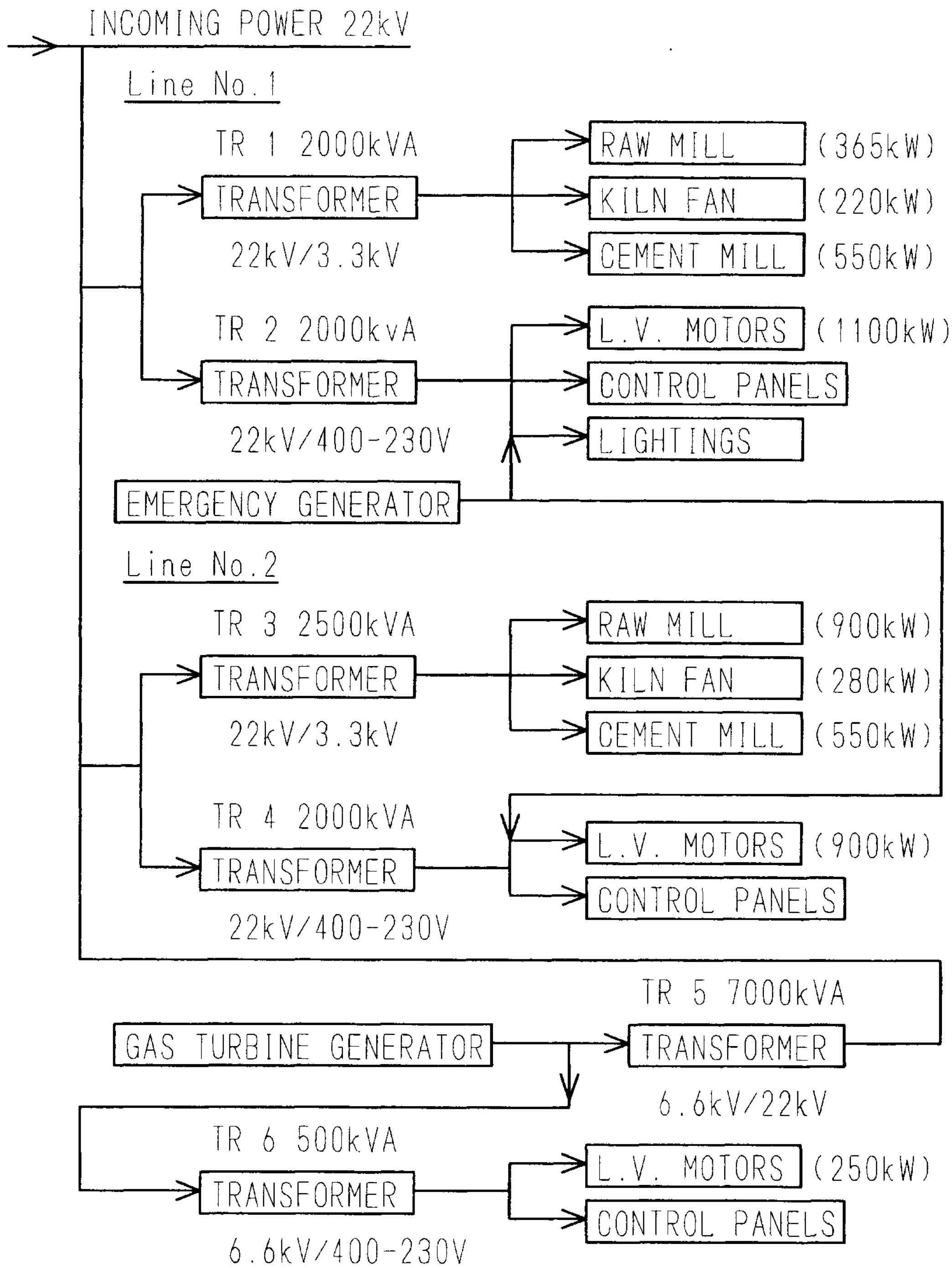


Figure 2-2-12. Power Supply System after Additions

Electricity room

Gas turbine generating equipment: Newly installed

Substation: Modification of existing equipment (extended)

Raw material receiving/Raw mill: Not changed

Clinker manufacturing: Modification of existing equipment (added)

Cement mill/Shipment: Not changed

Electronic dust collector: Not changed

Operation room

Gas turbine generating equipment: Newly installed (used in common with the gas turbine electricity room)

Raw material receiving/Raw mill: Not changed

Clinker manufacturing: Modification of existing equipment (added)

Cement mill/Shipment: Not changed

3) Plant layout after the modification

The layout of the new equipment to be introduced under the project is illustrated in Figure 2-2-13. Below is an outline of the facilities.

Gas turbine generating equipment and related equipment

As for the location of the gas turbine generating equipment and related equipment, the area on the west side of the clinker silo, which is currently used for outdoor clinker storage, is preferable, as it is next to the white cement plant and the required space can be secured. However, in order to supply clean combustion air to the gas turbine, the operation of the outdoor clinker storage requires some environmental considerations.

New heat exchanger

The new heat exchanger for the gas turbine exhaust gas and the kiln combustion air should be installed next to the gas turbine generating equipment. This ensures a shorter duct for the high temperature exhaust gas and lower radiation loss. As for the kiln combustion air duct, the existing duct from the heat exchanger to the kiln burner should be partly modified for connection to the new heat exchanger.

Swirl calciner

The swirl calciner should be installed in the space beneath the third cyclone of the existing preheater. The mixing chamber following the swirl calciner should be arranged in the location of the existing duct from the kiln inlet housing to the fourth cyclone. The duct to the fourth cyclone should be installed in the space on the kiln side of the existing preheater frame, where an additional frame is

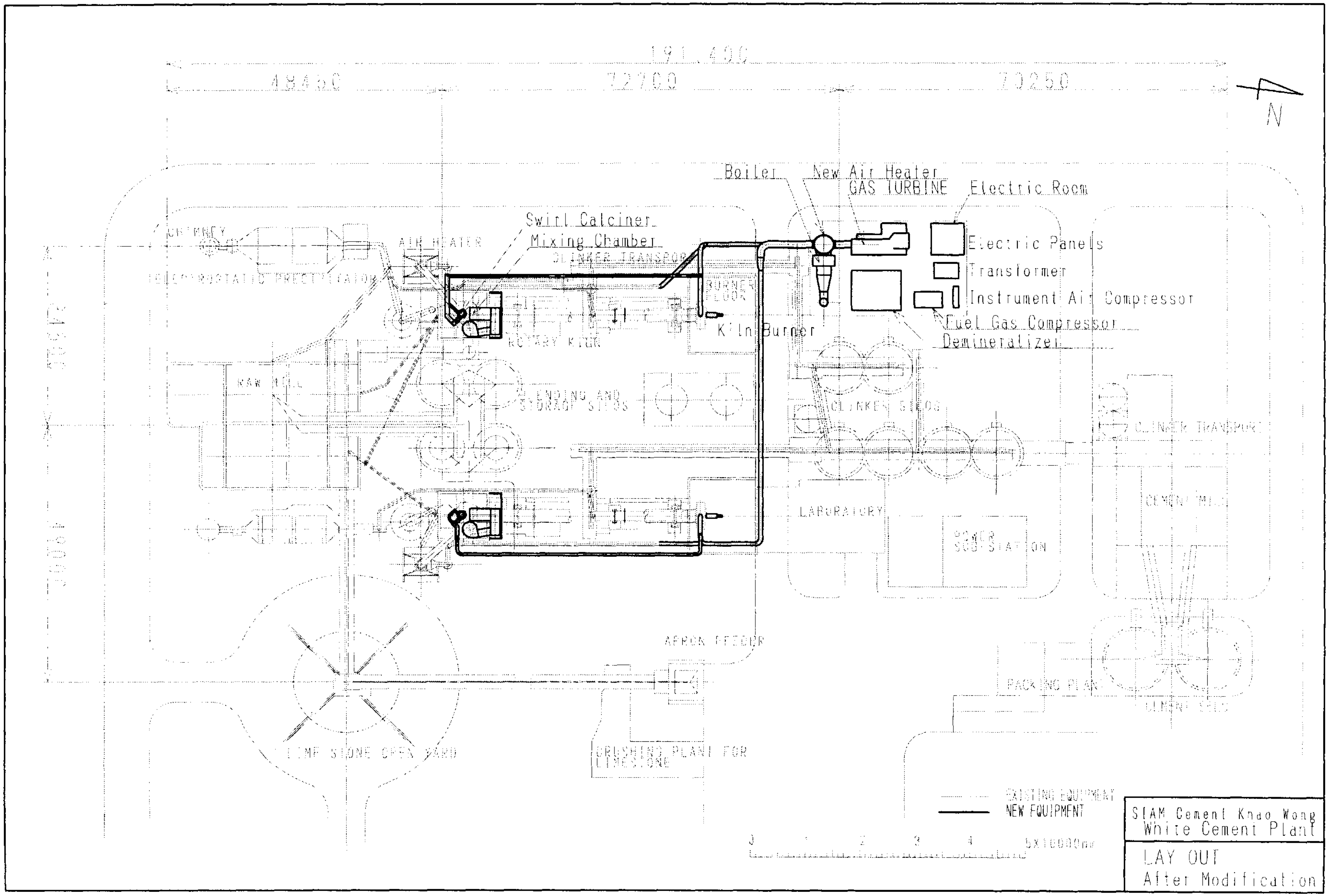


Fig .2-2-13 Plant layout after modification arranged to provide the capacity for the duct from the mixing chamber to the fourth cyclone.

(3) Estimated values of the project

The estimated values to be achieved under the project targeting reduced energy consumption are revealed in comparisons of the specifications before and after the plant modification.

1) Production

The production base should be the clinker base.

Before the Modification

The values for both Line No. 1 and Line No. 2 should be 220 t/d of clinker. This figure is obtained by rounding off the achievements of clinker production indicated in Table 2-2-2. Achievements for the Past Five Years.

After the Modification

The values for both Line No. 1 and Line No. 2, where production will be increased about 18%, should be 260 t/d clinker according to the achievements indicated in Table 2-2-2. Achievements for the Past Five Years. This considers the production increase effect resulting from the introduction of the swirl calciner and the capacity margin of the existing equipment.

2) Balance in the Clinker Production Department

The balance of quantities and conditions of the raw meal, fuel, gas, and air before the modification and after the modification in the Clinker Production Department is estimated according to the above-mentioned production. The results are indicated in Figures 2-2-14 and 2-2-15.

The fuel is regarded as heavy oil in Table 2-2-8. The fuel consumption before the modification is 1,420 kcal/kg-clinker, the value achieved during the survey (Table 2-2-2).

Before the Modification

Figure 2-2-14 shows the balance before modification. The balance shows the quantities and conditions of the raw meal, fuel (heavy oil), air (fresh air and combustion air), and exhaust gas required to manufacture 1 kg of clinker (indicated in cl) as follows:

Required material: 1.824 kg

Material temperature: 60°C

Required fuel: 0.1472 kg (Calculated on the basis of fuel consumption of 1,420 kcal/kg-clinker)

Fuel temperature: 120°C

Required combustion air: 1.395 Nm^3

Combustion air temperature: 30°C before heater; 350°C after heater

Preheater exhaust gas: 2.496 Nm^3

Preheater exhaust gas temperature: 455°C before heater; 250°C after heater

After the Modification

Figure 2-2-15 shows the balance after modification. The balance values before and after the modification are indicated in Table 2-2-20 for comparison of quantity and condition.

Table 2-2-20. Comparison of Balance Values before and after the Modification

(per kg-cl)

Item	Before	After	Remarks
Raw material required (kg)	1.824	1.824	Raw material remains unchanged
Raw material temp. (°C)	60	60	Raw material remains unchanged
Fuel required (kg) (kcal)	0.1472 1,420	0.1368 1,320	Reduced due to increased air temperature and introduction of swirl calciner
Fuel temp. (°C)	120	120	Same
Combustion air required (Nm^3)	1.395	1.291	Reduced in proportion to fuel quantity
Combustion air temp. (°C) Front of preheater Back of preheater	 60 350	 334 514	(New preheater after modification) Increased approx. 160°C
Preheater exhaust gas (Nm^3)	2.496	2.230	Reduced according to fuel decrease
Preheater exhaust gas temp. (°C) Front of preheater Back of preheater	 455 250	 455 255	Almost the same as a result

3) Energy of the kiln fuel

From the balance values indicated in Table 2-2-19, the kiln fuel energy required for clinker baking is as follows:

Before modification: 1,420 kcal/kg-clinker

After modification: 1,320 kcal/kg-clinker

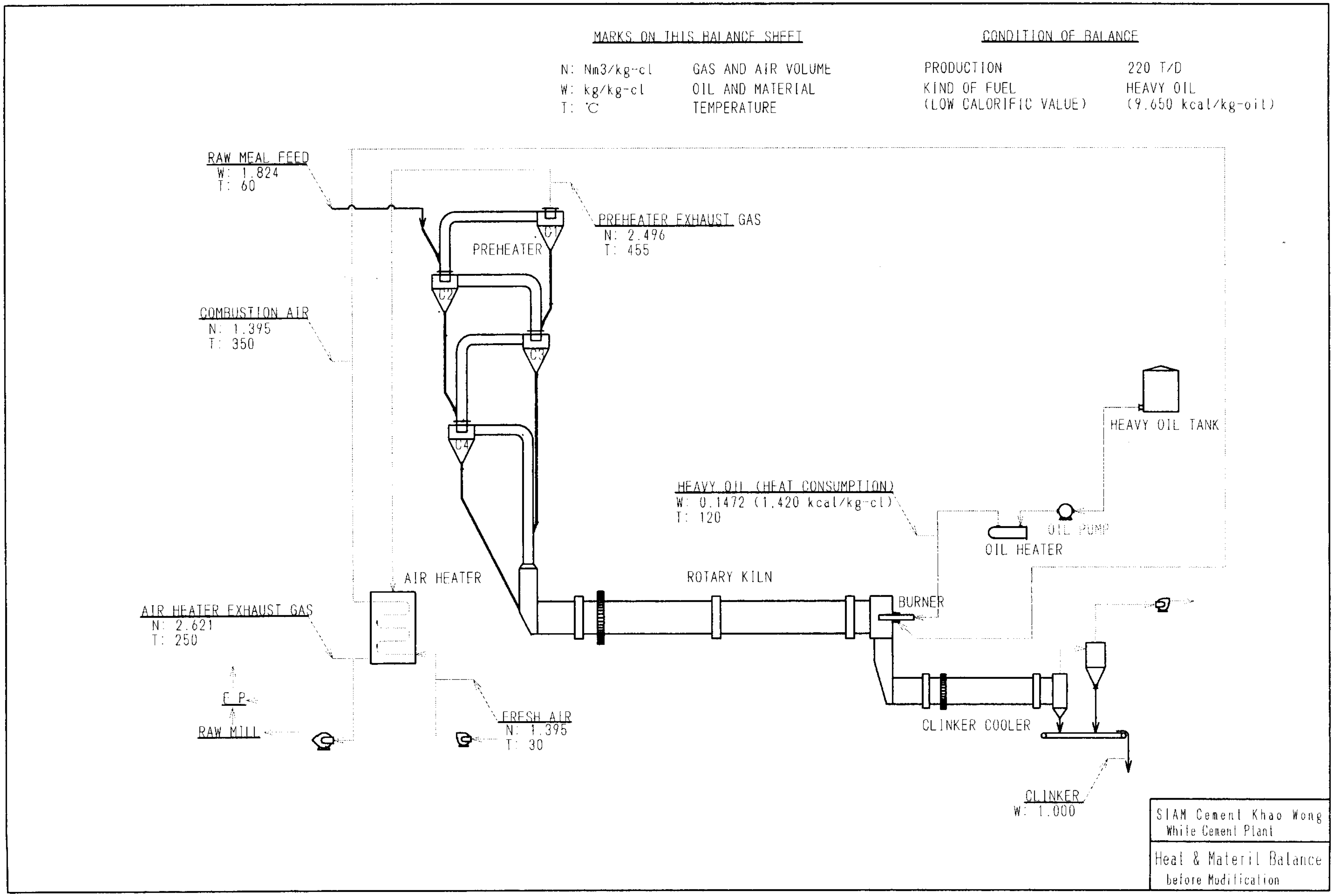


Fig. 2-2-14 Heat & material balances before modification

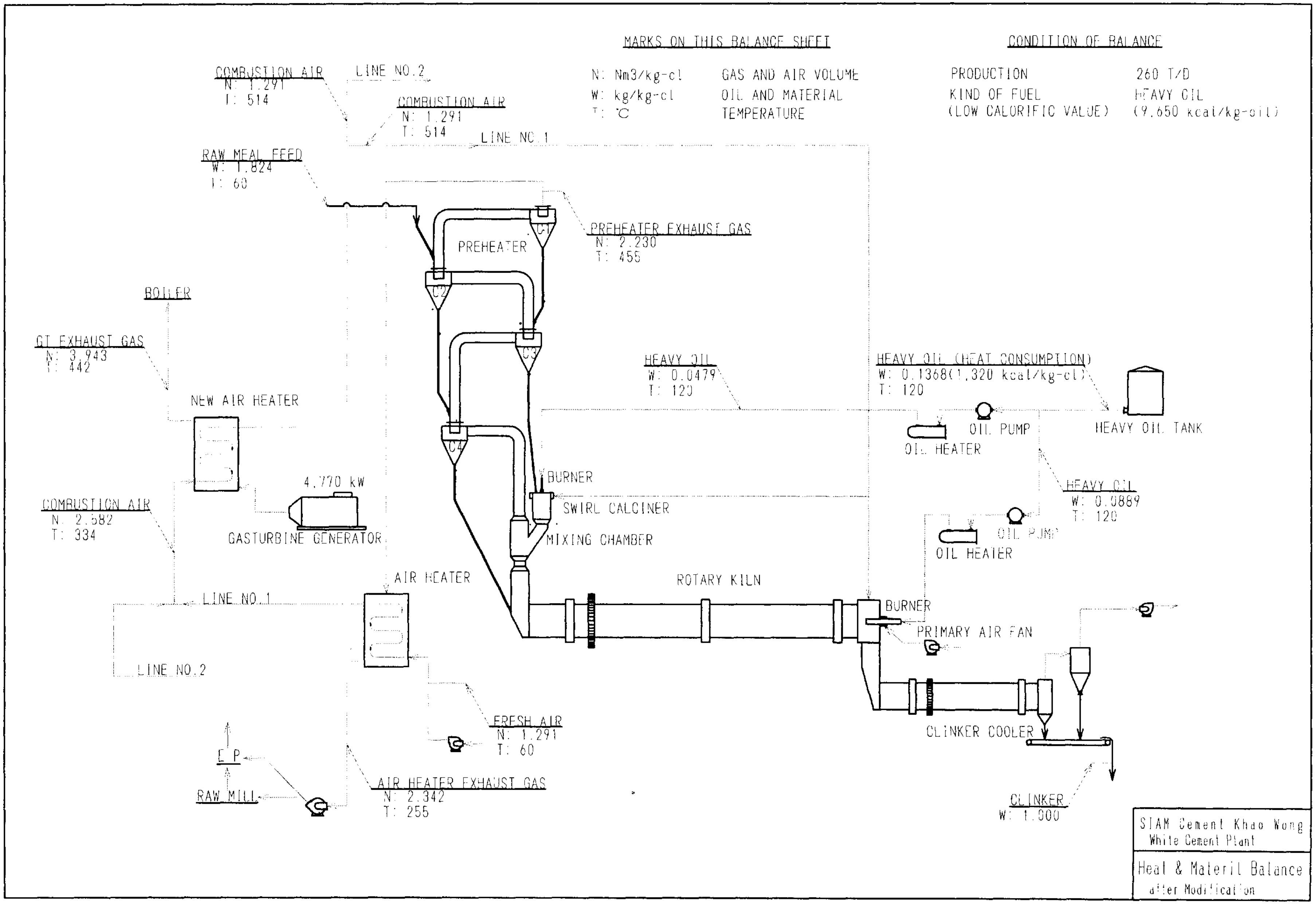


Fig. 2-2-15 Heat & material balances after modification

The difference before and after modification represents the energy saved, which is 100 kcal/kg-clinker. Table 2-2-21 illustrates the details.

Table 2-2-21. Kiln Fuel Energy Saved

		kcal/kg-clinker
1	Heating of combustion air with gas turbine exhaust gas	76
2	Calcination promoted by swirl calciner and mixing chamber	24
	Total kiln energy saved	100

4) Power Consumption

The power consumed by equipment before the modification and after the modification is estimated as follows.

Before the Modification

175.9 (kWh/t-opc), the average power consumption over five years based on Table 2-2-2 Achievements for the Past Five Years, is adopted.

The production of cement is estimated, with plaster mixed with clinker regarded as 4% and Lines No. 1 and No. 2 regarded as 220 t/d clinker.

220 t/d x 2 x (1+0.04) x175.9kWh/t x 1/24 d/h = 3,353.8kW → 3,360kW

After the Modification

The following power is added to the above-mentioned power as a result of the modification.

a) Resulting from the added equipment related to the cement manufacturing process

92kW/line x 2 (lines) x 0.65 (loading rate) = **120kW**

b) Due to the added gas turbine generating equipment auxiliaries

57kW x 0.65 (loading rate)=37 → **40kW**

c) Added gas compressor **80kW**

d) Increased equipment load resulting from production increase **100kW**

Total:

3,360 + 120 + 40 + 80 100 = 3,700kW

5) Fuel energy for power generation

The energy required for 1kW of power purchased from the external power grid when the power plant efficiency is 35.18%*1 is as follows:

1kWh x 860 kcal/kWh x 1/0.3518 = **2,444.6 kcal**

On the other hand, the energy required for 1kW of power from the gas turbine generator introduced under this project at a heat rate of 10.98 Mj/kWh (see the equipment specifications provided later) is as follows:

1kWh x 10.98 MJ/kWh x 238.8 kcal/MJ = **2,622.0 kcal**

*1: Source: MSTE (Ministry of Science, Technology and Environment, Thailand) *Electric Power in Thailand*

Before the Modification

Because the power consumption of 3,360kW estimated above is purchased from the external power grid, the energy of the power generation fuel for clinker conversion is calculated as follows:

3,360kWh x 2,444.6 kcal/kWh /(2 x 220,000 t/d/24h) = **448 kcal/kg-cl**

After the Modification

The output of the gas turbine generator is 4,770kW (see the equipment specifications provided later). Any power exceeding the required power of 3,700kW will reduce the amount of power that must be purchased for other plants. The power fuel energy is as follows:

Energy for private power generation:

4,770kW x 2,622 kcal/kWh = 12,506,940 kcal/h

Energy of reduced power purchased:

(4,770 - 3,700)kW x 2,444.6 kcal/kWh = 2,615,722 kcal/h

Energy of the required power generation fuel balance:

12,506,940 - 2,615,722 = 9,891,318 kcal/h

Basis of clinker conversion:

9,891,318 kcal/h /(2 x 260,000 t/d/24h) = **457 kcal/kg-cl**

The difference in energy saving before and after the modification is 448?457 = ?9 kcal/kg-cl. The energy of the required power generation fuel increases after the modification.

6) Total energy saved

As Table 2-2-22 shows, the total energy saved where the kiln fuel energy and the power fuel energy under this project are totaled according to the above estimates is 91 kcal/kg-clinker. This is equivalent to about 5% of the value before the modification.

$\{(1420 + 448) - (1320 + 457)\}/(1420 + 448) \times 100 = 4.9\%$

Table 2-2-22 Total Energy Saved

		kcal/kg-clinker
1	Kiln fuel energy	100
2	Power generation fuel energy	-9
Total energy saved		91

(4) Specifications of the related equipment after the project

The key points for selection, main specifications, design conditions, and other data related to the main equipment are as follows:

The figure in parentheses after the equipment name indicates its item number in this project. See Figure 2-2-9. Flow Chart after the Modification.

1) Gas turbine generating equipment (0100)

Key points for selection: Selected according to the following four points:

a) Having an output exceeding the 3,700kW power consumption mentioned above in "After the Modification"
b) Having a system utilizing the maximum waste heat from the exhaust gas in the above class capacity
c) Having an exhaust gas temperature and quantity suitable to meet the energy-saving objective
d) Having exhaust gas whose concentration of nitrogen oxides and other elements are environmentally friendly

Type: Steam injection gas turbine

Number: 1 unit (for both Line No. 1 and Line No. 2)

Table 2-2-23 shows the main specifications.

Table 2-2-23. Specifications of the Steam Injection Gas Turbine

	Unit	
Generation terminal output	kW	4,770
Heat consumption rate	MJ/kWh	10.98
Exhaust gas quantity	kg/s	15.86
Exhaust gas pressure	mmAq	400
Exhaust gas temperature	°C	580
Nox value	PPM	<250

With an outside air temperature of 30°C, altitude of 60 m, and average relative humidity of 70–90%.

Major components:

-Gas turbine generator	Gas turbine (GT), , Generator Reduction gears and couplings Soundproof steel enclosure Hydraulic starter Lubricating oil system
-GT intake system	
-GT enclosure ventilator	
-Fuel gas compressor	(1,800 Nm^3/h x 20 kg/cm^2G; however, the minimum inlet supply pressure should be 12.6 kg/cm^2G) and shutoff valve unit
-GT exhaust system	
-Exhaust damper	
-Inflammable gas detection system	
-Instrumentation air supply system	
-Electric/control equipment	GT control panel Generator control panel Generator breaker panel High and low pressure auxiliary panel Direct voltage source panel Low pressure auxiliary transformer panel Step-up transformer
-Waste boiler and auxiliary equipment	Waste boiler (7.5 t/h x 20 kg/cm^2)
-Boiler demineralizer (7.5 t/h)	
-Steam injection equipment	

Although natural gas will eventually be supplied as fuel from the Petroleum Authority of Thailand (PPT), the pipeline remains about 10 km from the plant. The properties of the natural gas are indicated in Table 2-2-24.

Table 2-2-24. Properties of Natural Gas

Gas composition: vol.%			Present gas quality	Gas quality in 2000–2004 end [1]		
			NORMAL (C-DAY)	MIN.[2]	NORMA L	MAX.[3]
Gas composition: vol.%	Methane	C1	72.47	73.09	73.66	65.33
	Ethane	C2	6.57	5.53	6.22	8.60
	Propane	C3	2.24	1.36	1.78	4.47
	Isobutane	IC4	0.53	0.32	0.41	1.05
	Normal butane	NC4	0.51	0.29	0.40	0.99
	Isopentane	IC5	0.13	0.10	0.10	0.26
	Normal pentane	NC5	0.11	0.11	0.09	0.21
	Hexane plus	C6 +	0.09	0.10	0.06	0.18
	Nitrogen	N2	2.11	3.24	2.15	1.87
	Carbon dioxide	CO2	15.24	15.85	15.13	17.04
Total			100.00	100.00	100.00	100.00
Calorific value Btu/scf	Lower (dry)		864	819	848	927
	High (dry)[4]		955	906	938	1021
	High (sat)		938	890	922	1003
Specific gravity (S G.)			0.785	0.776	0.773	0.855
Wobbe Index{HHV(dry)/SQR.(S G)}			1,078	1,028	1,067	1,104
Dew-point temperature (°F) @630 psi			24.57	26.97	17.14	56.89
△WI			0.00%	-3.60 %	0.00 %	3.50 %

Reference condition at 14.73 PSIA, 60F

Note 1 . This quality forecast until year 2004 before GSP-5 commissioning

2) In case of PTT revised low HV. Of NG. Pools instead of HV. Of NG. Pools

3) In case of all unit of Gas separation Plant shut down, such as power off, etc.

4) Heating value of sales gas for billing based on contract and calculate from saturated with water vapor volume.

Conversion Factors

HHV(dry) × 0.9826 = HHV(sat)

Btu/scf(sat)(60F) × 0.03797 = MJm^3(dry)(sat)

Btu/scf(sat)(16F) × 0.03796 = MJ/m^3(dry)(st)

2) Heat exchanger (1402)

The specifications of the heat exchanger are indicated below. Table 2-2-25 shows the fluid specifications.

Quantity	: 1 unit (common to both lines)
Type	: Shell and tube-shaped gas-to-gas heat exchanger
Shell	: Steel thermal insulator lining
Nest tube	: Material High temperature boiler tube JIS STBA24
	: Tube diameter 34 mm (outer diameter), Tube thickness 1.6 mm
	: Tube length 6,500 mm, Heating surface area Approx. 1,600 m^2
Design temperature	: 600°C

Table 2-2-25. Fluid Specifications

	Unit	Tube side	Shell side
Fluid	-	GT exhaust gas	Combustion air
Flow	Nm^3/h	48,200	28,000
Inlet temperature	°C	570	324
Outlet	°C	460	524

3) Heating air fan (1409/2409)

The capacity of the heating air fan is calculated as follows.

Considering the margin as 1.1 according to the balance after the modification shown in Figure 2-2-13,

1.291 Nm^3/kg-cl x 260 t/d x 1,000 x 1/24 x 1/60 x 1.1 = 256 Nm^3/min

Quantity	: 2 units (1 unit per line)
Type	: Turbo fan
Capacity	: 290 m^3/min
Pressure	: 1000 mmAq 30°C
Electric motor	: 90kW x 2p (each)

4) Swirl calciner (1421/2421)

Quantity	: 2 units (1 unit per line)
Type	: Steel refractory lining
Capacity	: 260 t/d-clinker
Approximate dimensions	: 1600 mm (D) x 3500 mm (H)

5) Mixing chamber (1422/2422)

Quantity	: 2 units (1 unit per line)
Type	: Steel refractory lining
Capacity	: 260 t/d-clinker
Approximate dimensions	: 2300 mm (L) x 2300 mm (W) x 5000 mm (H)

6) Kiln burner (1423/2423)

The combustion capability is calculated as follows:

Considering the margin as 1.2 according to the balance after the modification shown in Figure 2-2-15,

0.089 kg/kg-cl x 260 t/d x 1,000 x 1/24 x 1.2 = 1157 kg/h

Quantity	: 2 units (1 unit per line)
Capacity	: Max. 1200 kg/h
Type	: Pressure binary spraying type burner
Combustion unit	: Existing unit is used

7) 1424/2424 Kiln primary air fan

The capacity of the kiln primary air fan is calculated as follows.

Considering the kiln combustion air as 65% of all the combustion air, the primary air as 10%, and the margin as 1.2 according to the balance after the modification shown in Figure 2-2-15,

1.291 Nm^3/kg-cl x 0.65 x 0.1 x 260 t/d x 1,000 x 1/24 h/d x 1/60m/h x 1.2= 18.2 Nm^3/min

Quantity	: 2 units (1 unit per line)
Type	: Turbo fan
Capacity	: 20 m^3/min
Pressure	: 2,000 mmAq at30°C
Electric motor	: 15 kW x 2p (each)

8) Swirl calciner burner

The combustion capability is calculated as follows:

Considering the margin as 1.2 according to the balance after the modification shown in Figure 2-2-15,

0.048 kg/kg-cl x 260 t/d x 1,000 x 1/24 h/d x 1.2= 624 kg/h

Quantity	: 2 units (1 unit per line)
Capacity	: Max. 700 kg/h
Type	: Pressure binary spraying type burner
Combustion unit	: Screw type pressure pump and electric heater

(5) Impact of the Khao Wong Factory on the Ambient Air after Modification

Once new equipment has been introduced under the project, natural gas, which has good properties, will replace some of the heavy oil used as a fuel. As a result, the addition of the swirl calciner and the steam injection system to the gas turbine will reduce sulfur oxide and nitrogen oxide emissions. The amount of dust will not change appreciably. The amount and quality of wastewater will remain unchanged, while soundproofing measures will also be taken to reduce the noise of the gas turbine.

Consequently, we have concluded that modification of the system will not add any load to ambient air or to the environment in general.

2-2-5. Funding, equipment, service and other elements of the project provided by the two parties

(1) Funding

1) Cost of modifying the plant

This project will be implemented through funding by the Thai side (Siam Cement Corporation). The Japanese side will support the project by providing advice on the investment plan for plant and equipment and the profitability of the project.

2) Cost of laying the natural gas pipeline

In principle, the gas pipeline should be laid by PTT (Petroleum Authority of Thailand). However, their schedule is undecided. The user, Siam Cement, will have to lay the line at its own expense, if time becomes an issue.

3) CDM scheme

Once the Thai side has requested the cost-sharing of this project according to the CDM scheme of the Japanese side, the Japanese side will be willing to make offers to corporations in Japan that need to reduce CO_2 emissions. In addition, as for the funding it will discuss the CDM under the precondition of supplier's credits with the Thai side as soon as the CDM scheme has been determined.

(2) Facilities and equipment

All the facilities and equipment required for this project, including domestic and overseas products, should be planned, designed, procured, and transported by the project implementation department of the Thai side. The construction, installation, provision of utilities, trial runs, and training related to the facilities and equipment should follow the same procedure.

The Japanese side will give advice on the overall plan, implementation organizations, adoption of consultants, and other aspects in starting up the project implementation department.

(3) Other issues

When the cost is shared by corporations in Japan or under yen credits, the necessary permission and approvals should be obtained by the Thai side and the Japanese side in their respective countries.

2-2-6. Preconditions and problems related to project implementation

(1) Recovery of white cement demand

SCI has great need of this project, which will not only conserve energy but also increase productivity in the manufacture of white cement. On the other hand, SCI intends to implement the project when the need to increase production of white cement arises. Therefore, a recovery in the demand for white cement is a precondition for this project.

Due to the economic crisis in Asia, the production of white cement at this plant has decreased more than 20% since it reached a peak of 145 thousand metric tons in 1997. Unlike gray cement, the demand for white cement is easily influenced by business conditions. The economic climate in Thailand is expected to improve.

(2) Laying of natural gas pipeline

The fuel used in the gas turbine generator is natural gas. The laying of a natural gas pipeline to the plant is an important precondition for this project.

An on-site survey revealed that PTT's schedule does not make allowances for about 17km of pipeline joining the plant to the existing pipeline. For the new pipeline to become a reality, there are two options: the demand for natural gas should be developed in or around the plant sufficient to invite PTT to lay the pipeline, or SCI should lay it by itself at its own expense. Which route to take depends on SCI's plan for the future. At present, the latter is the only way to realize the plan.

(3) Power supply to the gray cement plant

The gas turbine generating equipment should be operated at full capacity to maintain its generation efficiency. It is more economical that power produced in excess of the demand of the white cement plant, or surplus power resulting from production adjustments, should be consumed by the adjacent gray cement plant, rather than sold to the system power company.

For power adjustments between the two plants, the wiring should be laid separately, or it should be consigned to EGAT. Which choice to take will be determined in the course of implementing the project. However, in the case of laying wiring, the amount of capital investment will increase, which will affect the economies possible under the project.

2-2-7 Project schedule

Table 2. 2-26 shows the project schedule to follow procurement of funding and acquisition of permits and approvals.

Table 2. 2-26. Project Schedule

Project stage	Period (Months)	1st Year 1 6 12	2nd Year 13 18 24
Survey/Design	6		
Procurement/ Manufacturing	1 2		
Transportation	2		
Construction/ Installation	1 0		
Trial run	3		

Section 3. Development of the Funding Plan

2-3-1 Funding Plan for Project Implementation

(1) Required Funds

The funds required to implement the project (construction costs) are summarized in Table 2-3-1. The details are as follows.

As stated in 2-2-4 (2) 1) "Details," the goal of this project is to conserve energy and reduce carbon dioxide emissions through the following:

a) introduction of a steam injection gas turbine generator;

b) introduction of a kiln air heater; and

c) modification of the raw material preheater with the addition of a swirl calciner.

The following is a comparison of the machinery and equipment costs to the construction costs:

In a), one steam injection gas turbine generator is installed for two white cement production lines. The details of the machinery and equipment costs related to this are indicated in 1)- 8), No. 1, Table 2-3-1. They total 157.5 million baht, which accounts for almost 50% of the total construction costs.

In b), the major device, the kiln combustion air heat exchanger, is installed next to the steam injection gas turbine generator in a). Its capacity covers Lines No. 1 and No. 2. Two sets of pipes and valves are required to connect the two lines and modify the existing piping.

In c), the preheaters and the kiln burners of Lines No. 1 and No. 2 are modified. Pipes and fans are modified and installed in relation to b) and c). The machinery and equipment costs relevant to the two white cement production systems in b) and c) total 61.9 million baht, which represents 19.7% of the total construction costs.

Transportation expenses total 5 million baht, or about 1.6% of the construction costs. These expenses consist of the cost of sea transport for the gas turbine generator and other machinery to be imported from overseas as well as the cost of transporting all equipment by land.

The installation work is estimated at 27.8 million baht, or about 8.8% of the construction costs. This includes the cost of dispatching an installation instructor for the gas turbine generator purchased from abroad as well as the cost of installing all the equipment.

The civil engineering and construction costs total 8.4 million baht, which represents about 2.7% of all the construction costs. This includes foundation work and construction of the electricity room for the gas turbine generator, foundation work for the white cement plant heat exchanger, and frame foundation work required for modification of piping and installation of the swirl calciner.

Indirect costs related to site work are expected to total 5.5 million baht, accounting for roughly 1.8% of the construction costs. These are expenses for general management work, including distribution and schedules.

The cost of coordinating the trial run, including the expenses for dispatching a trial run coordination instructor for the steam injection gas turbine generator and the white cement plant, totals 21.8 million baht, or about 6.9% of the total construction costs.

The project management and design costs, combining the general management costs and design costs from scheme design to detailed design, total 26.6 million baht and account for about 8.5% of the total construction costs.

Thus, the amount required for investment in plant and equipment under this project totals 314.5 million baht, which is equivalent to about ¥849 million (at an exchange rate of 1 baht to 2.7 yen).

Excluded from this amount is approximately 20 million baht (approximately ¥54 million), the cost of laying a 6-inch pipeline from the current terminal of the natural gas pipeline to the gas turbine installation site, a distance of 17 kilometers.

(2) Funding

Negotiations will continue to have this project considered a CDM project. Regardless, once the demand for white cement recovers, the possibility of implementing this project will be high. However, having the project declared a CDM project would have a significant effect on funding.

a. Implementation as a non-CDM Project

The funds required for construction are about ¥850 million, and the project would not total ¥1 billion even if the cost of laying the natural gas pipeline were included. Considering the capacities of SCI and its parent company, Siam Cement Group, we think it would not be difficult for SCI to raise the needed funds by themselves once the profitability of the project has been fully explained. Although some of the equipment, such as the gas turbine, should be imported from Japan, SCI is considering implementing this project as a self-funded initiative.

b. Implementation as a CDM Project

If special CDM loans are arranged in Japan or a part of the ODA budget (Japanese government loans) is provided for CDM under the terms of the COP6 (Bonn) agreement scheduled for July 2001, they will be put to use. However, the possibility remains uncertain at this point. Negotiations will be made with SCI on the basis of export credits (supplier's credits).

Essentially, 60 to 70% of the funds required for this project (upper limit) are expected to be raised by export credits to cover the gas turbine, which accounts for roughly 50% of the cost of investment in plant and equipment. In this case, the Japanese side will apply for the export credit.

The International Center for Environmental Technology Transfer (ICETT) will coordinate promotion of the project with SCI and MOSTE/OEPP, a control institution of CDM, as well as funding procedures and so on with the Japan Bank for International Cooperation and Japanese exporting corporations.

Table 2. 3-1. Cost of Modifying the White Cement Plant

	Details	Amount (Thousands of baht)
1. Machinery and equipment (Gas turbine-related)	1 set	<157,500>
1) Gas turbine package	4,770kW gas turbine, reduction gear, generator, control panel, enclosure, etc.	81,000
2) Electricity-related panels and transformers	Generator panel, auxiliary panel, DC power panel, low-voltage transformer, step-up transformer, etc.	21,500
3) Attached equipment	Instrumentation air equipment, cooling water pump, nitrogen oxide meter, hydraulic starter, etc.	4,300
4) Steam injection unit		5,900
5) Exhaust boiler	7.5t/h x 20K	16,300
6) Pure water system	7.5t/h	18,500
7) Exhaust tube		1,000
8) Fuel gas compressor	1800Nm3 x 20K	9,000
2. Machinery and equipment (related to white cement plant)		<61,900>
1) Kiln combustion air heat exchanger	1600 m^2 x 600℃: 1 unit	10,300
2) Piping & valves for kiln combustion air	2 sets	6,600
3) Kiln combustion air fans	250Nm^3/min x 1000mmAq 2units	500
4) Swirl calciners	2 units	1,400
5) Swirl calciner mixing chambers	2 units	8,700
6) Kiln burner	2 sets	8,400
7) Swirl calciner burner	2 sets	9,900
8) Swirl calciner slipstream duct	2 sets	2,000
9) Electrical and instrumentation equipment	2 sets	14,100
3. Transportation costs	1 set	<5,000>
1) Gas turbine-related	1 set	3,800
2) Related to white cement plant	1 set	1,200
4. Cost of installation work	1 set	<27,800>
1) Related to gas turbine	1 set	16,800
2) Related to white cement plant	1 set	11,000
5. Civil engineering and construction work	1 set	<8,400>
6. Indirect costs related to on-site work	1 set	<5,500>
7. Trial run coordination cost	1 set	<21,800>
8. Project management and design cost	1 set	<26,600>
Total	1 baht = 2.7 yen	<314,500>

Excluded work: Laying a pipeline from the current natural gas pipeline terminal to the gas turbine installation site

Calculated at an exchange rate of 1 baht = 2.7 yen

Operation and maintenance costs

	Specified period	Amount (Thousands of baht)
Gas turbine	1st year	2,400
	2nd year	2,400
	3rd year	2,400
White cement-related	Every year	40,800

2-3-2 Prospects for Funding

Considering the scale of SCI, we believe it would be relatively easy for the company to raise the funds necessary for this project on their own. Therefore, we will continue negotiations for a CDM project. Regardless of whether it is considered a CDM project, funding will not be a problem once it has been decided to implement this project.

If SCI agrees to this project as a CDM project, they will use a CDM special loan, funds from the ODA budget (Japanese government loan), export credits (supplier's credits) and other arrangements. Therefore, we will continue to examine better approaches to fundraising, paying careful attention to the international agreements on the CDM framework.

In any event, SCI's first priority is to be sure of the potential of this project. In this report, the economics are assessed on a self-funding basis.

Section 4. Things related to CDM conditions

2-4-1 Arrangement and adjustment with the partner for the purpose of realizing CDM: Setting project conditions and work responsibility by taking into account the actual situation of the project cite

1. Confirming the economic efficiency of the project and preparing a working plan
   Siam Cement shall primarily examine these matters and Japan shall give advice.

2. Making an agreement with Thai companies and the Thai Government about methods for defining and measuring an "additional" reduction in emissions by comparison with possible cases in the absence of the project.
   Siam Cement and Japan shall jointly make a trial calculation and then a proposal to meet with the approval of the Ministry of Science Technology and Environment (MOSTE) of the Thai Government.

3. Negotiations toward a common recognition that the project has priority as an energy-saving project in Thailand.
   To meet with the approval of MOSTE, Siam Cement shall negotiate with the Thai government, and Japan shall provide technical materials necessary for the negotiations.

4. Construction plan and construction work
   Siam Cement shall execute the planning, design, procurement, transportation, public engineering works, installation work, utilities, trial runs, education and training for the project, and Japan shall give advice on a general plan, executing organization, and employment of consultants. As for the details, further arrangements will be necessary.

5. Funds and allowances
   Siam Cement shall file an application for and Japan shall give advice on the choice of funds from Japanese additional ODA and the CDM, so as to meet with the approval of the governments of Thailand and Japan.

6. Application to the CDM administrative organization and obtaining a certificate of an amount of emissions reduction (CER).
   Japan shall primarily execute these matters and Thailand shall cooperate with Japan. Both

nations shall hold deliberations on the distribution of a certified amount of emissions reduction (CER).

2.4.2 Possibility to agree that the project is regarded as CDM

The Thai Government or Thai industry does not seem to have any definite policy about the CDM at present. In fact, the Thai Government's position is that they are on standby until details of the CDM will be officially decided at COP, according to an official of the Office of Environment Policy and Planning (OEPP) in MOSTE.

At present, the Japanese side guesses that whether the Thai Government will agree on the project as a CDM project depends on the following matters.

1. CO2 reduction is seen as an issue for developed nations to solve. The Thai Government would agree on the project if they admit that the project will reinforce the competitiveness of domestic companies as a result of cost reduction or fostering energy saving in the country.

2. The amount of CO2 reduction is too small to adopt the project as an independent CDM project. It should be taken up jointly with other energy-saving projects and fuel-conversion projects.

3. It will not be adopted as a CDM project until all the conditions—significant and prompt effectiveness and profitable financing conditions—are provided.

4. The Thai Government regards it as important that the source of the funds should not correspond to the primary ODA, but that the funds should be an additional budget.

5. The aim of CDM projects in Thailand will be affected by the evaluation of the results of Activities Initiated Jointly (AIJ) conducted in Thailand by Japan, according to an official of MOSTE/OEPP.

Chapter 3. Effects of the Project

This chapter describes the effects of the project on energy conservation, reduction in greenhouse gas, and influence on the productivity, and other factors.

Section 1. Energy-saving effect

3-1-1 Technical grounds for energy-saving effects

The energy balance by implementation of the project is as follows. As the total, energy-saving effects are generated.

1) The kiln's heavy oil consumption is reduced through use of the exhaust gas from a new gas turbine to preheat air in the cement kiln, and by modification the preheater to improve the calcination process ahead of the kiln.
2) Supplying the white cement plant and the adjacent gray cement plant with electricity generated by the gas turbine generator reduces the amount of power purchased. This, in turn, decreases the fuel consumption of the existing thermal power stations.

3-1-2 Baseline for calculating the effects

In order to carry out this facility improvement, we assume the following preconditions for evaluating its effects.

Output: Determined according to the operating records of the preceding five years
White cement (clinker base) 2 x 220 t-cl/d
Fuel consumption: Actual consumption at time of survey
Heat value per unit output of clinker 1,420 kcal/kg-cl
Electricity: Actual consumption at time of survey
Power purchased 3,360 kW

The energy consumption of the white cement plant includes the following:
- Heavy oil purchased as fuel for the cement burning kiln; and
- Power purchased for the white cement plant.

Table 3-1-1 shows the baseline energy consumption of the white cement plant.

Table 3-1-1. Baseline energy consumption of the white cement plant

Number	Classification	Base value for the amount of energy consumption	Gross energy $\times 10^6$ [kcal/y]	Crude oil equivalent [toe]	Ratio [%]
1	Heavy oil	1,420 kcal / kg-cl	187,440	18,744	76.0
2	Power purchased	3,360 kW	59,139	5,914	24.0
Subtotal (crude oil equivalent)			246,579	24,658	100.0

The calorific value of crude oil is set as 10,000 kcal/kg.

As shown in the above table, the amount of energy used in this plant is equivalent to about 25,000 metric tons of crude oil. The method of obtaining a crude oil equivalent will be given for each item from the following paragraph (1).

(1) Energy consumed as heavy oil

Output of clinker-base white cement= 2×220 t-cl / d
Energy required per unit output= 1,420 kcal / kg-cl
Operating days per year = 300 d / y

Gross calorific value of fuel
= (1,420 kcal/kg-cl $\times$ 1,000 kg/t) $\times$ (2×220 t-cl/d) $\times$ 300 d/y
= $187{,}440 \times 10^6$ kcal / y
Crude oil equivalent
= $187{,}440 \times 10^6$ kcal / y / 10,000 kcal/kg / 1,000 kg/t
= 18,744 toe/y

(2) Energy used to generate the power purchased

Generating efficiency of the thermal power station*1 = 35.18 %
Operating hours per year = 7,200 h/y
*1 MOSTE (Ministry of Science, Technology and Environment) "ELECTRIC POWER IN THAILAND 1999"

Gross calorific value of the fuel
=3,360 kW $\times$ 860 kcal / kwh /0.3518 $\times$ 7,200 h/y
=$59{,}139 \times 10^6$ kcal/y
Crude oil equivalent
= 59,139 $\times 10^6$ kcal/y / 10,000 kcal/ kg / 1,000 kg/t

= 5,914 toe/y

3-1-3. Concrete energy-saving effects

(1) Quantitative effect of energy conservation

Table 3-1-2 shows the energy conservation effect for each item. Details are provided in paragraph (2) for each item.

Table 3-1-2. Energy conservation effect by type of energy reduced

Number	Type		Gross amount of reduced energy $\times 10^6$ [kcal/y]	Crude oil equivalent [toe/y]	Ratio [%]
1	Reduction in heavy oil used for calcining the kiln		13,200	1, 320	110
2	Reduction in energy for electric power	Reduction in energy for thermal power station	75, 075	7, 507	-10
3		Energy consumed for operating the turbine	▲ 76, 211	▲ 7, 621	
Total energy reduction			12, 064	1, 206	100

* Calorific value of crude oil is set as 10,000 kcal/kg.

* The total may differ from the actual sum because the figures are rounded off.

This project makes it possible to save energy equivalent to 1,200 toe/y in total. The potential amount of energy saved is about 5% of the baseline, indicating high effectiveness. Assuming that the reduction is continued for 15 years the economical life of the gas turbine, the energy reduced will total about 18,000 toe, as indicated in the following equation.

The cumulative total energy reduction (crude oil equivalent)

= Energy reduction per year $\times$ 15 y

= 1,206 toe/y $\times$ 15 y

= 18,090 toe/y

(2) Calculation of energy saved from each item

Table 3-1-3 shows the preconditions (see Chapter 2) for calculating the baseline for energy savings before and after the present project.

Table 3-1-3. Preconditions for evaluating energy savings

Item	Unit	Before the project	After the project
Clinker output	t-cl / d	2×220	2×260
Heat value required for kiln	kcal / kg-cl	1,420	1,320
Electric power required	kW	3,360	3,700
Energy generated by turbine	kW	0	4,770
Consumption of energy generated by Thai thermal power stations	kW	3,360	−1,070

This project increases the productivity of white cement. After the modification, the output of white cement will increase from 2 x 220 t-cl/d to 2 x 260 t-cl/d. In the examination of the energy conservation effect by comparison with the baseline, the energy required by the modified kiln shall be the energy necessary to produce the base case, or 2 x 220 t-cl/d. A productivity increment of 2 x 40 t-cl/d shall be disregarded. From the next paragraph (A), the calculation of energy saved is explained in detail.

(A) Energy saved due to the reduction in heavy oil used for firing the kiln

The amount of energy reduction in the kiln is obtained as follows:

Energy required after the project

$= 1,320$ kcal/kg-cl $\times$ 1,000 kg/ t $\times$ (2$\times$220) t/d $\times$ 300 d/y

$= 174,240 \times 10^6$ kcal/y

Energy required before the project (baseline): According to the result of 3-1-2-(1)

$= 187,440 \times 10^6$ kcal/y

Energy reduction in the kiln

$= (187,440 \times 10^6$ kcal/y$) - (174,240 \times 10^6$ kcal/y$)$

$= 13,200 \times 10^6$ kcal/y

Crude oil equivalent

$= 13,200 \times 10^6$ kcal/y $/$ 10,000 kcal/kg $/$ 1,000 kg/t

$= 1,320$ toe/y

(B) Energy saved due to the reduction in energy used for power generation

The electric power generated by the newly introduced turbine is consumed in the white cement plant and its adjacent gray cement plant. Electric power exceeding the demand of the white cement plant is supplied to other plants, so the Siam Cement Company purchases less electricity. Therefore, the power purchased before the project and the excess electricity after the project can be deducted from the overall energy generated by the thermal power stations in Thailand.

Turbine-generated energy = 4,770kW
Energy consumed in the white cement plant after the project = 3,700kW
Excess electricity available for other plants: 4,770 – 3,700 = 1,070kW
Energy required to generate the above excess electricity in a thermal power station

$= 1{,}070\ \text{kW} \times (860\ \text{kcal/kWh} / 0.3518) \times 7{,}200\ \text{h/d}$

$= 18{,}833 \times 10^6\ \text{kcal/y}$

Energy required, with productivity improvements deducted

$= 18{,}833 \times 10^6\ \text{kcal/y} \times (220/260)$

$= 15{,}936 \times 10^6\ \text{kcal/y}$

Energy reduced from the baseline = (energy necessary to generate the purchased power before the project: baseline) + (energy necessary to generate the excess electricity after the project)

$= 59{,}139 \times 10^6\ \text{kcal/y} + 15{,}936 \times 10^6\ \text{kcal/y}$

$= 75{,}075 \times 10^6\ \text{kcal/y}$

Crude oil equivalent

$= 75{,}075 \times 10^6\ \text{kcal/y} / 10{,}000\ \text{kcal/kg} / 1{,}000\ \text{kg/t}$

$= 7{,}508\ \text{toe/y}$

(C) Fuel consumption for gas turbine operation

Turbine generation = 4,770kW
Rate of fuel consumption of new gas turbine = 10.98 MJ/kWh; according to the energy in fuel for power generation, Chapter 2, section 2-2-4(3) 5)

Additional energy required for turbine operation

$= 4{,}770\ \text{kW} \times (10.98 \times 10^3\ \text{kJ/kWh} / 4.1868\ \text{kcal/kJ}) \times 7{,}200\ \text{h/d}$

$= 90{,}068 \times 10^6\ \text{kcal/y}$

Energy required, with productivity improvements deducted

$= 90{,}068 \times 10^6\ \text{kcal/y} \times (220/260)$

$= 76{,}211 \times 10^6\ \text{kcal/y}$

Crude oil equivalent

$= 76{,}211 \times 10^6\ \text{kcal/y} / 10{,}000\ \text{kcal/kg} / 1{,}000\ \text{kg/t}$

$= 7{,}621\ \text{toe/y}$

3-1-4. How to confirm concrete effects

Major items to confirm are clinker production, fuel used for the kiln, gas consumed for the turbine generator, power consumption, energy composition in Thai power stations, and their power generation efficiency. Such data will be collected mainly by SCI. Their monitoring can be relied upon because of their qualification for ISO9001 and ISO14000. The data on Thai power stations are available from annual reports issued by EGAT, a state-operated corporation.

An explanation of the method of confirming the effect of this project on energy conservation is provided below for each item.

(1) Energy saved due to the reduction in heavy oil used for kiln calcination

The energy consumption rate of the year concerned in the white cement process is symbolized as B, and the energy consumption rate of the base year is symbolized as A. In this report, the energy consumption rate of the baseline is 1,420 kcal/kg-cl, the heat value required to produce 1 kg of clinker.

Energy saved (kcal/y)
= output of clinker-base white cement (kg-cl/y) x (A – B) (kcal/kg-cl)

(2) Energy saved due to the reduction in fuel used to operate thermal power stations in Thailand

Here, the energy saved is equivalent to the fuel consumed by the Thai thermal power stations in order to generate an amount of electricity equal to the sum of the excess turbine-generated electricity over the demand by the white cement plant and the electricity purchased in the base year.

A: Electricity generated by the turbine generator in the year concerned (kW)
B: Energy required to operate the plants in the year concerned (kW)
C: Adjustment factor for the productivity improvement compared with the base year
= (output of cement in the base year/output of cement in the year concerned)
D: Electricity purchased at the baseline (kW)
Assuming that generating efficiency of the Thai thermal power stations is 35.18%:

Energy saved (kcal/y)

$$= [(A-B) \times C + D] \times (860\ \text{kcal/kWh} / 0.3518) \times$$

(Operating hours per year h/y)

(3) Energy required for operation of the gas turbine

Assuming that the fuel consumption rate of a gas turbine changes year to year, it would be appropriate to obtain the actual fuel consumption in order to calculate the energy consumption.

Energy required (kcal/y)
= fuel consumption (Nm^3/h) x calorific value of fuel (kcal/ Nm^3)
x operating hours per year (h/y) x adjustment factor for the productivity improvement (mentioned as C in the above paragraph 3-1-4-(2) C)

Section 2. Effect on the Reduction in Greenhouse Gas

3-2-1. Technical background to the reduction in greenhouse gas

As stated in Section 1, the present project can reduce the fuel consumption equivalent to about 1,200 metric tons of crude oil. Such a reduction in fuel consumption can be expected to decrease carbon dioxide emissions. Below is an explanation of the technical background to the reduction in greenhouse gas as it relates to each item of this project.

1) By utilizing exhaust gas from a new gas turbine in order to preheat air in the cement kiln, and by promoting the calcinations with modified preheater prior to kiln calcinations, heavy oil consumption in the kiln is reduced, resulting in a reduction in greenhouse gas.
2) The introduction of a new gas turbine generator meets the demand for electricity in the white cement plant with privately generated electricity instead of purchased power. Through the use of a fuel that emits less carbon, the greenhouse gas produced is less than that produced by the existing thermal power stations generating the same amount of electricity.

3-2-2. Baseline for calculating the effect

(1) Determining the baseline

The baseline for evaluating the reduction in greenhouse gas is the CO_2 emissions resulting from production of 2 x 220 t/d of clinker-base white cement. Table 3-2-1 shows the baseline CO_2 emission of the white cement plant. The details of the calculation will be described for each item from paragraph (2).

Table 3-2-1. CO_2 emissions from the white cement plant (baseline)

No.	Classification	Base value of energy consumption	Gross calorific value $\times 10^6$ [kcal/y]	CO_2 emission [tCO_2/y]	Ratio [%]
1	Heavy oil as fuel for the kiln	1, 420 kcal/kg-cl	187, 440	60, 108	78
2	Power purchased	3, 360 kW	59, 139	16, 962	22
Total			246, 579	77, 071	100

As shown in Table 3-2-1, the baseline CO_2 emission from the Siam Cement Company's white cement plant was about 77,000 metric CO_2-tons. In detail, the CO_2 emissions from the kiln's fuel account for eighty percent of total emissions.

(2) Calculating CO_2 emissions

The IPCC formula*[1] was used as the method of evaluating CO_2 emissions.

Equivalent in CO_2 ($t\text{-}CO_2/y$) = $\boldsymbol{a}$ x $\boldsymbol{b}$ x $\boldsymbol{c}$ x $\boldsymbol{d}$ x (44/12)

Where, $\boldsymbol{a}$: fuel consumption (kt/y)

$\boldsymbol{b}$: Unit calorific value of the fuel (TJ/kt)

$\boldsymbol{c}$: Carbon-emitting unit consumption of fuel (t-C/TJ)

$\boldsymbol{d}$: Oxidation ratio factor of carbon (-)

$\boldsymbol{e}$: Molecular ratio of CO_2 and C (= 44/12)

If $\boldsymbol{a}$ x $\boldsymbol{b}$ (TJ/y) is a known value, it shall be used in the calculation.

*1 ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual

(A) Calculation of CO_2 emissions based on use of heavy oil as fuel for the kiln

Assuming that heavy oil is used to produce the heat required in the kiln, the CO_2 emissions from heavy oil shall be calculated hereinafter. The annual gross calorific value is based on the result of this report's examination. In the equation below, the factors $\boldsymbol{c}$ and $\boldsymbol{d}$ shall be the values used in IPCC Guidelines.

Annual gross calorific value $\boldsymbol{a}$ x $\boldsymbol{b}$: According to the result of the examination of 3-1-3(2), paragraph (A)

$$= (187{,}440 \times 10^6 \text{ kcal/y}) \times (4.1868 \text{ kJ / kcal}) \,/\, (1 \times 10^9)$$

$$= 784.77 \text{ TJ/y}$$

Carbon Emission Factor of heavy oil *c* ; Revised 1996 IPCC Guidelines for National
= 21.1 t-C/TJ Greenhouse Gas Inventories : Workbook
/ Table 1-2 [Residual Fuel Oil]

Fraction of Carbon Oxidized *d*: ; Revised 1996 IPCC Guidelines for National
= 0.99 Greenhouse Gas Inventories : Workbook
/ Table 1-4 [Oil and Oil Product]

CO_2 emission t-CO_2/y

$= (a \times b) \times c \times d \times (44/12)$

$= 784.77$ TJ/y $\times$ 21.1 t-C/TJ $\times$ 0.99 $\times$ (44 / 12)

$= 60{,}108$

(B) Calculation of CO_2 emissions from the fuel required to generate electricity equivalent to the purchased electricity

The electricity required by the white cement plant is purchased from thermal power stations in Thailand. They use several kinds of fuel that differ in CO_2 emission factor. In Thailand, the percentage of natural gas used as the fuel to fire thermal power stations is rising every year. Therefore, it is appropriate to consider the CO_2 emission factor of each kind of fuel.

Table 3-2-2 shows the share of fuel used in the thermal power stations in Thailand in 1999*[1] and the CO_2 emission when generating the baseline purchased power of 3,360kW. The generating efficiency shall be considered as 35.18%*[1].

Table 3-2-2. Breakdown of fuels used in thermal power stations in Thailand

Item	Heavy oil	Light oil	Coal	Natural gas	Total
Breakdown of fuels used by thermal power stations in 1999 (by caloric value)*1 (%)	20.0	0.7	19.4	59.9	100
Annual CO_2 emissions from generation of 3,360kW of electricity t-CO_2/ y	3,793	127	4,763	8,279	16,962

*1*Electric Power in Thailand 1999*, MOSTE (Ministry of Science, Technology and Environment)

According to Table 3-2-2, the CO_2 emissions from generating an amount of electricity equivalent to the power purchased by the white cement plant total about 17,000 metric tons-CO_2 per year. Below are explained the details of calculating the CO_2 emission of each kind of fuel.

The energy consumed by thermal power stations in Thailand to generate an amount of electricity equivalent to the power purchased is obtained as follows, according to the results of paragraph 3-1-2-(2).

Annual energy consumption

$= 59{,}139 \quad \times 10^{6}\,\mathrm{kcal / y} \times 4.1868\,\mathrm{kJ / kcal} \times 10^{-9}\ \mathrm{TJ / kJ}$

$= 247.60\ \mathrm{TJ/y}$

According to the actual allocation of fuel used in Thai thermal power stations in 1999, shown in Table 3-2-2, the consumption of each type of fuel is as follows.

Annual energy consumption ***a*** × ***b*** (TJ/y)

Heavy oil : 247.60 TJ/y × 0.200 = 49.520
Gas oil : 247.60 TJ/y × 0.007 = 1.733
Coal : 247.60 TJ/y × 0.194 = 48.034
Natural gas: 247.60 TJ/y × 0.599 = 148.312

Carbon Emission Factor ***c*** (t-C/TJ) ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-2

Heavy oil : 21.1 ; [Residual Fuel Oil]
Gas oil : 20.2 ; [Diesel Oil]
Coal : 27.6 ; [Lignite]
Natural gas : 15.3 ; [Natural Gas]

Fraction of Carbon Oxidized ***d*** ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-4

Heavy oil : 0.99 ; [Oil and Oil Product]
Light oil : 0.99 ; [Oil and Oil Product]
Coal : 0.98 ; [Coal]
Natural gas : 0.995 ; [Gas]

According to the IPCC formula, CO_2 emissions are obtained as follows:

CO_2 emissions $= (a \times b) \times c \times d \times (44 / 12)$

Heavy oil : 49.520 × 21.1 × 0.99 × (44 / 12) = 3,793 t-CO_2 / y
Light oil : 1.733 × 20.2 × 0.99 × (44 / 12) = 127 t /-CO_2y
Coal : 48.034 × 27.6 × 0.98 × (44 / 12) = 4,763 t-CO_2 / y
Natural gas: 148.312 × 15.3 × 0.995 × (44 / 12) = 8,279 t-CO_2 / y

The CO_2 emissions arising from energy consumed by the thermal power stations are the total of the above obtained CO_2 emissions. Therefore:

CO_2 emissions (total)

= 3,793 + 127 + 4,763 + 8,279

$= 16{,}962 \quad t-CO_2/y$

3-2-3. Concrete CO_2 reduction effects

(1) Reduction in CO2

Table 3-2-3 shows the effect on the reduction in CO_2. The details of the calculation are explained below for each item in paragraph (2).

Table 3-2-3. Effect on the reduction in CO_2

No.	Cause of the reduction in CO2 emissions		Type of energy reduced	Gross calorific value 10^6 kcal/y	Reduction in CO_2 emissions t-CO_2 / y	Ratio %
1	Reduction in heavy oil used for firing the kiln		Heavy oil	13, 200	4, 233	53. 2
2	Reduction in energy used to generate electricity	Reduction in energy used by thermal power stations	Several kinds of fuel	75, 075	21, 534	46. 8
3		Energy consumed to operate the turbines	Natural gas	▲76, 212	▲17, 812	
Total				12, 063	7, 955	100

As shown in Table 3-2-3, the present project can reduce CO_2 emissions by about 8,000 metric tons-CO_2, which is equivalent to ten percent of the baseline. In detail, the reduction in heavy oil used for the kiln accounts for 53% of overall CO_2 emissions. The reduction in energy used for generation is very effective. Natural gas, which is used for gas turbines, emits less CO_2. Therefore, gas turbine generation can reduce CO_2 emissions more than a general thermal power station using several kinds of fuel to generate the same amount of electricity. However, the effect of this project on the reduction in CO_2 emissions might diminish over time because the proportion of natural gas used in the Thai thermal power stations is increasing year by year. In addition, the turbine generator to be introduced is inferior in power generating efficiency to the thermal power stations in Thailand.

Assuming that the above-stated reductions in CO_2 emissions continue and are cumulative for fifteen years the economical life of the gas turbine, and that CO_2 emissions are maintained as stated above, CO_2 emissions are expected to decrease to 120,000 metric tons in total.

Reduction in CO_2 emissions

= Annual reduction in CO_2 emissions x fifteen years

$= 7{,}955 \times 15 = 119{,}325$ t-CO_2

(2) Reduction in CO_2 emissions due to reduction in amount of heavy oil used for the kiln

Annual reduction in energy ***a*** x ***b***: the result in 3-1-3-(2)-(A)

$= 13{,}200 \times 10^6$ kcal / y

$\times$ 4.1868 kJ / kcal $\times$ 10^{-9}

$=$ 55.27 TJ / y

Carbon Emission Factor of heavy oil ***c***: ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-2 [Residual Fuel Oil]

$=$ 21.1 t-C / TJ

Fraction of Carbon Oxidized ***d***: ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-4 [Oil and Oil Product]

$=$ 0.99

CO_2 emission

$= (a \times b) \times c \times d \times (44 / 12)$

$= 55.27 \times 21.1 \times 0.99 \times 44 / 12$

$=$ 4,233 t-CO_2 / y

(3) Reduction in CO_2 emissions due to the reduction in amount of energy used for thermal power generation

The reduction in energy consumed by thermal power stations in Thailand is obtained as follows, according to the results of paragraph 3-1-3-(2)-(B).

Annual reduction in energy

$= 75{,}075 \times 10^6$ kcal / y $\times$ 4.1868 kJ / kcal $\times$ 10^{-9} TJ / kJ

$=$ 314.32 TJ/y

Based on the actual share of fuel used in Thai thermal power stations in 1999, the reduction in energy consumption by type of fuel is as follows.

Annual reduction in energy ***a*** x ***b*** (TJ/y)

Heavy oil: 314.32 TJ/y $\times$ 0.200 $=$ 62.864

Gas oil : 314.32 TJ/y $\times$ 0.007 $=$ 2.200

Coal : 314.32 TJ/y $\times$ 0.194 $=$ 60.978

Natural gas: 314.32 TJ/y $\times$ 0.599 $=$ 188.278

Carbon Emission Factor ***c*** (t-C/TJ) ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-2

Heavy oil : 21.1 ; [Residual Fuel Oil]

Gas oil : 20.2 ; [Diesel Oil]

Coal : 27.6 ; [Lignite]
Natural gas: 15.3 ; [Natural Gas]

Fraction of Carbon Oxidized ***d*** ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-4

Heavy oil : 0.99 ; [Oil and Oil Product]
Gas oil : 0.99 ; [Oil and Oil Product]
Coal : 0.98 ; [Coal]
Natural gas: 0.995 ; [Gas]

According to the IPCC formula, the CO_2 emissions are obtained as follows:

CO_2 emissions: $= (a \times b) \times c \times d \times (44 / 12)$

Heavy oil : $62.864 \times 21.1 \times 0.99 \times (44 / 12) = 4{,}815$ t-CO_2 / y
Gas oil : $2.200 \times 20.2 \times 0.99 \times (44 / 12) = 161$ t /-CO_2 y
Coal : $60.987 \times 27.6 \times 0.98 \times (44 / 12) = 6{,}048$ t /-CO_2 y
Natural gas : $188.278 \times 15.3 \times 0.995 \times (44 / 12) = 10{,}510$ t /-CO_2 y

The reduction in CO_2 emissions attributable to the reduction in energy consumed by thermal power stations is the total of the amounts of CO_2 emissions obtained above. Therefore:
CO_2 emission (total)

$= 4{,}815 + 161 + 6{,}048 + 10{,}510$
$= 21{,}534$ t-CO_2 / y

(4) Energy consumed for turbine operation

Annual energy consumption ***a*** x ***b***: According to the results of paragraph 3-1-3-(2)-(c)

$= 76{,}211 \times 10^6$ kcal/y
$\times 4.1868$ kJ /kcal $\times 10^{-9}$
$= 319.1$ TJ/y

Carbon Emission Factor of fuel ***c***: ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-2 [Natural Gas]
$= 15.3$ t-C / TJ

Fraction of Carbon Oxidized ***d***: ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-4 [Gas]
$= 0.995$

CO_2 emissions

$= (a \times b) \times c \times d \times (44 / 12)$
$= 319.1 \times 15.3 \times 0.995 \times (44 / 12)$
$= 17{,}812$ t / y

3-2-4. Method of confirming the effect

The CO_2 emissions can be obtained from the amount of heavy oil used for firing the kiln, the power purchased, the electricity generated by the turbines, and the amount of natural gas used as fuel for turbine operation, as calculated when determining the baseline. Because these factors depend on outputs of products, however, confirming the effect of the present project is not so simple.

Therefore, the concrete effect of each item on energy conservation is to be confirmed through the method discussed in paragraph 3-1-4 and calculated by the above method.
Consequently, the concrete energy saving effect for each item should be confirmed by the approaches examined in 3-1-4 and calculated by the above-mentioned method. Monitoring by SCI, which is qualified for ISO9002 and ISO14001, is reliable. The data on Thai power stations are easy to confirm from annual reports by EGAT, a state-owned corporation.

Section 3 Effects on Productivity

As mentioned in 2-2-4(2) "2) Manufacturing process and equipment after the modification," this project aims at enhancing thermal efficiency (energy saving) and productivity (production increase) by introducing the swirl calciner to the clinker manufacturing department, where approximately 35% of the required furl is burned for heating of the material. This is because calcination, most of which has been effected in the rotary kiln, is moved to the draft heating zone before the kiln to improve heat exchange efficiency.
By introducing the swirl calciner, the baseline of the existing equipment, approximately 220 t/d clinker-base in each line, will be able to increase to 260 t/d clinker-base. This results in a productivity increase of approximately 18%. Modification of the equipment under this project will not affect the quality of cement.

Reference: Research on the effect of kiln fuel conversion on greenhouse gas reduction

SWCC is planning to convert its kiln fuel from heavy oil to petroleum coke in order to reduce fuel expenses. As a reference, here we explain research on two approaches to reducing CO_2 emissions: conversion of kiln fuel from 100wt% heavy oil to a combination of 90wt% petroleum coke and 10wt% heavy oil; and introduction of a gas turbine power generator.

1. Calculating CO_2 emissions from the kiln

CO_2 emissions were calculated according to the same preconditions as indicated in the main text. Table Re-1 shows the results. CO_2 emissions were evaluated according to the IPCC Guidelines. For the calculation method, please see paragraph 3-2-2-(2) in the main text.

Table Re-1. Calculating CO_2 emissions from the kiln

	Fuel= Heavy oil		Fuel=Heavy oil (10%) & petroleum coke (90%)	
	Baseline	After the project	Baseline	After the project
CO_2 emissions from petroleum coke t-CO_2/y	0	0	69,408	64,520
CO_2 emissions from heavy oil t-CO_2/y	60,108	55,875	6,853	6,371
Total CO_2 emissions t-CO_2/y	60,108	55,875	76,261	70,891
Reduction in CO_2 emissions t-CO_2/y	—	4,233	—	5,371

The details of petroleum coke and heavy oil used in the calculation are as follows:

Unit calorific value a (kcal/kg): from results of on-site investigation
Heavy oil : 9,650
Petroleum coke: 8,332

Energy required from each type of fuel after fuel conversion $a \times b$ (TJ/y)
Heavy oil : (required gross energy: TJ/ y, according to main text)
$\times$ [$(a_{\text{heavy oil}} \times 0.1)$ / {$(a_{\text{heavy oil}} \times 0.1) + (a_{\text{petroleum coke}} \times 0.9)$}]
Petroleum coke: (Required gross energy: TJ/ y, according to main text)

$\times$ [($a_{\text{petroleum coke}} \times 0.9$) / {($a_{\text{heavy oil}}$ x 0.1) + ($a_{\text{petroleum coke}}$ x 0.9)}]

Carbon Emission Factor c (t-C/TJ) ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-2

Heavy oil	: 21.1	; [Residual Fuel Oil]
Petroleum coke	: 27.5	; [Petroleum Coke]

Fraction of Carbon Oxidized d ; Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories : Workbook / Table 1-4

Heavy oil	: 0.99	; [Oil and Oil Product]
Petroleum coke	: 0.99	; [Oil and Oil Product]

2. Comparison of baseline CO2 emissions

According to Table Re-1 and the main text, Table Re-2 shows the baseline CO_2 emissions before and after the kiln fuel conversion.

Table Re-2. Comparison of baseline CO_2 emissions

	Kiln fuel	
	Heavy oil	Heavy oil (10%) & petroleum coke (90%)
CO_2 emissions from kiln t-CO_2 / y	60,108	76,261
CO_2 emissions due to power purchased t-CO_2 / y	16,962	16,962
Total CO_2 emissions t-CO_2 / y	77,070	93,223
Increase in CO_2 emissions due to fuel conversion t-CO_2/ y	—	16,153

As shown in Table Re-2, annual baseline CO_2 emissions will increase by about 16,000 metric tons-CO2 (representing an increase of 20% compared with use of heavy oil alone).

3. Comparison of CO2 emissions after the project

According to Table Re-1 and the main text, Table Re-3 lists CO_2 reductions resulting from the kiln fuel conversion.

Table Re-3. Comparison of reduction in CO_2 emissions after the project

	Kiln fuel	
	Heavy oil	Heavy oil(10%) & petroleum coke(90%)
CO_2 reduction due to energy saving at the kiln t-CO_2 / y	4,233	5,371
CO_2 reduction due to reduction in electricity consumed t-CO_2 / y	3,722	3,722
Annual CO_2 reduction in total t-CO_2 / y	7,955	9,093
CO_2 reduction rate at kiln %	53.1	59.1
Total baseline reduction in CO_2 emissions %	10.3	9.8

As shown in Table Re-3, when kiln fuel is mainly petroleum coke, reduction in CO_2 emissions resulting from energy saving at the kiln accounts for about sixty percent of the total CO_2 reduction.

Also, the annual reduction in CO_2 emissions will increase about 15% in comparison with the case in of no fuel conversion. Since fuel conversion will increase the baseline CO_2 emissions, however, the rate of reduction in CO_2 emissions at the baseline will drop 0.5%.

4. Accumulation of CO_2 reduction

Assuming that the energy conservation effect of the project would continue for 15 years the economical life time, we calculated the CO_2 reduction over that period. It is expected that CO_2 emissions would be reduced by 140,000 metric tons in total through fuel conversion, compared with a reduction of 120,000 metric tons with the kiln fueled by heavy oil.

Cumulative CO_2 reduction (t)

$$= \text{annual } CO_2 \text{ reduction} \times 15$$

$$= 9{,}093 \text{ t-}CO_2/\text{y} \times 15\text{y}$$

$$= 136{,}395 \text{ t-}CO_2$$

Chapter 4. Profitability

In Chapter 2, we proposed a project encompassing primarily the introduction of a gas turbine power generator and a partial improvement of the production process, and calculated the expenses required to carry out the project. In this chapter, we examine the expected reduction in fuel consumption after the project and the profit accruing from gas turbine generation in order to estimate the profitability of the project, such as its investment payback and cost-effectiveness.

Section 1. Economic Investment Payback

4-1-1. Standard of capital investment in SCI

A capital investment plan is the pillar of a management plan targeting corporate growth and stability. Therefore, in determining investment, it is necessary to consider a financial structure, a financing method and other characteristics of the corporation. As for the capital introduction and improvement proposed here, it is particularly necessary to properly estimate the profitability from the viewpoint of Siam Cement Industry Co.(SCI). Prior to the profitability study, we examined the SCI's method of evaluating a capital investment plan. Table 4-1-1 shows the results of this examination.

Table 4-1-1. SCI's method of evaluating a capital investment plan

Number		Examination results
1	Method of evaluation	The collection period method as the principal method and the internal rate of return method (IRR) as a subsidiary method
2	Amortization period	5–15 years (Periods of 10 years and 15 years are applied.)
3	Depreciation method	Straight-line depreciation (no residual value)
4	Depreciation period	5 years or 10 years, depending on the amount of money invested
5	Discount rate	7.5 %
6	Criterion	*Evaluation standard by the collection period method Within 4 years *Evaluation standard by the internal rate of return method IRR > 21%

4-1-2. Profitability study

(1) Preconditions

Here are the preconditions that are used in the profitability study. Other conditions will be mentioned separately.

1) After the project, the capacity for producing clinker-base white cement will increase from 2 x 220 t/d to 2 x 260 t/d. The profitability study will use the base production capacity of 2 x 260 t/d and the production capacity of 2 x 220 t/d, which is obtained by deducting the increase in productivity of 2 x 40 t/d from the base production capacity.
2) When the amount of power generated by the gas turbine generator exceeds the demand from the white cement plant, the excess power will be consumed in the adjacent gray cement plant of Siam Cement Company.

3) Table 4-1-2 shows the preconditions of fuel data.

Table 4-1-2. Fuel data (Results of on-site examination)

Type of fuel	Lower calorific value	Price
Heavy oil	9,650 kcal/kg	8,177 Baht/ton
Natural gas	845 Btu/SCF	116 Baht/MMBtu Note 1 129 Baht/MMBtu Note 2

Note 1: This is PTT Gas's preferred price for a new investment in cogeneration facilities, and is applied for the initial five years.

Note 2: This is a regular price applied to cogeneration facilities.

4) Table 4-1-3 shows the preconditions regarding power data.

Table 4-1-3. Power data (Results of on-site examination)

Generating efficiency (Note 3)	35.18 %
Unit price of power	2.1 Baht/kwh

Note 3: Ministry of Science Technology and Environment (MOSTE), *Electric Power in Thailand 1999*

5) Table 4-1-4 shows the factors relevant to the profitability study.

Table 4-1-4. Factors relevant to the profitability study

Exchange rate *4	2.7 yen/baht
Rate of rise in unit price of fuel *5	3.0 %/year
Rate of rise in unit price of power *5	3.0 %/year
Rate of rise in fixed costs *5	3.0 %/year
White cement production capacity	2 x 220 metric tons of clinker/day
Annual number of days of capacity utilization	300 days/year
Annual number of hours of capacity utilization	7,200 hours/year

Note 4: As of September 2000

Note 5: Quoted from *Report of the Social Economic Development Committee*

(2) Amount of capital investment

This project can improve the fuel consumption of existing production facilities. As well, private power generation by means of a gas turbine can reduce power expenses. Further, process improvements can increase productivity, and such productivity increases can be considered a special capital investment. In order to adjust the production base to that of existing facilities, construction costs related to productivity increases are deducted from the total capital investment according to the following equation:

1) Total capital investment

314,500 kBaht

2) Construction costs related to increased productivity

a) Increase in productivity = (260 t/day – 220 t/day) × 2 lines x 300 days/year

= 24,000 t/year

b) Unit construction cost = 6,666 baht/tonne-year

(Budget for the cement plant for which construction began in Malaysia in 2000)

c) Construction cost = increase in productivity × unit construction cost

= 24,000 t/year × 6,666 baht/tonne-year

= 160,000 kBaht

3) The amount of equivalent capital investment is obtained by deducting the capital investment for the increase in productivity.

The amount of equivalent capital investment = amount of total capital investment – cost of

construction for increased productivity.

= 314,500 kBaht – 160,000 kBaht

= 154,500 kBaht

(3) Profit accruing from reduced energy costs

Table 4-1-5 indicates the profit accruing from the reduced energy costs.

Table 4-1-5. Profit accruing from reduced energy costs

		Before the project	After the project	
			During initial 5 years	From 6th and subsequent years
Clinker production capacity	t/day	2 x 220	2 x 260	2 x 260
Annual operating hours	h/year	7,200	7,200	7,200
Power consumption	kw	3,360	3,700	3,700
Generated power	kw	0	4,770	4,770
Power purchased	kw	3,360	-1,070	-1,070
Unit price of power	Baht/kwh	2.1	2.1	2.1
Power cost	Baht/h	7,056	-2,247	-2,247
Heavy oil consumption	kg/h	2,698	2,964	2,964
Unit price of heavy oil	Baht/kg	8.177	8.177	8.177
Heavy oil cost	Baht/h	22,060	24,234	24,234
Natural gas consumption	MMBtu/h	0	49.651	49.651
Unit price of natural gas	Baht/MMBtu	———	116	129
Cost of natural gas	Baht/h	0	5,760	6,405
Energy cost	Baht/h	29,116	27,747	28,392
Equivalent energy cost*6	Baht/h	29,116	23,478	24,024
Profit accruing from reduced energy costs	Baht/h	Base	5,638	5,092
	kbaht/year	Base	40,594	36,662

Note 6: The is the energy cost from which the increase in productivity is deducted in order to adjust the base to that in effect before the project. It is obtained by multiplying the energy cost by the clinker production capacity ratio of 220/260.

Table 4-1-6 shows the profit accruing from the reduction in energy costs. The profit allows for an annual inflation rate of 3.0%.

Table 4-1-6. Profit accruing from the reduction in energy costs

(assuming an inflation rate of 3.0%)

	Profit accruing from the reduction in energy costs (assuming an inflation rate of 0.0%)	Profit accruing from the reduction in energy costs (assuming an inflation rate of 3.0%)
1st year	40,594 kBaht	40,594 kBaht
2nd year	40,594	41,812
3rd year	40,594	43,066
4th year	40,594	44,358
5th year	40,594	45,689
6th year	36,662	42,501
7th year	36,662	43,776
8th year	36,662	45,089
9th year	36,662	46,442
10th year	36,662	47,835
11th year	36,662	49,270
12th year	36,662	50,748
13th year	36,662	52,271
14th year	36,662	53,839
15th year	36,662	55,454

(4) Fixed costs

Operation and maintenance costs are considered fixed costs that will be required after the project. Since a gas turbine requires a principal inspection every four years and a periodic inspection annually, the operation and maintenance costs fluctuate year-by-year. Table 4-1-7 lists the fixed costs for each year.

Table 4-1-7. Fixed costs for each year (kbaht)

	Related to gas turbine	Related to white cement plant	Fixed costs	Equivalent fixed costs *7	Equivalent fixed costs (assuming inflation rate of 3.0%)
1st year	2,400	700	3,100	2,623	2,623
2nd year	2,400	700	3,100	2,623	2,702
3rd year	2,400	700	3,100	2,623	2,783
4th year	40,800	700	41,500	35,115	38,372
5th year	2,400	700	3,100	2,623	2,952
6th year	2,400	700	3,100	2,623	3,041
7th year	2,400	700	3,100	2,623	3,132
8th year	40,800	700	41,500	35,115	43,187
9th year	2,400	700	3,100	2,623	3,323
10th year	2,400	700	3,100	2,623	3,423
11th year	2,400	700	3,100	2,623	3,525
12th year	40,800	700	41,500	35,115	48,608
13th year	2,400	700	3,100	2,623	3,740
14th year	2,400	700	3,100	2,623	3,852
15th year	2,400	700	3,100	2,623	3,968

Note 7: These are fixed costs from which the increase in productivity is deducted in order to adjust the base to that in effect before the project. It is obtained by multiplying the fixed cost by the clinker production capacity ratio of 220/260.

(5) Profitability study

The profitability study is shown in detail in Table 4-1-9. Table 4-1-8 summarizes the study.

Table 4-1-8. Profitability study

	Amortization period	
	10 years	15 years
Total investment	849,150,000 yen (314,500 kBaht)	
Equivalent investment	417,150,000 yen (154,500 kbaht)	
Discount rate	7.5 %	
Investment payback period	4.7 years	
Internal rate of return (IRR)	17.7 %	21.0 %
Net present value (NPV)	206,593,000 yen (76,516 kBaht)	411,958,000 yen (152,577 kBaht)
Marginal investment	623,743,000 yen (231,016 kBaht)	829,108,000 yen (307,077 kBaht)

The capital investment standard of SCI specifies an investment payback period of within four years and an IRR greater than 21%. With a capital utilization period of ten years, the investment falls short of the investment standard by about 15%. With a capital utilization period exceeding fifteen years, the IRR exceeds 21%, suggesting a sufficiently profitable capital investment.

SCI's capital investment standard, specifying an investment payback period of within four years and an IRR greater than 21%, was set under rapid economic growth before the economic crisis. SCI also admits that this deviates from the actual state. SCI has requested us to examine the case where a calculation is made assuming an actual loan rate around 7.5% in addition to the existing capital investment standard in order to make an economic evaluation for each project.

- Evaluation with investment payback years

Invested capital will be recovered in about 4.7 years, which is somewhat longer than the 4 years or less under the existing capital investment standard. SCI has agreed to cases where investment payback periods were over 4 years when capital investment amounts were large. In this project, they say that the IRR calculation results should be prioritized.

- Evaluation by IRR

The existing capital investment standard for IRR is greater than 21%, which is reached using a calculation period of 15 years. When export credit is applied to a Thai corporation, the longest depreciation period is 10 years. 17.7% under this calculation period is less than the existing capital investment standard.

However, as mentioned above, the actual loan rate of around 7.5% of net worth is lowered when export credit is used. Therefore, the IRR calculation result of 17.7% is over 10 points higher than the actual loan rate, which indicates that this is a sufficiently economical investment.

Section 2. Cost-effectiveness of the project

4-2-1. Cost-effectiveness of energy conservation

The energy saved in a year is 12,064 x 10^6 kcal/year, including saved in power station for equivalent to a production capacity of 2 x 220 t/d. The equivalent capital investment is 154.5 Mbaht. Thus, the annual cost-effectiveness of energy conservation related to the initial investment is as follows (exchange rate: 1 baht = 2.7 yen, crude oil equivalent: 10,000 kcal = 1 kg of crude oil):

$12{,}064 \times 10^6$ kcal/year ÷ 154.5×10^6 baht = 78.1 kcal/baht-year

= 28.9 kcal/yen-year

= 2.9 toe-y/million yen

4-2-2. Cost-effectiveness of reduction in greenhouse gas

CO_2 emissions would be reduced by 7,955 t/year, including the reduction from power station for equivalent to a production capacity of 2 x 220 t/d. The equivalent capital investment would be 154.5 Mbaht. Thus, the annual cost-effectiveness of the reduction in greenhouse gas related to the initial investment would be as follows (exchange rate: 1 baht = 2.7 yen)

7,955 t-CO_2 /year ÷ 154.5 Mbaht = 51.5 t-CO_2/Mbaht-year

= 19.1 t-CO_2-y/million yen

Reference: Profitability when petroleum coke is used as the kiln fuel

SWCC is planning to convert the kiln fuel from heavy oil to petroleum coke in order to reduce fuel expenses. As a reference, here we explain research on two approaches to reducing CO_2 emissions: conversion of kiln fuel from 100wt% heavy oil to a combination of 90wt% petroleum coke and 10wt% heavy oil; and introduction of a gas turbine power generator.

1. Preconditions

1) Siam Cement Company's capital investment standard

Table Re-4.shows the results of the examination, which are similar to the paragraph 4-1-1 in the main text.

Table Re-4. SCI's evaluation method for capital investment plans

No.		Examination results
1	Method of evaluation	The collection period method as the principal method and the internal rate of return method (IRR) as a subsidiary method
2	Amortization period	5–15 years (Periods of 10 years and 15 years are applied.)
3	Depreciation method	Straight-line depreciation (no residual value)
4	Depreciation period	5 years or 10 years depending on the amount of money invested
5	Discount rate	7.5 %
6	Criterion	-Evaluation standard by the collection period method within 4 years -Evaluation standard by the internal rate of return method IRR > 21%

2) Kiln fuel

The kiln fuel is converted from heavy oil to petroleum coke, and other types of fuel (natural gas and electricity) are the same as indicated in the main text. The ratio of petroleum coke to heavy oil throughout the year is 9 to 1.

Table Re-5 shows the preconditions regarding fuel data.

Table Re-5. Fuel data (Results of on-site examination)

Type of fuel	Lower calorific value	Price
Heavy oil	9,650 kcal/kg	8,177 baht/ton
Petroleum coke	**8,332 kcal/kg**	**2,200** baht/ton
Natural gas	845 Btu/SCF	116 Baht/MMBtu Note 1 129 Baht/MMBtu Note 2

Note 1: This is PTT Gas's preferred price for a new investment in cogeneration facilities, and is applied for the initial five years.

Note 2: This is a regular price applied to cogeneration facilities.

3) Factors relevant to the profitability study

The factors relevant to the profitability study and the equivalent capital investment are the same as those of paragraph 4-1-2 of the main text, as shown in the following Table Re-6.

Table Re-6. Factors relevant to the profitability study

Exchange rate	2.7 yen/baht
Rate of rise in the unit price of fuel	3.0 %/year
Rate of rise in the unit price of power	3.0 %/year
Rate of rise in fixed costs	3.0 %/year
White cement production capacity	2 x 220 tonnes of clinker/day
Annual number of days of capacity utilization	300 days/year
Annual number of hours of capacity utilization	7,200 hours/year
Equivalent capital investment	154,500 kBaht

2. Results of the study

1) Profit accruing from reduced energy costs

Table Re-7 indicates profit accruing from reduced energy costs.

Table Re-7. Profit accruing from reduced energy costs

		Before the project	After the project	
			During initial 5 years	From the 6th and subsequent years
Clinker production capacity	t/day	2 x 220	2 x 260	2 x 260
Annual operating hours	h/year	7,200	7,200	7,200
Power consumption	kw	3,360	3,700	3,700
Generated power	kw	0	4,770	4,770
Power purchased	kw	3,360	-1,070	-1,070
Unit price of power	Baht/kwh	2.1	2.1	2.1
Power cost	Baht/h	7,056	-2,247	-2,247
Heavy oil consumption	kg/h	**3,076**	**3,379**	**3,379**
Unit price of heavy oil	Baht/kg	**2.798**	**2.798**	**2.798**
Heavy oil cost	Baht/h	**8,607**	**9,454**	**9,454**
Natural gas consumption	MMBtu/h	0	49.651	49.651
Unit price of natural gas	Baht/MMBtu	———	116	129
Cost of natural gas	Baht/h	0	5,760	6,405
Energy cost	Baht/h	15,663	12,967	13,612
Equivalent energy cost*[6]	Baht/h	15,663	10,972	11,518
Profit accruing from reduced energy costs	Baht/h	Base	4,691	4,145
	kbaht/year	Base	33,775	29,844

Note 3: The ratio of petroleum coke to heavy oil is 9 to 1.

Note 4: The is energy cost from which the increase in productivity is deducted in order to adjust the base to that in effect before the project. It is obtained by multiplying the energy cost by the clinker production capacity ratio of 220/260.

Table Re-8 shows the profit accruing from the reduction in energy costs. The profit allows for an annual inflation rate of 3.0%.

Table Re-8. Profit accruing from the reduction in energy costs

(assuming an inflation rate of 3.0%)

	Profit accruing from the reduction in energy costs (assuming an inflation rate of 0.0%)	Profit accruing from the reduction in energy costs (assuming an inflation rate of 3.0%)
1st year	33,775 kBaht	33,775 kBaht
2nd year	33,775	34,788
3rd year	33,775	35,832
4th year	33,775	36,907
5th year	33,775	38,014
6th year	29,844	34,597
7th year	29,844	35,635
8th year	29,844	36,704
9th year	29,844	37,805
10th year	29,844	38,939
11th year	29,844	40,107
12th year	29,844	41,311
13th year	29,844	42,550
14th year	29,844	43,826
15th year	29,844	45,141

2) Fixed costs

Fixed costs required after the project are the same as those stated in the main text. Table Re-9 lists the fixed costs for each year.

Table Re-9. Fixed costs for each year (kbaht)

	Related to gas turbine	Related to white cement plant	Fixed costs	Equivalent fixed costs *7	Equivalent fixed costs (assuming inflation rate of 3.0%)
1st year	2,400	700	3,100	2,623	2,623
2nd year	2,400	700	3,100	2,623	2,702
3rd year	2,400	700	3,100	2,623	2,783
4th year	40,800	700	41,500	35,115	38,372
5th year	2,400	700	3,100	2,623	2,952
6th year	2,400	700	3,100	2,623	3,041
7th year	2,400	700	3,100	2,623	3,132
8th year	40,800	700	41,500	35,115	43,187
9th year	2,400	700	3,100	2,623	3,323
10th year	2,400	700	3,100	2,623	3,423
11th year	2,400	700	3,100	2,623	3,525
12th year	40,800	700	41,500	35,115	48,608
13th year	2,400	700	3,100	2,623	3,740
14th year	2,400	700	3,100	2,623	3,852
15th year	2,400	700	3,100	2,623	3,968

Note 4: This is a fixed cost from which the increase in productivity is deducted in order to adjust the base to that in effect before the project. It is obtained by multiplying the fixed cost by the clinker production capacity ratio of 220/260.

(3) Profitability study

The profitability study is shown in detail in Table Re-11. Table Re-10 summarizes the study.

Table Re-10. Profitability study

	Amortization period	
	10 years	10 years
Total investment	849,150,000 yen (314,500 kBaht)	
Equivalent investment	417,150,000 yen (154,500 kBaht)	
Discount rate	7.5 %	
Investment payback period	5.8 years	
Internal rate of return (IRR)	10.9 %	15.1 %
Net present value (NPV)	64,247,000 yen (23,795 kBaht)	218,263,000 yen (80,838 kBaht)
Marginal investment	481,397,000 yen (178,295 kBaht)	635,413,000 yen (235,338 kBaht)

The capital investment standard of SCI specifies an investment payback period of within four years and an IRR greater than 21%. With a capital utilization period of ten years, the IRR falls short of the investment standard by about 50%. With a capital utilization period fifteen years, the IRR does not exceed 21%, suggesting a insufficiently profitable capital investment.

(4) Cost-effectiveness of the project

1) Cost-effectiveness of energy conservation

The energy saved in a year is 12,064 x 10^6 kcal/year, including power equivalent to a production capacity of 2 x 220 t/d. The equivalent capital investment is 154.5 Mbaht. Thus, the annual cost-effectiveness of energy conservation related to the initial investment is as follows (exchange rate: 1 baht = 2.7 yen, crude oil equivalent: 10,000 kcal = 1 kg of crude oil):

12,064 x 10^6 kcal/year ÷ 154.5 x 10^6 baht = 78.1 kcal/baht-year

= 28.9 kcal/yen-year

= 2.9 toe/million yen

2) Cost-effectiveness of reduction in greenhouse gas

CO_2 emissions would be reduced by 9,093 t/year, including the power equivalent to a production capacity of 2 x 220 t/d. The equivalent capital investment would be 154.5 Mbaht. Thus, the annual cost-effectiveness of the reduction in greenhouse gas related to the initial investment would be as follows. (exchange rate: 1 baht = 2.7 yen)

9,093 t/year ÷ 154.5 Mbaht = 58.9 t-CO_2/Mbaht-year

= 21.8 t-CO_2/million yen-year

Chapter 5. Examining the Benefits of Widespread Adoption

In this chapter, we examine the possibility that the technology introduced under this project may be adopted throughout Thailand. Energy conservation and greenhouse gas reduction are mentioned as benefits of widespread adoption.

Section 1. The Possibility of Nationwide Adoption of the Technology Introduced

It is impossible to apply the technology of this project directly to the production process of gray cement (ordinary cement), which accounts for the majority of the cement produced*. The white cement manufacturing industry, however, is suffering from the high costs of its high fuel consumption. Therefore, the goals of this project — energy conservation and reduced carbon dioxide emissions — are suggested as a solution to the problem. It is believed that, once its advantages have been confirmed, this technology will spread throughout the white cement manufacturing industry**. In Thailand, SWCC's white cement production capacity is 150,000 metric tons per year, while other corporations produce a total of 40,000 metric tons annually. Therefore, it is also necessary to consider the effects this innovation will have on neighboring countries such as Malaysia.

In addition, this project introduces an energy conservation technology that uses exhaust heat from a gas turbine generator burning natural gas as fuel in the production system, and uses the remaining exhaust heat to generate steam for power generation. In other words, it is an energy conservation technology in which utilization of exhaust gas heat is integrated into the gas turbine cogeneration equipment.

Therefore, the technology is applicable to production plants capable of using the exhaust gas heat from the gas turbine in their production process***. It also requires electricity (and steam). A separate detailed survey is required to determine the exact needs.

The basic technology applied — cogeneration technology to supply power and steam — is widely applicable to the auto industry, the electronics industry, the chemical industry, and others, although it is not exactly the same as the technology to be used in this project.

The power generation industry has adopted the full-fired heat recovery combined cycle generation plant in order to enhance output and heat efficiency****. In other words, it aims to improve the thermal efficiency of the entire plant by increasing the output of the existing generating equipment with the addition of a gas turbine generator. In addition, it uses the exhaust gas (500-600°C, with an O_2 concentration of approximately 15%) of the gas turbine as the existing boiler combustion air (heat recovery).

In Japan, the Tokyo Electric Power and Chubu Electric Power companies have adopted this approach by using LNG. It has also been adopted in Europe. This technology, which requires only a short construction period to enhance output and thermal efficiency, can be expected to be adopted in Thailand once the power supply becomes adequate.

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*The gray cement production process does not require heating with exhaust gas. Air is used for clinker cooling instead of water, and the cooled air from the cooler is 600-700°C.

**It is necessary, however, to select an area where natural gas is available and where the cost of power and gas turbine fuel make this approach profitable.

***For example, factories requiring heat at around 400°C for air preheating, drying and other purposes.

****Conversely, a general combined-cycle generation plant is called an "unfired heat recovery combined cycle generation plant."

Section 2. Benefits of Widespread Adoption

In this project, gas turbine exhaust gas heat is utilized in the production process and in a wide range of factories requiring electricity. Quantitatively determining the effects of widespread adoption of this technology is very hard to do. Therefore, we will examine here the benefits of the adoption of this technology by cement manufacturers.

Siam Cement Industry, the company surveyed for this project, is a leading company in the Thai cement industry, accounting for 42% of the country's cement production capacity (Chapter 2, Section 2). Although the white cement production capacity of the company we surveyed is not large, its fuel consumption will be reduced by the supply of the required power through the introduction of gas turbine generator fueled by clean natural gas, and by the use of the resulting high-temperature exhaust gas in the production process. This approach, which conserves energy and reduces greenhouse gas emissions, is also applicable to gray cement, which accounts for the majority of cement production.

5-2-1 Energy Conservation

PTT has been promoting the introduction of natural gas, the main energy source, from Malaysia, Myanmar and Indonesia. It has also been exploring gas deposits in the Gulf of Siam. As a result of EGAT's promotion of gas-fired power generation, it is developing demand and maintaining a pipeline network. Gas prices have also been discounted for private power generation and IPP.

Among the key cement production areas in Thailand, Saraburi (Chapter 2, Section 1), which we studied for this feasibility study, is ready to introduce natural gas. Production facilities with a total output of 43.85 million metric tons per year are centralized in Saraburi, including SCI and four other corporations. The following benefits can be expected if this technology is adopted there.

(1) Conversion of the cement production capacity into clinker production capacity

43.85 million metric tons x 0.83 = 36.4 million metric tons

(2) If the same benefit as seen with white cement (0.132 million metric tons/year) is available,

(3) the energy conserved will be

1,206 toe/y x 36.4/0.132 = 332,000 toe/y.

5-2-2 Reduction of Greenhouse Gas Emissions

If the result is as indicated in section 5-2-1, the reduction in carbon dioxide emissions will be as follows:

7,955 t-CO_2/y x 36.4/0.132 = 2.2 million t-CO_2/y

Chapter 6. Other Benefits (Far-reaching Environmental, Economic and Social Benefits)

In this chapter, we state the benefits of the energy conservation measures of this survey on the environment, economy and society of Thailand in addition to the managerial improvements to the surveyed company.

This survey shows that a small but welcome energy conservation benefit can be expected under this project. In addition, the survey indicates that increased production is possible. However, circumstances do not permit immediate implementation of the project because the availability of the gas supply infrastructure and rapid recovery of cement demand are not anticipated. Once these circumstances improve and the prerequisites for the start of the project have been arranged, the use of CDM can be considered an option for raising the project funds and maintaining the infrastructure. The benefits of this survey are not limited to managerial improvements of one company through the promotion of energy conservation measures. As indicated below, we can expect ongoing benefits to the environment, economy and society.

1) Impact on Pollution Control and an Improved Regional Environment

Partial fuel conversion from heavy oil to natural gas and reduction of energy consumption under the energy conservation project will result in reduced emissions of sulfur and nitrogen oxides as well as carbon dioxide. This will help to remove air pollutants, thus bringing environmental benefits by protecting the entire ecosystem across the region. As well, it will improve the living environment in the area. Reduction of carbon dioxide emissions, an environmental conservation measure intended to prevent global warming, is directly linked to local environmental measures. Reduction of fuel consumption reduces transport costs, which controls air pollution from traffic. The Saraburi area, the location of SCI's Khao Wong plant, is surrounded by forests and several national parks are located nearby. Therefore, conservation of the natural environment must be carefully monitored.

Considering the enormous cost of repairing environmental destruction, we believe that the investment saved by preventing the projected destruction will be substantial.

2) Benefits to Energy Policy

Promoting the use of natural gas reduces Thailand's reliance on imported energy sources (such as oil and coal) and improves the environment by switching the fuels used for power generation and industrial from oil, coal and brown coal to natural gas.

Thailand has few deposits of oil and coal, the primary energy sources, and much of this fuel is imported. Development of additional hydraulic power plants is almost impossible.

On the other hand, natural gas deposits have been confirmed off the Gulf of Thailand, some of which have already been developed for use mainly as a power generation fuel. Thailand has already contracted the importation of natural gas from the Joint Development Area (JDA) with Myanmar and Malaysia. Construction of some of the related facilities has begun. However, the long-term prospects for power demand, the main application for natural gas, have been repeatedly lowered since the onset of the currency crisis and economic crisis. This has resulted in reduced estimates for natural gas demand as well.

Implementation of this project will contribute to more sophisticated energy production with natural gas at SCI's Khao Wong Plant. The success of this project would surely encourage various other industries to adopt natural gas. In turn, this would lead to increased national demand for natural gas, which would reduce reliance on imported energy sources and minimize the environmental impacts.

3) Expansion of Energy Conservation and Technological Enhancement

Due to the slow growth of the national economy as a result of the currency crisis and economic crisis, domestic demand for cement has been dropping. SCI has been promoting exports to Vietnam, Bangladesh, and other Asian nations, and they are putting great effort into measures to conserve energy and resources in order to strengthen their international competitiveness. As one example, they are examining the use of waste (petroleum coke, waste tires, or waste oil) or clay alternatives (coal ash) through technological cooperation from Japan.

This project is intended to refine energy use through partial modification of the manufacturing process, which is unprecedented in Thailand. Implementation of this project by SCI, one of Thailand's leading companies, would prompt industries besides the cement industry to apply it. The benefits in terms of energy conservation and environmental improvement would be considerable.

The project manager of SCI mentioned that the project feasibility study (FS) would be very helpful in enhancing our technology. It is expected that the project will contribute significantly to the technological upgrading of Thailand's entire cement industry.

Conclusion

One of the essential requirements to solve various problems such as global warming is to reduce energy consumption. It is needed to take an energy-saving action. Though the energy-saving action obtained a certain excellent results in the advanced countries, especially in recent years, developing country: the energy-saving technology has not yet been penetrated into the society in Asian countries, where the measures for the promotion of industries are carried out and industrialization has been rapidly progressed, due to the shortage of engineers, the lack of funds, late modernization of plant and equipment, and others.

In these circumstances, "The 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change" (COP3) was held in Kyoto in December 1997. The adopted Kyoto Protocol aimed to reduce the mean emission value of greenhouse effect gases including CO_2 in 2008 - 2012 by minimum 5% compared to the level in 1990. The reduction goal of Japan was 6%, which was very high, following EC 8% and USA 7%. Japan faced some economic crises in the process of industrialization for the past 30 years, but each time the Japanese industries piled up the energy-saving measures and technologies. So it is difficult for Japan to take further measures into account. The set goal may be very high. Other advanced countries as well as Japan have each circumstance. Accordingly, there were various hot arguments at the COP3 about Joint Projects, CDM, Bargains of Emission, etc. It is the most important requirement for all the countries to do their best to attain their own reduction goals of greenhouse effect gas emission. The atomic energy development encounters severe criticisms and the natural energy development faces the difficulty of high cost. When these things are taken into consideration, it may be very important for Japan to progress the reduction projects including CDM with developing countries.

The CDM had been planned to start in 2000, but there was no concrete developments at COP6 held in The Hague. We must wait for the final conclusion until the COP6 meeting is restarted in Bonn in July 2001. At the present, it is difficult for developing countries to express their receiving attitudes openly. The Government official in charge at OEPP in MOSTE told that they were also waiting for the formal decision at COP. Therefore, it may depend on the following five points if the Thai Government agrees to the project as CDM at present.

1. The CO_2 reduction is the special necessity in advanced countries. The Thai Government may agree to the reduction if they recognize that the reduction will contribute to the increase of the competitive power of the Thai companies as the result of cost down or to the promotion of their energy-saving activities.
2. The CO_2 quantity to be reduced is too small to carry forward this project alone as CDM. It is necessary to carry forward the project jointly with some other energy-saving

projects and fuel conversion projects.

3. Scale of effects, speediness, and advantageous financing conditions: When all the conditions completes, the project will be executed as CDM.
4. The financial source must not conflict with the original ODA. It should be an additional budget or fund. The Thai Government attaches great importance to it.
5. Evaluation of the AIJ result, which is now executed by Japan, is also reflected on the CDM in Thailand.

The trial calculations of the total energy-saving effect and CO_2 reduction in this project are 1,200t/year (in crude oil equivalent) and 8,000 t-CO_2/year respectively. These values are not so high, but the production increase by approx. 18% maybe expected. However, under the present conditions, this project cannot be carried forward immediately as the gas supply infrastructure is incomplete and as the prospect for the demand for white cement is still dim.
When the demand for white cement revives in future and when this project can be carried forward, CDM can be selected as one of the methods to raise funds including those for preparation of infrastructure. We will continuously contact with SCI, 1) to get SCI plan working information including their own plan, 2) to provide SCI with information on CDM activities including COP6, and 3) to continue contacting with OEPP (Office of Environmental ~~Polic~~y and Planning) or Thai Government official agency of CDM. We will continue to discuss to realize the project with fixing our eyes on SCI's preparations to receive CDM.

If this project is executed, SCI can attain highly efficient energy utilization with natural gas at Khao Wong Plant. This project may be the pioneer in utilizing natural gas. There is a large possibility to extend natural gas to various industries. Accordingly; it can be expected to increase the domestic demand for natural gas, which may result in reducing dependence on the imported energy and reducing the environmental bad effect.

Finally, we were deeply impressed during this investigation that SCI engineers and other members actively exchanged opinions based on various technical data. We are deeply grateful to many people in Thailand and Japan who gave us valuable information and honest opinions during the investigation.

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Phone 03 (3987) 9466
Fax 03 (3987) 5103