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CASE STUDY OF THE CEMENT INDUSTRY

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Preface

NRMP-IEA Technological Scenarios

The Natural Resources Management Project (NRMP) assisted by USAID in association with the Institute for Economic Analysis (IEA) at New York University is carrying out a modelling exercise to project the economic, employment and environmental consequences of different development paths for the Indonesian economy. The purpose is to provide advice to the Indonesian National Planning Agency (BAPPENAS) to assist in the development of the next five-year plan (Repelita VI) and the next Long-Term Development Plan. The first stage of this work has already been completed with the support of the Environmental Programming Support Services Project of CIDA.

The analysis, of which the present paper is a component, will provide advice on the trade-offs and complementarities between the growth of income and employment on the one hand, and the levels of natural resource depletion and degradation of the natural environment on the other. For instance, it is important for policy makers to know how the development of the pulp and cement industries over the next 20 years is likely to affect air and water pollution and how costly or cost-saving it will be to adopt cleaner technologies than are being used now.

The analytical framework includes a dynamic input-output model covering all economic activities. The model is dynamic in two senses. First, it incorporates a representation of investment in which levels of sectoral investment depend on expected growth of output, the technology in use and levels of capacity utilisation. Secondly, the model is dynamic in that it explicitly incorporates projections of changes in technology for a range of sectors in the economy, including agricultural sectors, forestry, energy sectors and key manufacturing sectors.

Technological scenarios are developed for each of these sectors using detailed information about likely technological and institutional changes obtained from technical experts. They include expected changes in intermediate inputs, notably energy and raw materials, capital stocks and human resources of different skill types as well as expected changes in natural resource usage and environmental degradation associated with current and alternative future technologies.

This paper is one of a series of working papers prepared by NRMP and IEA researchers in collaboration with industry experts. The papers will form a vital part of the data base for the numerical computations. In addition, they will be valuable as stand-alone analyses of technological futures for a range of important industries in Indonesia.

It should be noted, however, that some of these working papers (especially those on manufacturing sectors) were prepared under severe time limits and should not be taken to represent the last word on technological change in the industries in question.

I Introduction

Cement production has grow rapidly in Indonesia during the last 15 years, with annual output increasing from some 6.8 million tonnes in 1980 to 17.8 million tonnes in 1990. More than 90 per cent of the cement produced in Indonesia is portland cement (PC) type I; other types include: PC type II, PC type V, white cement, and oilwell cement, which have special uses and limited demand (Data Consult 1992). Average utilization of the industry's capacity in 1990 was 90 per cent. There were a total 10 companies in 1990, with production dominated by PT Indocement Tunggal Prakasa (ITP), with a 46 per cent share of total production (Table 1). The second biggest company is PT Semen Cibinong (SC), with a 17 per cent share of total production capacity.

Table 1 Cement Production Capacity 1985 and 1990 ('000 tonnes p.a).

Company	1985	1990
Semen Padang (SP)	2,130	2,130
Semen Gresik (SG)	1,500	1,500
Semen Tonasa (ST)	1,210	1,180
Semen Cibinong (SC)	1,500	1,500
Indocement Tunggal Prakasa (ITP)	7,500	7,700
Semen Nusantara (SN)	750	950
Semen Baturaja (SB)	500	500
Semen Andalas Indonesia (SA)	1,000	1,000
Semen Kupang (SK)	120	120
Tridaya Manunggal Perkasa (TMP)	1,200	1,200
Total	17,410	17,780

The abbreviations in brackets following the company names, e.g. Semen Cibinong (SC) - are used throught the remained of this case study.
Sources: Data Consult 1992, page 19, PT Semen Cibinong, 1985.

In most years, almost all of year-to-year production is consumed with little carry-over of stocks, indicating that the industry's capacity is almost fully utilised. Despite the strength of domestic demand, exports of cement more than tripled over 1985-90, rising to about 10 per cent of total production (Table 2).

Table 2 Cement Production, Supply, Consumption and Export, 1985 and 1990.

('000 tonnes)	1985	1990
Production	9,017	15,783
Total Supply	9,767	15,592
Domestic Consumption	9,174	13,779
Exports	685	1,830

Source: Indonesia Cement Association.

Consumption and use of cement

Over 1985-90 Java has slightly increased its proportion of consumption of cement products (Table 3) to over two thirds of total production, with consumption growing by over 50%. The rest of Indonesia consumed in total in 1990 than the increase in consumption on Java alone over 1985-90.

Table 3 Cement Consumption by Province, 1985 and 1990 ('000 tonnes).

Province	1985	Share (%)	1990	Share (%)
Sumatera	1,708	18.8	2,433	17.7
Java	6,152	67.7	9,430	68.5
Kalimantan	250	2.7	365	2.6
Sulawesi	484	5.3	716	5.2
Nusa Tenggara	358	3.9	657	4.8
Eastern Indonesia	130	1.4	161	1.2
Indonesia	9,081	100.0	13,762	100.0

Source: Indonesia Cement Association.

The construction industry is the major user of cement, consuming nearly 90% of total production by value in 1985 (Table 4). The remaining 10% is used by other manufacturing sectors, including manufacture of non-metalic mineral products and other products.

Table 4 Cement using Sectors, 1985

Sector	Sector No.	M Rp	Coefficient (Rp/Rp)
Construction	23	565,105	0.03165
Other manufacturing	17	76,358	0.00557
Cement	16	6,088	0.00897
Oil refineries	18	2,341	0.00034
Food, beverages & tobacco	11	1,135	0.00007
Pulp and paper products	13	277	0.00031
Social & other services	29	139	0.00004
Wood products	12	117	0.00004
Chemicals	15	70	0.00000
Total		651,637	

Source: NRMP-IEA Input-Output table 1985, 30-sectors.

In 1992 total annual production capacity in the cement industry was 20.4 million tonnes. An additional 7.6 million tonnes per annum of production capacity is expected to be completed over 1993-94. Additionally, there are seven major new investments in process with a planned capacity of 11.5 million tonnes per annum, these are planned for completion in 1995 (Prospek 1992). If all these are completed, production capacity in Indonesia will have increased to about 40 millon tonnes per annum before the year 2000.

Most of the information in this case study comes from experts working for ITP and SC, their promotional literature and annual reports. Information from the Indonesian Cement Association (ASI), BPPT (Badan Pengkajian dan Penerapan Teknologi - Agency for Technology Assessment and Application) and other sources is also used. The case study focuses on production technology used by ITP and SC, which together accounted for about two thirds of national production in 1990.

Within the industry, ITP is considered to be using the most advanced technology and have the most efficient production methods, while SC is regarded as being fairly representative of other large manufacturers; Semen Kupang (SK) is regarded as being the least advanced in technology and efficiency (Prospek 1992). In this regard, ITP probably represents the likely average technology and efficiency of the industry in 5-10 years time, and is representative of the types of production plants that will be constructed in the coming few years.

II Production Technology

There are two types of production process in the cement industry: the wet process and the dry process. In the wet process, raw materials are ground, mixed with water and the slurry

fed into the kiln. In the dry process, raw materials are dried before or during grinding, and the dry, ground materials are fed to the kiln (World Bank 1984).

The wet process has some advantages over the dry process:

Simpler technology for raw materials mixing, preparation and control;

Lower labor requirements; and

Less pollution of the environment by dust. (ibid)

Despite these advantages, the wet process has the disadvantage of consuming significantly more energy per unit of production than dry process, as the water added to the raw mixture has to be evaporated during processing in the kiln. Due to its higher energy consumption, the wet process had been phased out since 1986 (Semen Cibinong, pers.com.). Thus, the technology discussed in this case study refers only to dry process technology.

Raw Materials

The main inputs to cement manufacturing are limestone (80% of total), clay (5-10%) and gypsum (2-5%). Additives such as silica sand, iron ore, pyrite cinder, are used in differeing proportions depending on the type of limestone and clay used, and on the type of cement being manufactured. In the first stage of production, limestone, clay and a small amount of additives (silica sand/iron ore) are mixed and heated in a rotating kiln. The product of this process is called *clinker*.

The ratio of materials needed to make one tonne of clinker (the *clinker ratio*) varies between cement plants. The clinker ratio for ITP is 1.6:1, i.e. 1.6 tonnes of raw materials are required to produce 1 tonne of clinker; the ratio for SC is 1.75:1. The average clinker ratio (weighted according to share of production of ITP and SC) is 1.644:1. In the next stage of processing about 5% of gypsum is added to the clinker and the mixture ground to form the final product, cement. The purpose of adding gypsum is to control the setting speed of cement (Shreve et al 1977). According to ITP and SC, the proportions of limestone and clay used for clinker production has remained unchanged over 1985-90.

In 1985 total clinker production was 4.7 million tonnes, of which 195 thousand tonnes were exported. Production in 1990 was just over 16 million tonnes, of which 514 thousand tonnes were exported.

Table 5 lists the main intermediate inputs to cement production in 1985 by value, inputs from these nine sectors account for over 90% of total intermediate inputs. From this table it is clear that energy inputs from petroleum refining (oil and natural gas) and for other mining (limestone and clay) were the most important. It is of importance to note that coal,

a minor input in 1985, had by 1990 become the major energy source for cement production, as a substitute for oil and natural gas.

Table 5 Major Intermediate Inputs to Cement Production, 1985

Sector	Sector No.	M Rp	Coefficient (Rp/Rp)
Petroleum refining	18	99,214	0.14612
Other mining	10	74,908	0.11033
Pulp and paper products	13	51,796	0.07629
Tspt and comms	26	33,820	0.04981
Electricity	20	26,465	0.03898
Chemicals	15	19,945	0.02938
Real estate & finance	27	16,477	0.02427
Coal	7	9,739	0.01434
Construction	23	6,944	0.01023
Total (incl. other minor inputs)		455,977	

Source: NRMP-IEA Input-Output Table 1985, 30-sectors.

Capital Investments and Fixed Assets

Information on fixed capital assets for 1985 and 1990 was only available from SC (Table 6). In Table 7 this data is used to calculate capital requirements per tonne of capacity for these two years.

Table 6 Semen Cibinong - Value of Fixed Assets, 1985 and 1990 (Rp millions)

Asset	1985	1990
Land (quarry) & rights	1,015.0	972.6
Buildings	39,585.4	69,639.1
Machinery & equipment	38,287.2	88,662.8
Vehicles & mobile equip.	5,506.5	10,672.6
Accumulated depreciation	-22,430.3	-51,340.7
Total	61,963.8	118,606.4

Notes: Values for 1985 and 1990 are at market not constant price.
Source: Financial Statement PT SC.

In 1990 SC's plant underwent a major refit, raising production capacity from 1.5 to 3 million tonnes per annum. In the table that follows (Table 7) capital requirements per

tonne of production are calculated on an installed capacity basis using capacity figures, rather than actual production data. Actual production in 1985 was 1.039 million tonnes, and estimated production in 1990 (assuming no loss of production due to plant upgrading and use of new capacity) would have been about 2 million tonnes.

Table 7 Semen Cibinong Ratio of Fixed Assets to Production (MRp/tonne).

Asset	Ratio 1985	Ratio 1990	Change 1985-90 (%)
Land (quarry) & rights	0.677	0.324	-52.1
Buildings	26.390	23.213	-12.0
Machinery & equipment	25.523	29.554	15.8
Vehicles & mobile equip.	3.671	3.558	-3.1
Accumulated depreciation	-14.954	-17.114	14.4
Total	42.633	40.199	-5.7

Notes: Actual production in 1985 was 1.039 million tonnes and in 1990 0.989 million tonnes. The ratio is asset value divided by total production for each year. Values for 1985 and 1990 are at market not constant prices.
Source: Financial Statement PT SC.

Note should be taken of the fact that the cost of machinery per unit of installed capacity rose at 3% p.a. over 1985-90, despite the slight overall decline in the amount of assets (nominally) required to produce cement. This figure may be indicitive of the annual increment in additional investment per unit of productivie capacity for the cement industry; it should be noted that no allowance has been made for inflation over 1985-90. However, it is highly unlikely that the absolute value of land (see Table 6) had fallen during the 1985-90 period. It is difficult to know for certain whether per unit depreciation costs actually rose over 1985-90, because of a change in accounting standards during this period.

Land Requirements

From a total area of 1,750 ha at Citeureup, West Java, owned by ITP, 250 ha are used for the cement plant and the remaining 1,500 ha are limestone quarry; over 1985-90 these areas have remained unchanged. On this basis, land area per thousand tonnes of production in 1985 was 0.0638 ha (actual production 3.918 million tonnes), in 1990 this had fallen to 0.0328 ha (actual production 7.619 million tonnes).

Land requirements are ignored in further calculations, as the land requirements for quarrying limestone (which is not covered by this study) are about six times greater than for manufacturing cement.

Labour Requirements

Official data on the 1985 workforce in the cement sector (including limestone quarrying) is in serious conflic: BPS (1990) I-O data reports a workforce of 102,340 persons (which probably includes the workforce engaged in limestone quarrying), while the national intercensual survey (SUPAS) gives a figure of 17,406 persons; no data is available directly from cement industry sources for 1985. At the beginning of 1990 total labor in the cement industry was 16,354 persons, according to industry sources (FBCII 1991).

On the basis of this industry data for 1989, production totalled 15.853 million tonnes and 16,354 people were employed. Labour requirements, i.e. number of person-years per thousand tonnes of production - varied by factor of about six, from a minimum of 0.573 (at ITP) to a maximum of 3.399 (at SK).

According to information collected from ITP and SC, their total workforces in 1990 were 4,126 and 934 persons respectively, and in 1992/93, 4,028 and 1,136 persons respectively. For 1992/1993, the labour force's educational background for these two companies (which are responsible for about two thirds of total production) is presented in Table 8; no data are available on the educational background of their labour force for 1990.

Table 8 Educational Levels of Labour in the Cement Industry 1992/93.

Education level	ITP	Share (%)	SC	Share (%)	Total	Share (%)
Elementary school	1,084	26.9	-	-	1,084	21.0
Junior high school	498	12.4	463	40.8	961	18.6
Senior high school	2,209	54.0	551	48.5	2,760	53.5
Diploma	146	3.6	45	4.0	191	3.7
University	91	2.3	77	6.8	168	3.3
Total	4,028		1,136		5,164	

Notes: For SC the figure for Junior high school combines both elementary and junior high school levels.
Sources: ITP and SC, pers. comm.

It is clear that unskilled and semi-skilled workers make up the bulk of the workforce for both companies, with highly-trained technical staff in the minority. Except for a slight increase in the proportion of diploma and university educated personnel, this pattern is expected to persist into the future.

Table 9 Labour Required per tonne of Production 1992/93, by educational level

(person-years/'000 t) Education level	ITP	SC	Weighted average
Elementary school	0.151	0.0	0.118
Junior high school	0.069	0.230	0.104
Senior high school	0.307	0.274	0.300
Diploma	0.020	0.022	0.021
University	0.013	0.038	0.018
Total	0.560	0.565	0.561

Notes: Total production in 1992/93 for ITP was 7.198 million tonnes, and for SC was 2.010 million tonnes.
Sources: ITP and SC, pers. comm.

In 1990 ITP's total production was 7.619 million tonnes, with a total labour force of 4,126 persons. Thus, labour required per thousand tonnes of production was 0.542 person-years; this is 3.33% (net) less than labour required per thousand tonnes in 1992/93. On an annual basis, this is an increase in labour required of 1.1% p.a. per unit of production. Because SC's production facilities underwent a major up-grading in 1989/90, and their production declined to well below normal levels, it is not possible to compare their labour requirements for the period 1990-1992/93.

Accepting the SUPAS figure of 17,406 persons employed in the cement industry in 1985, and total production in 1985 of 9.817 million tonnes, gives an overall labour requirement of 1.773 person-years per thousand tonnes of production. In 1990 the labour force was 16,354 (FBCII 1991) persons and production had risen to 15.783 million tonnes, implying a labour requirement of 1.036 person-years per thousand tonnes of production, a net decline of 42% per unit output over 1985-90, or a 29.6% decline in the amount of labour required per unit of production. On this basis, in 1990 ITP's production technology was approximately half as labour intensive as the industry as a whole (0.542 vs 1.036); by 1992/93 SC's labour productivity, after plant upgrading, was similar to ITP's at 0.565 person-years per thousand tonnes of cement.

Energy Consumption

The main consumption of energy in cement production occurs in the clinker kiln, where the mixure of limestone and clay undergoes heat treatment. Three different fuels can be used: fuel oil, pulverized coal or natural gas. Thermal energy consumption of kilns varies widely depending of the type of process used, quality of the clinker required, effectiveness of kiln insulation and of the kiln itself, and the effectiveness of the control system. Estimated

energy requirements, including electric power consumption, by stage of production, are given in Table 10.

Table 10 Theoretical Estimates of Specific Energy Requirements by Process Stage - Dry Production Method (GJ/tonne)

Type of Energy and Process Stage	Energy required (GJ/tonne)
Thermal Energy	
Raw material preparation	
- per tonne of clinker	0.73
- per tonne of cement	0.59
Clinker firing	
- per tonne of clinker	3.14
- per tonne of cement	2.57
Total per tonne of cement	3.18
Electrical Energy	
Raw material preparation and clinker firing	
- per tonne of clinker	0.14
- per tonne of cement	0.12
Cement milling	
- per tonne of cement	0.25
Total per tonne of cement	0.37
Total thermal and electrical energy	3.54

Source: UNIDO 1985.

Actual energy consumption may be double or even triple these theoretical requirements. This difference is due to various factors related to plant and kiln design, the condition of the kiln (maintenance), type of fuel, clinker quality requirements, operational routines, and use of energy saving equipment.

With regard to electricity requirements, most of the producers have their own generating capacity but also buy electricity from PLN (Perusahan Listrik Negara - State Electricity Company). Only one producer (ITP) relies entirely on own-generated electricity. Unfortunately, in the survey conducted by BPPT (Lubis 1990) no data is provided on either purchased electricity or fuel consumed for own-generated electricity for any of the

producers. Thus, the figures that follow (Table 11) are underestimates of actual energy consumption. Based on the data from Table 10, electricity consumption, including generation and transmission losses, would add approximately 30% to the direct fuel consumption data in Table 11. Taking into account electricity use, estimated total energy consumption per unit of production in 1985 was 4.363 GJ/tonne and in 1990 4.408 GJ/tonne.

Table 11 Thermal Energy Consumption per tonne of Cement 1985 and 1989

Company	1985	1990	Change (%)
Semen Padang	4.352	3.427	-21.3
Semen Gresik	4.185	5.065	21.0
Semen Tonasa	3.707	3.099	-16.4
Semen Cibinong	3.017	4.052	32.3
Indocement Tunggal Prakasa	3.147	3.288	4.5
Semen Nusantara	1.773	1.970	11.1
Semen Baturaja	3.258	3.310	1.6
Semen Andalas Indonesia	3.323	2.799	-15.8
Semen Kupang	-	2.510	-
Tridaya Manunggal Perkasa	2.867	3.291	14.8
Total	3.356	3.391	1.0

Notes: Units are GigaJoules (GJ) of thermal energy per tonne.
Sources: Lubis 1991

The energy diversification programme for the cement industry in Indonesia has led to a substitution of coal for oil and natural gas. For example, in 1985 55% of ITP's energy came from IDO (Industrial Diesel Oil) and 45% from natural gas, by 1989 coal provided about 95% of energy, with only 1% coming from IDO and 4% from natural gas (IDO is only used for preheating and producing certain types of cement, e.g. white cement). Nationally, in 1985 coal supplied 26% of total energy, fuel oil 26%, IDO 20% and natural gas 28%; by 1989 coal was supplying 78% of the industry's total energy, fuel oil less than 4%, IDO less than 2%, but natural gas use had increased four times to 17%.

The slightly higher per unit production energy requirements overall in 1990 are probably related to the impact of less efficient conversion of coal into usable thermal heat, as compared to IDO or fuel oil. However, it is notable that a number of plants achieved quite significant reductions in energy requirements over 1985-90, while others (including SC) became significantly less energy efficient. Some of these changes in energy requirements

per unit of production could well be due to changes in plant design and standard of maintenance, about which we have no information. In addition, because electricity consumption is not accounted for, a part of the changes in energy requirements may result from changes in the proportion of own-generated and purchased electricity over 1985-90.

Environmental Impacts

The major stages in production are: drying and raw grinding, kiln burning and cooling, finish grinding and packing. Air pollution, the main form of pollution, can originate from several of these operations, the primary one being from kiln operations (World Bank 1984). Pollution sources and types of pollution are summarised in Table 12.

Table 12 Sources of Air Pollution from Cement Production

Source	Emission
Raw materials grinding and handling	particulates (dust)
Kiln operations and clinker cooling	particulates (dust) CO, SOx, NOx, hydrocarbons aldehydes, ketones
Product grinding, handling packaging and shipping	particulates (dust)

Source: World Bank 1984.

The main source of dust in cement plants is the kiln, and both ITP and SC use a range of dust control equipment (e.g. multi-cyclones and bag filters) plus (newly installed) electrostatic precipitators (EPs) to reduce dust emissions and recycle dust; the EPs at both ITP and SC are rated at 99.99% efficient. In practice, the efficiency of such equipment depends greatly on the temperature of the dust particles and the amount of water in the particles (Marlin 1987).

Based on data from IC Consult (1991), dust generation from kiln operation with dry process cement production using multi-cyclones (rated at 80% efficiency) is 24.4 kg/t, or 122 kg/t without such pollution controls; if dust control is 99.99% effective, dust emissions would be reduced to 0.012 kg/t of production. Data collected directly from SC staff suggests that (uncontrolled) dust production is approximately 30-40 t/hour (average 35 t/hour) with a throughput of 137 t/hour in 1985 (1.053 million tonnes and 7,680 hours

operation per annum). This is equivalent to 0.255 tonnes of dust per tonne of production or 25% of production throughput.

It should be noted that dust generation represents a significant fraction of clinker production throughput (about 12% according to IC Consult's data). There are thus obvious economic incentives to recycle clinker dust, which has already consumed substantial amounts of capital, energy and labour in processing to a semi-finished state. According to SC's staff, using an EPs (and other dust control equipment), 99.99% of dust is recycled to produce clinker. The investment required for their first two EPs in 1990 (for 1.5 million tonnes per annum capacity) was approximately Rp 10.5 billion, with a projected payback period of 5 to 8 years.

Despite assertions by the cement producers of highly effective dust control measures, the area surrounding the ITP plant, for instance, is covered in cement dust and a cloud of dust hangs over the plant. Residents in the area have complained to ITP for some time about the health impacts and physical damage caused by the dust; walking anywhere in the vicinity of ITP's plant results in one's hair and skin becoming clogged with cement dust. Local resident also report that at night and when it is raining dust pollution, including what appears to be flyash fallout from coal combustion, is much more severe. It may well be that ITP turns off their dust control equipment whenever they can. Thus, cement production probably has much more severe environmental impacts than the 'official' air quality statistics reveal.

It appears, on the basis of direct observation, highly unlikely that only 1.67 kg/hour of dust is released into the air (0.012 kg/t times 137 t/hour). If, for instance, only 99% of dust is captured by the dust control equipment (including EPs), this would result in the release of some 167 kg/hour (1.2 kg/t times 137 t/hour), one hundred times the 'official' figure.

Table 13 Official Dust Emissions (stack discharge) at ITP (mg/Nm^3)

Plant No.	Minimum	Maximum
1	100	150
2	120	130
3	60	100
4	60	100
5	40	60
6	60	80
7	60	80
8	40	80

Notes: Nm3 = normal (standard) cubic metre of air.
The KLH standard is 400 mg/Nm^3 and World Bank standard 50 mg/Nm^3.
Source: ITP's response to a questionnaire from BPPT.

The figures in the Table 13 were obtained from ITP, but are slightly different from the figures cited by the President Director of ITP (Kompas, February 18, 1993), who said that dust emissions from chimney stacks are currently 125 mg/Nm^3.

Thus, given that estimated dust production per unit of clinker throughput (based on data obtained from plant operators) is technically and economically unreasonable, we are forced to use the estimate of dust emissions from IC Consult for the base year 1985, i.e. uncontrolled dust emission of 122 kg/t of production. For 1985, before the installation of EPs by any of the cement producers, we assume that only 95% of dust from kiln operations was recycled, this gives an estimate of 6.1 kg/t of production for technically advanced producers such as ITP and SC. It should be noted this estimate may be optimistic, as such data as were available were collected from the two largest, most technically advanced producers.

In addition to particulate emissions, fuel combustion for cement production also generates CO, SOx, and NOx and smaller quantities of hydrocarbons, aldehydes and ketones. Based on IC Consult's data (1991) for SO_2 generation by cement kilns (assuming 91% of kiln fuel is coal and 9% natural gas) emissions of SO per tonne of cement production are 3.83 kg/t (from natural gas) and 5.1 kg/t (from coal); in addition, 1.3 kg/t NOx is generated during fuel combustion. Kiln operations also result in emission of 0.06 kg of lead per tonne of cement (ibid).

Unfortunately, the basis for calculating the data presented in Table 14 is unavailable. That is, we have not been able to discover the basis of either measurement or calculations of

what 'x% of volume' means. To make sense of this data we would need to know, at a minimum: where the data were collected, for how long, and consumption of air per unit time - BPPT staff were unable to assist us with this information.

Table 14 Emissions from Fuel and Combustion.

Emission	ITP	SP	SK	SG
CO				0.4
Particles	80-150	250.0		293.0
SO_2	8-10	0.3	8.3	16.0
N_2				76.8
CO_2		20.0	14.5	6.8

Notes: For CO, SO_2, N_2 and CO_2 units are % of volume, the unit for particulates is mg/m^3 - for evaporation from and combustion of fuel. ITP: ADO (Automotive Diesel Oil), fuel oil and coal; SP, ADO and coal; SK, ADO and coal; SG, ADO, fuel oil, IDO and coal.
Source: Cement producers' responses to BPPT questionnaire.

All these pollutants have negative effects on the health of humans and other animals, e.g. respiratory congestion, eye and respiratory tract irritation. In addition, acid rain (from formation of dilute acid solutions of N_2 NOx and SO in the athmosphere precipitating) corrodes metal (KLH-BPPT 1992).

The World Bank standard limits for the most important combustion-generated pollutants are:

SO_2 (at ground level).

Inside Plant Fence	Annual	Arithmetic mean	100 ug/m^3
		Max. 24 hour peak	1000 ug/m^3
Outside Plant Fence	Annual	Arithmetic mean	100 ug/m^3
		Max. 24 hour peak	500 ug/m^3

Particulates/Dust (dry basis).

From clinker kiln	150 g/t Feed
From clinker cooler	50 g/t Feed
Ground level outside plant fence	80 ug/m^3
Stack discharge	50 mg/m^3

Cost Structure

Of total manufacturing costs, electricity and fuel constitute more than half (e.g. 57.8% for SC in 1985). Table 15 presents data on SC's estimated costs of production for 1985 and 1990. Table 16 presents data on the producers price (ex factory) for the same company and years.

Table 15 Cement, Producer's Costs - PT Semen Cibinong (ex factory)

Rupiah	1985	1990
per tonne	44,354	72,530
per sack	1,774	2,901

Notes: Prices are at market not constant (1985) prices; the government controls cement prices.
Source: Annual Report, PT Semen Cibinong, 1985 and 1990

Table 16 Cement, Producer's Prices - PT Semen Cibinong (ex factory)

	1985	1990
Net sales (MRp)	63,179	96,060
Quantity ('000 tonnes)	1,034	1,045
Price/tonne (Rp)	61,101	91,923

Notes: Net sales are cost of production (from Table 16) plus gross profit.
Prices are at market not constant (1985) prices.
Source: Annual Report, PT Semen Cibinong, 1985 and 1990.

Based on the NRMP-IEA I-O 30-sector model, total intermediate input costs for the cement (and limestone) sector in 1985 were Rp 455,977 million and other costs (including wages and profits) Rp 222,993 million, a total of Rp 678,970 million; total production in 1985 was 9.817 million tonnes. On this basis, costs of intermediate inputs in 1985 were Rp 46,448 per tonne and other costs Rp 22,715 per tonne, a total of Rp 69,163 per tonne. Hence, SC's costs were slightly lower than the national average, and their reported revenue per tonne from sales slightly higher (see Tables 16 and 17).

III Future Technology

Most technological development in the cement industry focuses on energy savings, due the need to reduce the current levels of per unit production energy consumption. The greatest potential for energy savings relate to the process of burning clinker, which consumes about 90% of the total energy required. Improvements in kiln design and system control technology (real-time computer control) and grinding technology are the main means by which this will be achieved. Assuming that cement companies in Indonesia keep on producing portland cement as their main product, the proportions of raw materials used are expected to remain constant to 2020.

Pollution control is the other area of production that requires serious attention, for both combustion products (gaseous and particulate) and for clinker and cement dust generated during kiln and other operations. Reductions in pollution from fuel combustion will come in part from improved energy efficiency (less fuel consumed per unit of production) and from improved control of stack emissions of fly ash and other particulates. As should be apparent, the industry (particularly the more advanced producers) have fairly up-to-date clinker and cement dust control equipment available or in place, but fail to either operate it properly or on a full-time basis. Improvements in this area will require both equipping all plants (existing and planned) with effective dust control equipment and enforcing its use. Improvements in this area appear to be more a matter of political will (enforcement of existing regulations) than the availability of the technical means or skills.

Energy Consumption

Since 1985 there has already been an almost complete revision in the sources of energy used in cement production - from petroleum products (IDO and LPG, in the main) to coal. By 1990 almost no liquid fossil fuels were being used (except for transport) and LPG use was restricted to very minor uses (e.g. kiln pre-heating). These fuels had been completely replaced by coal, for firing clinker kilns and on-site generation of electricity. This shift in fuel sources is estimated as resulting in a 90% reduction in the use of products from petroleum refining, and a 100% reduction in LPG use. The savings in energy use possible from improvements in process efficiency are described below.

Compared to wet method cement production, the dry process method (with a suspensed preheater kiln system) results in a significant reduction of energy consumption (40-50%/tonne), and has already resulted in widespead adoption of dry process technology. This is a major once-off energy saving that is unlikely to be repeated, because there are minimum thermodynamic limits on the energy required for achieving the necessary chemical reactions during clinker procesing. Thus, energy savings in the future will be

incremental rather than sudden, however the scale of potential energy savings is still significant.

Further potential reductions in energy consumption could come from: calcination of clinker in a fluidized bed kiln; changing the mineralogy of cement, by using a mineralizer; low temperature technology for clinker processing, using calcium chloride; and technical improvements to grinding mills, and the use of roller mills and grinding aids to reduce consumption of electricity for grinding clinker. Considerable energy savings can be realised by using secondary (recovered) energy for heating purposes, drying raw materials and generating electric power. These technologies and their potential for energy savings are summarised in Table 17 (UNIDO 1984, Ritonga 1991).

A comparison of the wide range of energy consumption rates for 1985 and 1990 (Table 11), shows major energy savings are readily achievable, and have already been achieved by some producers, despite lower thermal efficiencies caused by switching to coal. If we assume the average plant in the year 2000 has achieved Semen Tonasa's (ST) 1990 level of production efficiency (3.099 GJ/t) compared to the 1990 national average of 3.391 GJ/t, this represents a net improvement of 8.6%, or a reduction of 7.9% in thermal energy requirements per tonne of cement. This would then make Indonesian cement production in 2000, on average, about as thermally efficient as possible with existing technology (3.18 GJ/t, from Table 10, cf also IC Consult 1991).

Additional energy savings are possible if the technologies listed in Table 17 are put into place after (or before) the year 2000; by which time most plants now in operation will probably be due for replacement or major up-grading. With some combination of these technologies, further improvements in thermal efficiency of at least 25% (less than half the minimum possible according to UNIDO) should be achieveable by 2020. A further 25% improvement in efficiency by 2020 (over 2000), would reduce thermal energy required to about 2.32 GJ/t, a saving of 31.5% compared to 1985.

Table 17 Potential Energy Saving Technologies for Cement Production

Energy-saving technologies, equipment and measures.	Potential Saving
Calcination of clinker	**Fuel**
In kiln with decarboniser, compared to kiln with a cyclone heat exchanger [a]	5-7%
Intensification of calcining process, including reduced suction of ambient air, utilising mineralisers, automatic control systems, efficient heat exchangers, fuel combustion systems.	10-15%
Utilisation of ashes, slags, and other materials containing CaO, calcium silicates or aluminates [b]	10%+ (depends on additive used)
Utilisation of combustible industrial waste and domestic garbage for fuel	equivalent to amount of waste used as fuel
Utilisation of fluidized kilns for calcining clinker (compared to rotary kilns) [c]	25-35%
Utilisation of secondary energy for electric power generation, raw material drying	8-20%
Potential fuel savings	58-87%
Clinker grinding	**Electricity**
Milling cement in roller mills (compared to ball mills) [d]	15-25%
Utilisation of milling intensifiers, optimization of granulometric composition.	10-15%
Potential electricity savings	25-40%

Notes: a) Increase of capacity by 2.5 - 7.5 times, respectively and decrease of consumption of refractories by 4 - 5 times; b) Savings in raw materials components; c) Reduction of capital investments by 20-30%, potentiality for burning shale and low-grade coal; and d) Reduction in capital investments for construction, potentiality for additional cooling of clinker in milling processes.
Source: UNIDO 1984

In terms of sources of fuel, coal will continue to be dominant in the cement industry; a small proportion of IDO will still be used in producing certain types of cement. It should be noted that a part of coal requirements are currently met by importing coal from Australia and China (data on imports is not available).

Changes in the Product Mix

Neither PT ITP or PT SC, the main producers, expect there will be major changes in the technology related to type of products required and, hence, the proportions of raw material inputs, i.e. they assume 90% of the cement produced in the future will still be portland cement. However, it is possible that by 2020 there maybe significant changes in the product-mix demanded of and offered by the cement industry; we have no data on specific production requirements. Given the current and estimated medium-term scale of portland cement production, i.e. about 40 million tonnes by 2000 - demand for one million tonnes per annum of new types of cement, for instance, would not radically affect average technological input requirements.

According to Ritonga (1991), research in the building materials industry directed to finding an alternative building material for construction of low-cost housing has identified a number of potential product substitutions for portland cement, these are listed below.

Lime Pozzolan Cement: A hydraulic cement produced from dry powdered natural pozzolan mixed with dry powdered slaked lime. It is a cheaper substitute for portland cement for structures which do not need high compressive strength, stabilisation of soil for building foundations and as a sub-base for road construction. Lime and natural pozzolan are found in many placess in Central Java.

Artificial Lightweight Aggregates: Suitable for the construction of multi-storey residential buildings located in the earthquake regions, where it is more economical to use lightweight concrete with lighter aggregates. In East Kalimantan, for instance, where natural aggregates are scarce, it could be used as an overlay for road construction; it can be produced from shales, which are found in many parts of East Kalimantan. In addition, fly ash, a type of waste material from the burning of pulverized coal can be used as raw material.

Rice Husk Ash: Besides the two alternative products above, there is also a cement made of rice-husk ash (RHA) and lime. RHA is a highly siliceous and easily grindable residue obtained from the combustion of rice-husks. It has significant economic advantages for countries that have large quantities of rice husk readily available, and virtually free of cost

(UNIDO 1984). RHA masonry cement can be used as mortar and plaster, for concrete floors and as a lime concrete in foundations.

Labour Requirements

ITP and SC's combined labour requirements in 1992/93 were about 0.560 person-years/1000 t (Table 18). Assuming production in their existing plants reaches 90% of design capacit. with the existing workforce, their labour requirements should fall to about 0.463 person-years/1000 t in the near future. Compared to the 1989 national average of 1.032 person-years/1000 t, this repesents a net decline in labour inputs of about 57%, or a reduction in labour requirements of 36% per unit of production. This level of labour requirements is probably close to the minimum achievable, given the physical limits on the size of production units, and a slight increase in labour use required for coal fuel. Thus, for 2020 national average labour requirements are estimated at 0.463 person-years/1000 t, given that most additional capacity planned for construction will be as advanced technologically as ITP and SC's production facilities.

Since 1988/89, ITP has stopped recruiting people with only elementary or junior high school qualifications, graduation from senior high school being the minimum acceptable qualification. In the future they will increasingly recruit labour with diploma and university qualifications, increasing the proportion of their workforce with these qualifications from about 4.12% (1992) to 10% by 1995. However, they are not planning an overall reduction in the size of their workforce. Assuming other companies follow this trend, in the next 25 years the workforce in the cement industry will change primarily in terms of educational composition.

Raw materials handling, product packing and truck loading and dispatch will require maintaining a substantial semi-skilled labour force, despite the trend to recuiting a more highly qualified workforce and the introduction of computer-controlled processing. Industry sources do not expect increases in plant scale to result in significant reductions in the need for semi-skilled labour per unit of production.

Table 18 Estimated Labour Required per tonne of Production in 2020, by Educational Level (person years per thousand tonnes)

Education level	ITP/SC 1992/93	ITP/SC 2020	Change (%)
Elementary school	0.118	0	-100
Junior high school	0.104	0	-100
Senior high school	0.300	0.416	38.7
Diploma	0.021	0.025	19.0
University	0.018	0.021	16.7
Total	0.560	0.463	-17.3

Notes: Assuming 90% utilisation of ITP and SC's combined capacity of 12.4 million tonnes, production in 2020 would be 11.16 million tonnes; combined production in 1992/93 for ITP and SC was about 10 million tonnes. In 2020, dimploma holders are assumed to make up 5.5% and university graduates 4.5% of the total workforce.
Sources: Based on Table 9 above.

Environmental Impacts

The main environmental impacts requiring improved control are dust emissions and various emissions from fuel combustion. The technology for achieving greatly improved levels of control is already available. However, if anaecodatal evidence of turning off dust control equipment already installed is even partially valid, more attention and resources will need to be directed to monitoring compliance with standards and enforcing regulations. In addition, there will be a need for substantially increasing the number of trained personnel available for equipment operation and maintenance, given that increases in the efficiency of most types of emission controls depends crucially on operational and maintenance standards.

According to both ITP and SC, they have already installed equipment capable of controlling dust (stack) emissions from kiln operations to well below GOI environmental standards (400 mg/m ^{3}); this is 8 times the World Bank standard of 50 mg/m ^{3}. As the available data on gaseous emissions from combustion (CO, SO $_x$ and NO $_x$) is flawed, it is impossible to estimate to what extent compliance with GOI or other standards is being observed.

Dust Emissions

For 1985, we estimated a level of 6.1 kg of dust emissions per tonne of cement production, based on dust control equipment being 95% effective. If efficiency improves to 99%, this would reduce dust emissions to 1.22 kg/t of production. Reductions below this level will be (exponentially) harder to achieve, requiring markedly higher investments in dust control equipment and its maintenance. For lack of better information 1.22 kg/t is the estimated level of dust emissions for 2020. Compared to 1985, this is a five-fold reduction in dust emissions per unit of production.

Gaseous Emissions

Reductions in gaseous emissions (SO_2, NOx, etc.) depend on two factors: fuel consumption per unit of production and the level of combustion emission control achieveable. By 2020, thermal fuel consumption is estimated to have declined to 2.32 GJ/t, a reduction in requirements of 31.5% over 1985. By itself, this will result in an identical reduction in the level of gaseous pollution from combustion. Substantial additional reductions are possible with the application of existing pollution control equipment.

IV Summary of Technological Coefficients for 1985 and 2020

The technological coefficients for the cement sector for 1985 and 2020, based on the foregoing assumptions and estimations, are presented below in Table 19.

Table 19 Technological Coefficients for Cement (Sector 16), 1985 and 2020

Intermediate inputs			Change in coefficient 1985-2020(%)
7	Coal		(.0716)*
18	Petroleum refining		-90
19	LNG		-100
20	Electricity		-8
Labour inputs			
Total employment per unit output			-17
Capital inputs			
17	Other manufacturing		+17
23	Construction		
Environmental impacts			
		1985 level	
Dust	kg/tonne	6.1	-80

* The coefficient for coal is the absolute level of coal inputs per unit output in Rp/Rp

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