PN-ABR-959
89230

NRMP-IEA Input-Output Working Paper No. 12

CASE STUDY OF THE CHEMICALS SECTOR

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Jakarta

March 1993

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 expert 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.

1 Introduction

This case study describes current and future technologies in the Indonesian chemicals sector (Sector 15 in the NRMP-IEA 30-sector classification system). It relies on two case studies of the manufacture of polyvinyl chloride (PVC) and formaldehyde resins to estimate technological coefficients and environmental impacts, and to illustrate the technological changes expected in the period 1985-2020.

The reader should be aware that this study is based on very incomplete information about this complex industrial sector. What follows is best regarded as a set of 'briefing notes' rather than an in-depth study of the sector. The estimations of likely changes in technological coefficients for the sector to the year 2020 should be treated with caution.

In the period 1986-93 the Indonesian chemicals industry underwent rapid growth, with a large number of new plants starting production, many of them producing chemicals for downstream use in the processing and manufacture of petrochemicals and plastics. The focus of development in the sector has been petrochemicals making use of Indonesia's petroleum resources. This has required the parallel development of inorganic chemicals production capacity (acids and other reagents). The sector has relied almost wholly on imported technology and expertise, with most of the major manufacturers set up as joint ventures with Japanese, European or American partners.

The scale of production of basic inorganic chemicals and tyres by 1991/92 was sufficient to both meet local requirements and provide a surplus for export (Table 1).

Official data on the 1985 workforce in the chemicals sector (BPS 1986) reports a workforce of 248,631 persons. In 1990 the workforce, according to an industry report, was 385,462 persons, an increase of around 36 per cent.

Table 1 Production, Capacity and Local Requirements for Chemical Products - 1987-93

	1987/88	1990/91	1992/93
Basic inorganic chemicals ('000 t)			
Production	26,663	34,509	
Prod. capacity			50,572
Local requirement	24,063	32,305	26,767
Basic organic chemicals ('000 l)			
Production	104,034	137,967	
Prod. capacity			370,591
Local requirement	106,814	76,089	85,130
Basic inorganic chemicals (gas) ('000 m^3)			
Production	93,259	134,940	
Prod. capacity			368,694
Local requirement	93,259	134,715	173,233
Safety Glass ('000 m^2)			
Production	1,008	1,467	
Prod. capacity			3,045
Local requirement	1,008	1,467	1,940
Tire manufacture ('000 tyres)			
Production	18,911	27,789	
Prod. capacity			42,725
Local requirement	15,200	17,700	19,600

Source: Perindustrian (n.d.)

The rate of growth in this sector is illustrated by the rapid increase in investments in new production facilities and expansion of existing plant during the 1985-90 period (Table 2). During this period annual investment has risen over 12-fold, from Rp 1.2 to Rp 18.8 billion.

Table 2 Investment Growth in the Chemicals Sector 1985-90.

Year	B Rp
1985	1,216
1986	1,041
1987	2,910
1988	8,944
1989	7,370
1990	18,779

Note: The investments include new projects and expansion of existing production facilities.
B Rp = Billion Rupiah.
Source: Perindustrian, n.d.

2 Intermediate Inputs and Users of Chemicals

The sector relies largely on inputs coming from within the sector; these accounted for about 60 per cent of total intermediate inputs in 1985 (Table 3).

Table 3 Major intermediate inputs to the chemicals sector, 1985

Sector Name	NRMP-IEA 30-sector	Share of total (%)	Coefficient
Chemicals	15	59.69	0.57203
Wholesale & retail trade	24	12.21	0.11705
Other manufacturing	17	5.76	0.05517
Transportation & communication	26	5.21	0.04986
Estate Crops	3	5.07	0.04861
Food, beverage & tobacco	11	4.15	0.03148
Real estate & financial	27	3.11	0.02979
Pulp & paper product	13	1.88	0.01080
Petroleum refining	18	1.69	0.01619
Coal	7	1.25	0.01184

Note: See Annex 1 for a complete listing.
Source: NRMP-IEA Input-Output Table 1985, 30-sectors.

Table 4 Chemicals using sectors, 1985

Sector Name	NRMP-IEA 30-sector	Share of total (%)	Coefficient
Other manufacturing	17	38.41	0.36237
Chemicals	15	23.18	0.21865
Fertilizer & pesticide	14	11.67	0.11004
Social & other services	29	10.39	0.09805
Water utilities	23	4.83	0.04561
Wood products	12	3.64	0.03431
Crude oil	8	2.67	0.02519
Food, beverages & tobacco	11	2.59	0.02446
Pulp, paper & products	13	1.50	0.01426
Petroleum refining	18	1.11	0.01045

Note: See Annex 2 for a complete listing.
Source: BPS (1989)

The Other Manufacturing sector (17) is the major user of chemicals, consuming 38.4 per cent of total outputs by value in 1985 (Table 4). The chemicals and fertiliser and pesticides sectors were the second and third largest users, consuming 23.2 per cent and 11.7 per cent of output respectively in 1985.

3. Case Study: PT Asahimas Subentra Chemical (PT ASC)

In addition to PT ASC, there are four other major caustic soda producers: PT Indoprint (PT Indochlor Prakarsa Industries), PT Tjiwi Kimia, PT Soda Waru and PT Indah Kiat. However, only PT ASC and PT Indoprint produce caustic soda for sale, the other companies use their output in downstream processing, e.g. pulp and paper production.

Most of the information for this case study comes from technical experts working for PT ASC, the company's literature and environmental evaluation studies. Information from experts working in the petrochemical and gas sections of PT Pertamina and experts from PT Indochlor Prakarsa Industries were also consulted. The case study focuses on production technology used by PT ASC, which started production of PVC in mid-1989; its integrated plant is currently the sole producer of PVC in Indonesia.

3.1 Production Technology

PT ASC is an integrated petrochemical plant, with three linked production units: chloralkali, vinyl chloride monomer/ethylene dichloride (VCM/EDC), and polyvinyl chloride (PVC).

There are three types of chloralkali industrial processes available: mercury, diaphragm and ion-exchange membrane. Currently, PT ASC is the only Indonesian producer using the ion-exchange technology; this technology was developed by Asahi Glass Co. (Japan). PT Indoprint, for example, uses the mercury system, which has more severe environmental impacts. Table 5 compares these three technologies in terms of product quality, environmental impacts, and energy consumption (electricity and steam). On the basis of this comparison, the ion-exchange technology causes the least environmental damage and rates moderately in terms of energy requirements.

Table 5 Comparison of chloralkali production technologies

Type of Process	Product Quality	Environmental Impact	Electricity Consumption	Steam Consumption
Ion-exchange	Best	Least	Moderate	Moderate
Mercury	Moderate	Worst	Worst	Best
Diaphragm	Worst	Moderate	Moderate	Worst

Source: Integrated Petrochemical Plant PT ASC.

The main inputs to production are sodium chloride (NaCl) and ethylene. In the production process these are reacted with soda ash, sulphuric acid, alcohol, flocculant, catalyst and chlorine gas. Raw salt is imported from Australia because of the purity of the salt (about 99 per cent pure, local salt is only about 60 per cent pure); ethylene is currently imported from Saudi Arabia. Table 6 lists inputs to PVC production, and the amounts required to produce one tonne of output.

Table 6 Inputs to petrochemical production and for PVC, 1992

Inputs	Tonnes/ annum	Total in/out	for PVC in/out
NaCl	210,000	0.6422	0.2749
Ethylene	80,000	0.2446	0.1047
Soda Ash	1,300	0.0040	0.0017
H_2SO_4 acid	1,600	0.0049	0.0021
PV Alcohol	60	0.0002	0.0001
Flocculant	1.3	0.0000	0.0000
Catalyst	250	0.0008	0.0003
Chlorine gas	3.5	0.0000	0.0000
Total inputs	293,214.8	0.8967	0.3839

Note: PVC is 42.8 per cent by volume of output of the plant, and the total inputs/output in the third column have been *pro rated* on this basis to estimate PVC production requirements.
Source: Environmental Evaluation Study, Soda Caustic, EDC, VCM and Vinyl Chloride Industries, PT ASC, 1992, Jakarta.

Total production sold in 1992 was 327,000 tonnes, of which 140,000 tonnes or 42.8 per cent was PVC. Thus, in Table 6 the range of inputs necessary for all of the steps in producing PVC have been multiplied by 0.42 to estimate the requirements for PVC alone. (The same procedure has been followed for estimating labour, energy and other production requirements.)

In the chloralkali process, the salt (NaCl) is dissolved in water and further purified. The high purity salt solution is then electrolysed to produce caustic soda (NaOH), chlorine gas

(Cl_2), hydrogen gas (H_2), and sodium hypochlorite (NaClO); part of the chlorine is consumed in producing EDC. Chlorine is also combined with hydrogen to produce hydrochloric acid (HCl).

The overall PVC production process can be divided into three steps: polymerisation, vinyl chloride monomer (VCM) stripping and product drying. The raw materials (VCM, demineralised water, initiator and other chemicals) are introduced into an air-free batch reactor, and the polymerisation reaction then occurs at a constant controlled temperature. The final product is a VCM-PVC mixture in the form of slurry; unreacted VCM is stripped-out from the slurry and recovered for reuse. The slurry, now relatively free of VCM, is dried and the resulting PVC resin is sifted and transferred to silos for bagging.

The steps in the chemical process are as follows: chlorine gas from the chloralkali plant is reacted with ethylene (C_2H_4) to produce ethylene dichloride (EDC), which is further processed (cracked) to produce VCM. In the PVC plant, the VCM is polymerised (made into a long chain molecules) into PVC. The HCl co-product is recycled for production of EDC through the oxy-chlorination process.

Labor requirements

According to information collected from PT ASC, their total workforce in 1992 was 620 persons, all of whom had senior high school or more advanced qualifications (Table 7). Thus, in 1992 labor required per 1000 tonnes of total production was 1.9 person-years and 0.8 person-years per tonne of PVC.

Table 7 PT ASC Labor Force by Educational Level, 1992

Educational Level	Persons	% of labour	Labour per unit of output (P-y/1000t) total	PVC
Senior high school	500	80.6	1.5	0.6
Diploma	95	15.3	0.3	0.1
University	25	4.0	0.1	0.0
Total	620		1.9	0.8

Source: Budirahardjo, PT ASC, pers. comm.

Energy consumption

PT ASC relies on electricity from PLN (Perusahaan Listrik Negara - State Electricity Company) for most its energy requirements. It also have its own back-up generating plant.

Process heat for the VCM plant is supplied by oil-fired boilers. Total energy consumption by PT ASC for 1990 is presented in Table 8.

Table 8 PT ASC electricity and diesel fuel consumption, 1990

Plant	Unit	per annum
Electricity		
C/A plant	MWh	337,550
EDC/VCM plant	MWh	13,320
PVC plant	MWn	28,700
Total electricity		379,570
IDO	10^3 l	9,529

Notes: IDO = industrial diesel oil
Source: pers. comm., PT ASC

Based on annual total production of 327,000 tonnes and annual PVC production of 140,000 tonnes, energy consumption per tonne of PVC is estimated as 496 KWh of electrical power and 12.5 litres of IDO (Table 9).

Table 9 PT ASC electricity and IDO consumption per tonne of output

Energy	total	PVC
Electricity (KWh)	1,160	496
IDO (litres)	29.14	12.48

Source: Based on annual production for 1992 and Table 8

3.2 Environmental Impacts

Waste water

Total water use per annum in 1992 was 1.1 million cubic metres (Table 10), and water output about one million cubic metres, the difference being used in production and lost through evaporation. On the basis that PVC represents 43 per cent of annual production, water input per tonne of PVC was 1.41 cubic metres and water output per tonne of PVC 1.35 cubic metres.

Table 10 PT ASC annual water input and output, 1992

	Volume m^3	Water input/ tonne of output	Water input tonne of PVC
Water input	1,072,764	3.28	1.41
Water output	1,029,084	3.15	1.35

Source: VCM 1992

The composition of waste water has been estimated from a study conducted by PT VCM in 1992 (Table 11). On this basis, water pollution by PT ASC in 1992 was well below government standards for every coefficient.

Table 11 PT ASC water pollution coefficients, 1992

Parameter (g/m^3)	Quality	Std
Sus. solid	3.54	<400
BOD-5	8.25	300
COD	13.48	500
NO3	6.11	30
NO2	0.03	3
NH3	0.445	-
PO4	0.008	-
Total HCO	4.49	70
Cr	0.008	3
Mn	0.04	3
Ni	0.005	-
Zn	0.043	10
Cu	0.05	3
Hg	0.0008	0.05

Note: Quality standard for West Java Province.
Source: VCM 1992

Air pollution and solid wastes

PT VCM's study also measured air pollution and solid waste production by each of PT ASC's production units; unfortunately the report gives no details of relevant air quality standards. The volumes of waste from each plant are summarised in Table 15.

Table 15 PT ASC pollution, 1992

Quantity	Parameters	
Chloralkali plant		
Liquid	+/- 5 m^3/hour	ph: +/- 7
Gas	+/- 2,000 Nm^3	N_2, O_2, H_2O
EDC/VCM plant		
Solid waste catalyst	+/- 500 drums/y	Clay, Copper Potassium
Gas	10,000 Nm^3/hour	Cl_2: +/- 5 ppm HCl: +/- 35 ppm
PVC plant		
Liquid	16 m^3/hour	ph: +/- 7 con: 20-5- ppm

Each drum of waste catalyst from the EDC/VCM plant contains 200 litres.
Source: VCM 1992

Gas and liquid waste processing

PT ASC has waste treatment and recovery systems that both reduce direct environmental impacts and capture economically valuable chemical by-products. These units processes liquid and gas wastes from the LP-EDC and VCM sections; other wastes are burnt in an incinerator to produce process heat for steam generation. The waste gas from the incinerator is cooled and scrubbed to capture hydrochloric acid that is then reused in the chloralkali process. Waste water treatment focuses on removing organic compounds and heavy metals from the effluent.

3.3 Technological Change to the Year 2020

As PT ASC is already using state-of-the-art production technology no change is planned. Any expansion of plant capacity will rely on existing technology, except for improvements in computer-based process control.

Raw materials

There is no substitute for the basic raw materials (raw salt and ethylene), and rate of use is determined by chemical reaction requirements. However, development of domestic sources of ethylene and high purity salt will be utilised as soon as they become available.

Water use

PT ASC has made a feasibility study for recycling waste water output but concluded that the process was too expensive. In the future, however, PT ASC plans to obtain their water from the adjacent Krakatau iron and steel plant, and possibly in 5-10 years begin to recycle waste water. In the near term they are aiming to reduce water consumption by about 5 per cent through improved maintenance and process control.

Labor requirements

The extension of computer-based control systems throughout the complex will lead to the need for a more highly qualified workforce in the future. Company staff who were consulted were unable to quantify the anticipated change, or the likely changes in total labour force.

4 Case Study: PT Dover Chemicals (PT DC)

The total installed capacity of the adhesive resin industry was 910,000 tonnes per annum in 1990/91 and actual production 854,200 tonnes (Departmen Perindustrian 1993).

PT Dover Chemicals specialise in producing formaldehyde resins for use in the plywood industry; their main product is urea formaldehyde resin. In 1990/91 they produced 4,200 tonnes of formaldehyde, 4,200 tonnes of melamine formaldehyde (MUF) resin and 25,800 tonnes of urea formaldehyde (UF) resin.

4.1 Production process

The production of the resins begins with the oxidation of methanol, combined with sodium hydroxide, with air to form formaldehyde. The products of this reaction are vaporised, then superheated and reacted over a silver gauze catalyst. About 65 per cent of the methanol is converted to formaldehyde on each pass through the reactor, and the output is separated and unreacted methanol recycled. The resulting formaldehyde is diluted with water to form a 37 per cent strength solution of formalin, prior to further reaction steps.

The formalin from the first reaction is used in two further reactions: production of MUF resin and UF resin. The reaction processes are similar -- except that in the latter melamine is not used -- with the formalin combined with steam and urea over a catalyst.

PT DC has its own generating capacity which consumes some 445,200 litres or 378.4 tonnes of diesel per annum. Water consumption, for cooling, steam and chemical processes, is 37,440 cubic metres per annum.

Material and energy inputs

Data from PT DC does not separate formaldehyde that is sold from that which is used in resin production, or that which is used for MUF as opposed to UF production, thus we have estimated technological coefficients for the whole process (Table 16).

Table 16 PT DC -- inputs to formaldehyde, MUF and UF resin production

Input	tonnes	input/output
Methanol	10.0	0.0003
Catalyst	2.41	0.0001
NaOH	60.0	0.0018
Urea	9,600	0.2807
Melamine	7.2	0.0002
Diesel fuel	378.4	0.0111
Water	37,440	1.0947

Source: PT Dover Chemicals, pers.comm.

Labour requirements

The total labour force at PT DC is only 26 persons. Ten have primary school education, seven have completed junior high school, seven have completed senior high school, and two have diplomas.

On the basis of their annual total production of 34,200 tonnes of formaldehyde and resins, each 1000 tonnes of output requires 0.8 person-years of labour.

4.2 Environmental Impacts

Waste water from the production process is the main source of pollution, with dust, sulphur dioxide and nitrous oxides from fuel combustion the primary source of air pollution. Annual water output is estimated by PT DC as 28,800 cubic metres. This is equivalent to 0.8421 tonnes per tonne of production. Table 17 presents details of the main pollutants and output per unit of production.

Table 17 PT DC Composition of Waste Water

Item	unit	output	poll/output
Water			
BOD	kg/t	0.0001	-
COD	kg/t	3.44	0.0029
Copper	kg/t	0.03	-
Lead	kg/t	0.01	-
Mercury	kg/t	0.01	-
Cadmium	kg/t	0.03	-
Air			
Dust	ug/m^3	78	
SO_2	ug/m^3	0.67	
NOx	ug/m^3	0.16	

Note: This pollution data comes from different factory, but one using an identical process.
Source: Environmental Evaluation Presentation, PT Gelora Citra Kimia Abadi, Desa Beringin, Kecamatan Alalas, Kabupaten Barito Kuala, Propinsi Kalimantan-Selatan, 1992.

5 Summary of Technological Changes to 2020

The changes in technological coefficients presented below (Table 18) are based in part on the material presented above and partly on information from both industry experts and general technical knowledge. As noted in the introduction, these estimates of change should be treated with caution. In addition to doubts about the reliability of our estimates, the chemicals sector is undergoing rapid change, both in terms of scale and composition of production. These changes, of themselves, introduce a further note of uncertainty into estimates of technological change for the sector as a whole.

Improvements in process chemistry (catalysts) are expected to result in increases in yields (outputs of chemicals per unit of raw materials inputs) of some 25 per cent. Energy use per unit output are estimated to decline by 20 per cent due to improvements in heat recovery, insulation and more efficient electric motors (especially for pumping). Automation of process control is expected to reduce unit labour requirements by 40 per cent and to increase capital costs by 5 per cent (plus 1 per cent increase in capital costs due to energy

savings). Because of very limited information on pollution, and the great diversity of products and effluents within the sector, no estimates of changes in pollution are offered.

Table 18 Changes in Technological Coefficients in the Chemicals Sector

			Change between 1985 & 2020 (%) S1
Intermediate inputs			
15	Chemicals		-20
17	Other manufacturing		-20
18	Petroleum refining		-40
20	Electricity		-40
Labour inputs			
Total employment per unit output			-60
Capital inputs			
Total new capital requirements			+6
17	Other manufacturing		+6
23	Construction		+6
Natural resource impacts			
		Unit	1985 level	
Water input/output		m3/t	1.250	0
Water output/output		m3/t	1.200	0
BOD		mg/l	8.25	
COD		mg/l	13.48	
Suspended solids		mg/l	3.45	

Note: Intermediate inputs use the NRMP-IEA 30-sector classification.
Sources: see text

References

Anon 1993 Bakrie Bangun Pabrik PTA, Kompas, Tuesday, March 16, 1993.

BPS 1986 Economic Census of Large and Medium Manufacturing Establishment Sectors 1986, Volume II. Biro Pusat Statistik, Jakarta.

BPS 1989 Tabel Input- Output 1985, Volume 1. Biro Pusat Statistik, Jakarta.

BPS 1990 Annual Survey of Large and Medium Manufacturing Establishment Sectors 1990, Volume II, Biro Pusat Statistik, Jakarta.

VCM 1992 Environmental Evaluation Studies 1992 Caustic Soda, VCM, Vinyl Chloride Industries, PT Asahimas Subentra Chemical, Jakarta.

JETRO 1991 List of Japanese Investment Project in Indonesia 1991 JETRO (Japan External Trade Organization).

Perindustrian n.d. National Capacity Development of Industrial Sector, 1987-1994, Departmen Perindustrian (Ministry of Industry), Jakarta.

Tecnon 1993 Fibres & Intermediate Consulting Service, Tecnon (UK) Ltd., Calico House, London, UK, No.16, 22nd January 1993.