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# NATURAL RESOURCES MANAGEMENT PROJECT

BAPPENAS – Ministry of Forestry
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# ENVIRONMENT AND DEVELOPMENT IN INDONESIA
# AN INPUT – OUTPUT ANALYSIS OF NATURAL RESOURCE ISSUES

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# Abbreviations, Acronyms and Units

*Abbreviations*

| | |
|---|---|
| BOD | biological oxygen demand |
| COD | chemical oxygen demand |
| FB&T | food, beverages and tobacco |
| FTE | full-time equivalent |
| HS1 | high growth path with technological scenario 1 |
| HS2 | high growth path with technological scenario 2 |
| IDO | industrial diesel oil |
| LNG | liquified natural gas |
| LPG | liquified petroleum gas |
| MS1 | moderate growth path with technological scenario 1 |
| MS2 | moderate growth path with technological scenario 2 |
| p.a. | per annum |
| S1 | technological scenario 1 |
| S2 | technological scenario 2 |
| TCE | thermal conversion efficiency |
| TSS | total suspended solids |

*Acronyms*

| | |
|---|---|
| AMDAL | Analisis Mengenai Dampak Lingkungan (Environmental Impact Analysis) |
| BAPPENAS | Badan Perencanaan Pembangunan Nasional (National Development Planning Board) |
| BPPT | Badan Pengkajian dan Penerapan Teknologi (Agency for the Assessment and Application of Technology) |
| BPS | Biro Pusat Statistik (Central Bureau of Statistics) |
| FAO | Food and Agriculture Organization of the United Nations |
| GOI | Government of Indonesia |
| IEA | Institute for Economic Analysis |
| IRRI | International Rice Research Institute |
| KLH | (Menteri Negara) Kependudukan dan Lingkungan Hidup (State Ministry of Population and Environment) |
| MoFr | Ministry of Forestry |

| | |
|---|---|
| NRMP | Natural Resources Management Project |
| PLN | Perusahaan Umum Listrik Negara |
| PT | Perseroan Terbatas, Limited Liability Company |
| Repelita | Rencana Pembangunan Lima Tahun (Five-Year Development Plan) |
| RePPProT | Regional Physical Planning Programme for Transmigration |
| SOW | Centre for World Food Studies (Stichting Onderzoek Wereldvoedselvoorziening |
| TPTI | Tebang Pilih Tanam Indonesia (Indonesian Selective Cutting and Planting System) |
| UNIDO | United Nations Industrial Development Organization |
| USAID | United States Agency for International Development |

*Units of measurement*

| | |
|---|---|
| $10^6$ | million |
| $10^9$ | billion |
| boe | barrels of oil equivalent |
| btu | British thermal units |
| GJ | gigajoules ($10^9$ joules) |
| GW | gigawatts ($10^9$ watts) |
| GWh | gigawatt hours ($10^9$ watt hours) |
| ha | hectare |
| kg | kilogram |
| kWh | kilowatt hours |
| l | litre |
| m | metre |
| $m^3$ | cubic metre |
| mg | milligram |
| MW | megawatt ($10^6$ watts) |
| p-y | person year |
| Rp | Rupiah |
| t | metric ton (tonne) |
| TWh | terawatt hours ($10^{12}$ watts) |

# EXECUTIVE SUMMARY

This report presents the results of a model designed to project the impact of economic growth and technical change on employment, natural resource use and environmental degradation in Indonesia. The study draws on data generated by twelve case studies of economic sectors that reflect the views on technological change of engineers, production managers, agricultural experts, energy specialists and government policy advisors. The model is a dynamic input-output model that incorporates measures of natural resource use and environmental degradation.

The time period of the model is 1985-2020, through the end of Indonesia's Second Long-Term Development Plan. It makes projections about two possible paths for GDP growth, a high growth path with annual growth averaging 7 per cent and a moderate growth path with annual growth averaging 5 per cent. Two technological scenarios are defined; Scenario 1 (S1) assumes the continuation of current commercial trends and government policies, whereas Scenario 2 (S2) postulates technological changes that would be introduced if government policies placed heavier emphasis upon environmental protection and resource conservation. Technological change is defined broadly to include changes in intermediate, capital and labour inputs per unit of output as well as measures of natural resource use (such as land and water) and environmental impact (such as air pollution and soil erosion).

The base scenario used for comparative analysis is the moderate economic growth path combined with the S1 set of technological assumptions, MS1. The principal results of the analysis are as follows.

*Employment*

The moderate growth path (with GDP growing at around 5 per cent) with assumed rates of technological change provides 144.6 million jobs, enough to accommodate an anticipated labour supply of 134 million in 2020. All of the disguised unemployment in agriculture is absorbed and the share of agriculture in total employment demand falls from 53 per cent in 1985 (including disguised unemployment) to 26 per cent in 2020. The shares of both manufacturing and services rise substantially. On the high growth path (with GDP growing at around 7 per cent) a large labour shortage emerges: labour demand of 251 million is almost double the supply of 134 million. However, rates of technological change faster than those assumed here may reduce projected demand.

Large increases in the supply of skilled and highly skilled workers will be required due to both structural shifts to industries that use more highly skilled labour and increasing

application of technologies that require skilled workers. The results show that due to structural shifts alone on the moderate growth path Indonesia will require two and a half times more workers educated at the senior high school and university levels. Overcoming these bottlenecks in the supply of skilled labour will require large investments in education, both in the expansion of facilities and the upgrading of teaching. This should receive very high priority for government investment.

*Forest land*

Even with moderate growth under MS1 the existing 61 million hectares of natural production forests cannot satisfy demand for logs from natural forests which would require an area of over 100 million hectares. Both high growth scenarios (HS1 and HS2) show demands in 2020 much greater than the capacity of natural forests to supply. In contrast, if forest plantations provide two thirds of moderately growing timber demand then there appears to be no constraint due either to the limited area of natural forest or to availability of land suitable for plantations.

The shift to plantations is consistent with Indonesia's abundance of labour and emerging shortage of forested land. However, in order to minimise environmental damage, it will be necessary to ensure that new plantations are established only on already degraded land. As much of the land suitable for plantations is subject to traditional community ownership rights, the GOI should investigate ways of integrating the need to develop plantations with the needs of local communities to develop sustainable methods of increasing income, employment and welfare. Further, the GOI should consider funding an extensive research program to supplement presently inadequate information on the most suitable species, sites and management systems for tropical timber plantations in Indonesia.

The GOI could consider the following methods of ensuring more sustainable natural forest logging practices: introducing an independent forestry inspection and enforcement service, imposing a moratorium on granting new concessions, making renewal of concessions subject to an independent review of past logging practices, and raising the reforestation fund and forest fee to a combined $40 per cubic metre.

*Agricultural land*

At projected rates of growth in demand for paddy, there is unlikely to be any serious land shortage in this sector. Further, the results of the analysis suggest that Indonesia will be able to maintain rice self-sufficiency in the next decades but that substantial investments in improving the efficiency of irrigation will be required to relieve possible water shortages. It is likely that the attention of the government will need to shift from rice to other food

crops, for two reasons. First, maintenance of soil fertility will become increasingly difficult, threatening the long-term sustainability of yields. Secondly, land requirements are barely adequate to meet the demand for other food crops on the moderate growth path. On the high growth path, much greater imports of these crops will be necessary, especially to sustain the rapidly growing intensive livestock sector. In the estate crops sector a significant land shortage emerges, with requirements exceeding the maximum available area by 37 per cent under MS1.

*Atmospheric emissions*

Atmospheric emissions of carbon dioxide and oxides of sulphur and nitrogen increase rapidly between 1990 and 2020 under all scenarios -- roughly 400 per cent on the moderate growth path and 700 per cent on the high growth path. The assumed differences in technology are mostly swamped by the impact of growth of polluting sectors. While all sectors produce some atmospheric pollution, results indicate that three sectors are responsible for most of the air pollution: transportation services, electric utilities and households. These sectors offer the best prospects for significantly reducing air pollution through increased use of cleaner, more energy-efficient technologies and through reductions in the need for goods and services produced by energy-intensive sectors.

Greater fuel efficiency for all vehicles would cut emissions significantly, and could be achieved by the establishment of higher fuel efficiency standards, higher fuel prices or some combination of the two. The introduction of catalytic converters for motor vehicles and a reduction in the sulphur content of diesel oil would also reduce emissions. Even with greater fuel efficiency and the widespread adoption of catalytic converters, atmospheric emissions are likely to be high and relatively concentrated geographically. Measures to provide alternatives to private transport are likely to be required to reduce pollution to tolerable levels in the future. Clean, efficient mass transit systems could make a major contribution to reducing urban air pollution.

This is a critical time for encouraging the introduction of new, more efficient designs for household appliances because the rate of appliance ownership in Indonesia is low and is expanding rapidly. The establishment of energy efficiency standards (or taxes on less efficient appliances) which would gradually tighten over the next decade is one important means of achieving significant energy savings.

Nowhere is the choice of fuel more important than in the electric power industry, which is planning to expand its use of coal rapidly in the next decades. The application of cleaner coal burning technologies, such as coal gasification and fluidised-bed combustion used in combined-cycle plants, is worthy of serious consideration by the GOI. The imposition of

emission standards for electric power plants and the provision of financial incentives for achieving them, including penalties for exceeding standards and subsidies for the investments necessary to meet them, would go a long way towards ensuring the use of cleaner technologies and cleaner fuels.

*Water use and water pollution*

Under all scenarios, water withdrawals actually fall over the period 1985 to 2020. This is true despite steep rates of increase in water withdrawals in a number of manufacturing sectors and a doubling of household use of water. Savings in water uptake are made possible by the assumption of greater efficiency in paddy irrigation from its current level of 25 per cent to 50 per cent with investment in upgrading irrigation systems. These improvements, however, also require substantial changes in farmer behaviour which will not occur without government intervention including appropriate water pricing.

The results suggest that with moderate growth of the manufacturing sectors, accompanied by pressure on manufacturers to reduce water pollution, adequate control of water pollution can readily be achieved with available technologies. However, if very rapid growth takes place in major water-polluting sectors, strict monitoring will be more necessary to make certain that these sectors meet effluent standards. The GOI should give unambiguous signals that it intends to enforce environmental protection regulations.

*Cautions and further work*

A study of this sort can always be improved by further data development and refinement. The areas of high priority for further work include improvement in the capital stock data and macroeconomic projections and extension of the modelling framework to account for concentrations of air and water pollution in addition to emissions. A further valuable addition would be the investigation of feedbacks from environmental change on economic activity and human welfare.

Other priorities for further work include greater disaggregation of sectors such as other manufacturing, pulp and paper, wood products and forest products allowing much more detailed and accurate evaluation of alternative development paths for those sectors. In addition, disaggregation of the economy-wide model and database into a series of interrelated regional models would make it feasible to explore specific local issues of resource use and pollution.

# CHAPTER 1

# INTRODUCTION

The Government of Indonesia (GOI) is presently formulating its strategy for the Sixth Five-Year Development Plan (Repelita VI) and the Second Long-Term Development Plan (1994-2019). In the course of the First Long-Term Development Plan, Indonesia achieved a rapid overall growth rate, the initiation of the process of industrialisation and self-sufficiency in rice. An appropriate balance between the modernisation of traditional sectors and the establishment of completely new industries, and identification of industries worthy of encouragement, is a challenge for the Second Long-Term Development Plan. In addition to the established aims of government policy -- growth, employment and equity -- there is a growing concern in Indonesia, as in the rest of the world, about potential long-term damage to the natural environment as a result of development. It is increasingly recognised that the various forms of environmental degradation are associated more with certain paths of development than others.

The GOI faces some difficult choices in forging a plan of action that balances the objectives of higher income and employment against the exhaustion of natural resources and potential damage due to water pollution, air pollution, land degradation and deforestation. It may well be the case, however, that the apparent trade-offs between growth and the environment can be avoided by adoption of clean, more efficient technologies and more effective use of existing technologies. There is mounting evidence from developed countries that many measures that are less harmful to the natural environment are not very costly and that others that appear costly may be cheaper in the long run. It is also generally true that it is much less costly to take measures to prevent environmental damage than to undertake rehabilitation after the environment has been allowed to deteriorate.

Broadly speaking the GOI can influence the impact of development on the environment by two types of policies:

- introducing regulations or market incentives to influence the behaviour of firms and individuals and, in particular, the technologies that industries use; and

- influencing the pattern of investment directly so as to promote economic activities and industries that do less harm to the natural environment.

However, both of these options need to be based not on general principles alone but on an assessment of the specific direction to be followed. To date, there has been very little work

describing detailed development paths in terms of the opportunities afforded by alternative sectoral objectives and technological choices or of the combined effects of pursuing several objectives simultaneously. In addition, there is a paucity of reliable information about the relationships between different ways of proceeding and the associated impacts on the natural environment. The purpose of the present study is to provide a firmer basis for national economic decisions by developing an information base for assessing the current and likely future implications of development for natural resource use and the environment.

This study has been undertaken by the Natural Resources Management Project (NRMP) on behalf of the National Development Planning Board (BAPPENAS) and the Ministry of Forestry. NRMP is funded by the United States Agency for International Development (USAID) which is also providing support for the Institute for Economic Analysis (IEA) at New York University; NRMP and the IEA have worked in close collaboration on this study. Financial support to the IEA for this and an earlier related study has also been provided by the Environmental Programming Support Services Project of the Canadian International Development Agency.

This study is intended to produce two types of outputs. One output consists of substantive information about future options for the Indonesian economy and policy advice based on that information. The other objective is the institutionalisation within the GOI of the capacity to do the sort of analytical work contained in this report.

This Final Report reflects a considerable amount of scenario development, data collection and modelling work beyond that of the Interim Report. In particular, the Final Report takes into account the data developed by the case studies of technological change and data on atmospheric emissions, water use and water pollution. The modelling scenarios were formulated to reflect our understanding of the policy alternatives facing the GOI. The strength of the modelling framework of this study is that the same database and model can now be used, with relatively little additional work, to analyse many other kinds of scenarios.

The data for this study come from two different sources. For the last 'benchmark year' (1985), the description of the economy in terms of the use of goods and services and of capital and labour in all sectors of the Indonesian economy was provided by the Central Bureau of Statistics (BPS). The data on resource use in the base year and assumptions about all future changes in technologies were assembled in the course of case studies of technological possibilities in a number of important sectors of the economy. Considerable time was also devoted to making projections of the components of final demand along two alternative macroeconomic growth paths. Both sources of data have their strengths and

their weaknesses; the weaknesses will need to be addressed in future work within this framework.

In the process of developing this report the authors have benefitted from feedback from BAPPENAS on the macro projections and on some of the technological case studies. Comments elicited from BAPPENAS and other interested parties on the modelling framework, the data and the initial results are reflected in the priorities for further work. The modelling strategy described in the next chapter has been designed as far as possible to shed light on the actual policy choices that BAPPENAS and the GOI face.

# CHAPTER 2

# THE MODEL AND THE SCENARIOS

## 2.1 The Modelling Framework

The purpose of this study is to describe several alternative scenarios about the likely future path of the Indonesian economy and to calculate for each one its implications for economic well-being, natural resource use and environmental degradation. The analysis is carried out within the framework of a dynamic input-output model of the Indonesian economy and a corresponding database. Each scenario has significant information requirements which need to be systematically integrated into the basic database using consistent classifications, definitions, conventions and units of measure.

For this study, the following key sets of information have been required:

- the levels and composition of private and government consumption for the goods and services produced by each sector of the economy and the levels and mixes of imports and exports also by each sector;

- the technologies or production processes used in each sector, described in terms of the quantity and mix of goods and services required as inputs per unit of each sector's output. Inputs also include different types of labour and detailed requirements for capital goods per unit increase in each sector's capacity;

- natural resource use and environmental degradation associated with the current technologies and scales of operation of economic activities. This includes the use of land and water per unit of output and emissions of pollutants per unit of fuel burned;

- projections about future changes in the levels and composition of final deliveries (private and government consumption, exports and imports); and

- projections about changes in technologies reflecting technical progress, resource and environmental constraints and changes in prices of major inputs.

The database is built from two sources: information that is already regularly collected the Central Bureau of Statistics (BPS), such as the official input-output tables for Indonesia; and a series of case studies carried out as part of this study and designed to develop information on future technological change.

The structure of the database is governed by the mathematical form of the dynamic input-output model. The model serves as a powerful [redacted] for examining the impact of the changes specified in the scenarios on output [redacted]ment, investment and the environment.

## 2.2 The Dynamic Model

The framework guiding the development of the scenarios, and consequently the collection of data, is the dynamic input-output model developed for the Indonesian economy. The basic model, initially developed by Duchin and Szyld (1985) and here extended to include natural resource impacts, is set out in detail in Appendix A. It represents an advance over the familiar static input-output model, as well as over earlier dynamic input-output formulations, because it makes investment endogenous (that is, it brings it into the model as one of the variables to be determined in the solution process) in a theoretically satisfactory way, one that also lends itself to empirical application. Investment is made endogenous through its dependence on expected growth in each sector's output, the technologies in use and rates of capacity utilisation. This representation of investment is an extension, and a multi-sectoral version, of the well-known accelerator principle.

*Physical and price models*

The dynamic input-output model can be written as a set of relationships among physical stocks and flows and is a 'dual' model expressing the corresponding relationships between costs and prices. Then the two can be integrated in an income model showing the distribution of income among labour, land and capital. In this study we confine ourselves to the dynamic physical model because it is the form most useful for showing the relationships between economic growth, employment and environmental impacts. Implementing the dynamic price and income models would require the development of a set of factor prices, including the average wage rates of the different categories of labour and the rates of return on capital.

*Model time horizon*

The period over which projections are made is 1985-2020. Although it is not possible to project detailed changes in the economy over the coming thirty-years with any degree of accuracy, one can anticipate the major avenues of technological advance. Furthermore, this horizon is necessary because environmental effects often take many years to make themselves felt. It is important to stress that we do not claim to predict the future. In any modelling exercise, and especially one involving environmental impacts, unexpected events

will always upset the forecasts. Instead, we explore the implications of several alternative scenarios, and the projections indicate what will happen based on the assumptions underlying each scenario. The model serves as a framework for drawing together all of the information available in a consistent format and pointing to the implications.

## 2.3 The Input-Output Database

*Representing technological change*

A sector's technology can be represented by columns of figures showing the amounts of inputs of goods and services used by that sector in a given period of time; these figures are assembled in official input-output tables. When the inputs are calculated on a per unit of output basis, they are called input coefficients. Input coefficients are also required to describe the use of different types of labour and the amount and mix of capital goods per unit increase in capacity. For this study, yet another set of coefficients was necessary to describe natural resource effects (such as land and water requirements per unit of output) and environmental damage (such as carbon emissions per unit of fuel used and tonnes of soil erosion per hectare cultivated). This way of representing a sector's technology as columns of coefficients is illustrated in general terms in Table 2.1.

These data for all sectors of the economy can be gathered into matrixes of intermediate input coefficients (A), labour input coefficients (L), capital coefficients (B) and natural resource coefficients (N) as shown in Table 2.2.

*The basic input-output database*

For the base year of 1985 most of the data requirements are satisfied by the official input-output table produced by BPS. BPS has also provided data on employment by several categories of education for the 30 sectors used in this study. The capital requirements are more problematic. BPS assembles related information about capital flows and has constructed, especially for this study, a matrix of capital stocks. However, the capital stock data used in this study still require a great deal of development and refinement and should be considered as rough first approximations only.

BPS has thus provided data for the A, L, and B coefficient matrices for 1985, the year chosen as the base year because the most recent input-output tables are for that year. However, BPS does not yet systematically collect data about environmental variables, the N coefficients, and does not describe current technologies except to the extent that they are implied in the input-output tables.

**Table 2.1 Representation of technology in the input-output model for sector j**

| | 1985 | 2020 |
|---|---|---|
| Intermediate inputs | $a_{1j}$ | $\overline{a_{1j}}$ |
| | $a_{2j}$ | $\overline{a_{2j}}$ |
| | ⋮ | ⋮ |
| | $a_{30j}$ | $\overline{a_{30j}}$ |
| Labour inputs | $l_{1j}$ | $\overline{l_{1j}}$ |
| | $l_{2j}$ | $\overline{l_{2j}}$ |
| | ⋮ | ⋮ |
| | $l_{6j}$ | $\overline{l_{6j}}$ |
| Capital inputs | $b_{1j}$ | $\overline{b_{1j}}$ |
| | $b_{2j}$ | $\overline{b_{2j}}$ |
| | ⋮ | ⋮ |
| | $b_{30j}$ | $\overline{b_{30j}}$ |
| Natural resource inputs or impacts | $n_{1j}$ | $\overline{n_{1j}}$ |
| | $n_{2j}$ | $\overline{n_{2j}}$ |
| | ⋮ | ⋮ |
| | $n_{kj}$ | $\overline{n_{kj}}$ |

**Table 2.2 The matrixes representing technology**

| Coefficient | 1985 | 2020 |
|---|---|---|
| Intermediate inputs | A | $\overline{A}$ |
| Labour inputs | L | $\overline{L}$ |
| Capital inputs | B | $\overline{B}$ |
| Natural resource impacts | N | $\overline{N}$ |

Data on future technologies, represented by changes in the A, L, B and N matrixes, have been developed specifically for this study.

*Macroeconomic projections*

The simplest and most commonly used input-output models require exogenous information about all categories of final deliveries for past years and exogenous projections for the future. While investment is endogenous in the dynamic model used in this study, the other categories of final deliveries still need to be provided as exogenous information. For 1985 this information comes from the official BPS input-output table. But for future years, these other categories of final deliveries need to be provided in the form of alternative 'macroeconomic projections'. These projections about the growth of GDP and its components to the year 2000 were based on information from a variety of sources, including the World Bank, BAPPENAS and our own calculations. The two alternative sets of macroeconomic projections are summarised in Chapter 3 and are described in more detail in Chapter 5.

## 2.4 The Case Study Approach to Projections of Technological Change

The impact of future economic activity on the natural environment will depend critically on the technologies that are in use. Water requirements and the discharge of pollutants, for instance, depend not only on what is produced but also on the methods of production. Cleaner technologies are being developed and adopted as governments around the world introduce stricter emission and discharge controls. A crucial part of the data development work for this study involves alternative projections about technological change in several sectors of economic and environmental importance. This data work has been organised as a set of input-output case studies carried out for the sectors indicated in Table 2.3.

While official input-output tables can be compiled by applying formal methods of manipulation to census and survey data, implementing a case study requires assembling information from many sources, some of them highly informal such as the opinions of experts. It was necessary to design data sheets as a device to organise and communicate this information. The methodology for carrying out the input-output case studies is described in detail in Duchin and Lange (1992c) and in Hamilton (1992).

**Table 2.3 Sectors selected for technological case studies**

| Sector No. | Sector Name |
|---|---|
| 1 | Paddy |
| 2 | Other food crops |
| 3 | Estate crops |
| 4 | Livestock, poultry & products |
| 5 | Forest products |
| 11 | Food, beverages & tobacco products |
| 13 | Pulp, paper & products |
| 15 | Chemicals |
| 16 | Cement & limestone |
| 17.2 | Textiles, leather & wearing apparel |
| 17.5 | Basic iron & steel |
| 20 | Electricity |

In addition to the data described above, a matrix of environmental coefficients, N, was defined in terms of a specified set of environmental variables including land and water use coefficients, water pollution coefficients and air pollution coefficients. Each coefficient measures an environmental input or impact per unit of economic activity. In the course of the case studies, the N matrix for 1985 was quantified for the variables relevant to each sector and future changes were projected for each coefficient.

The next step was to develop projections about the technologies that could be used in each case study sector in the future. Once identified, these technologies had to be represented by the percentage changes that would be experienced by the relevant coefficients in the A, L, B, and N matrices between 1985 and 2020. This exercise required consulting specialists such as chemical engineers, hydrologists, environmental scientists, energy experts and agricultural scientists as to the technologies likely to be adopted over the next several decades under two alternative sets of assumptions. For those sectors not the subject of case studies, estimates of changes in labour and capital input coefficients have been developed from other sources. These are described in Chapter 14.

## 2.5 The Alternative Scenarios

Six scenarios have been designed for this report; they combine three sets of technological assumptions with two sets of macroeconomic assumptions. Broadly speaking, the technological assumptions under Scenario 1 (S1) assume the continuation of current commercial trends and government policies. Scenario 2 (S2) postulates technological

changes that would be introduced in the case study sectors if government policies placed heavier emphasis upon environmental protection and resource conservation within the existing broad guidelines of development planning. In the case of the electricity sector we have developed a third technological scenario (S3) which assumes that cleaner and more efficient methods of burning fossil fuels will be used in 2020.

The two sets of macroeconomic projections (moderate and high) reflect different expectations about overall economic expansion and the implications for individual components of final deliveries. The high growth path (H) embodies an annual growth rate of around 7 per cent through to 2020 and reflects the assumptions that are made by BAPPENAS. The moderate growth path (M) embodies an annual growth rate of around 5 per cent through to 2020 and is closer to the World Bank's expectations for Indonesia. [1] While lower than the BAPPENAS expectations, the moderate growth path remains high by international standards.

The combinations and their summary names are shown in Table 2.4. In the next chapter we will see that MS1 is used as the base scenario for analysing the results.

**Table 2.4 The alternative scenarios**

| | Technological scenarios | | |
|---|---|---|---|
| Macro projections | S1 | S2 | S3 |
| Moderate growth | MS1 | MS2 | MS3 |
| High growth | HS1 | HS2 | HS3 |

Table 2.5 provides a summary of the assumptions about technological change in the case study sectors. The detailed development of assumptions for each case study sector can be found in Part 2 of this report.

1 The macroeconomic growth paths are described in detail in Chapter 5.

**Table 2.5 Key technological changes in the case study sectors (between 1985 and 2020)**

| *Sector* | | *Scenario 1 (S1)* | *Scenarios 2 & 3 (S2 & S3)* |
|---|---|---|---|
| 1 | Paddy | improved yields (and thus less labour per unit output) due to better seeds & input management leading to less chemicals; improved irrigation efficiency and higher cropping intensity | higher growth of yields due to S1 changes plus biotechnology (new IRRI varieties); cropping intensity high than S1 |
| 2 | Other food crops | improved yields due to improved cultivars & input management leading to fall in labour, land and other inputs needed per unit output; but rising erosion | slower growth in yields due to soil conservation erosion declines sharply |
| 3 | Estate crops | large growth in yields due to better cultivars & input management; output shares of estates & smallholders less chemicals per unit output | n/a |
| 4 | Livestock & poultry | share of intensive production grows from 41% to 84%; automation of battery chickens; per unit labour, energy, water & feedstock inputs rise | n/a |
| 5 | Forest products | more sustainable management of natural forests and shift to plantations (for 40% of log supply); labour inputs rise but land falls as do erosion and deforestation | more sustainable management of natural forests; greater share of plantations (68% of supply) |
| 11 | Food, beverages & tobacco | marked changes in processing technologies; large labour savings; energy savings; improved water pollution control; change in mix of products | n/a |
| 13 | Pulp, paper & printing | extended & oxygen delignification, ozone bleaching; energy savings & shift to coal from IDO; automated control; less water use & pollution | n/a |
| 15 | Chemicals | process improvements resulting in yield rises of 25%; energy savings; automation & fall in labour inputs | n/a |

| | | | |
|---|---|---|---|
| 16 | Cement & limestone | energy savings; computerisation of process control; some labour savings; improved dust control; | n/a |
| 17.2 | Textiles, leather & wearing apparel | chemical recycling, energy saving & shift to LNG; air-jet machines replace shuttles in weaving; use of chrome phased out in leather; automation in apparel leading to labour saving | n/a |
| 17.5 | Basic iron & steel | large energy savings & shift to coal; share of mini-mills rises thus reducing electricity consumption; 50% savings in labour due to management efficiencies | n/a |
| 17 | Other manufacturing | energy savings due to conservation, shift to coal & gas & shift from captive to PLN power; labour savings due to mechanisation & computerisation | n/a |
| 20 | Electricity | PLN scenario; large shift away from diesel to coal; coal 45%; gas 25%; diesel 5%; hydro 18%; geothermal 2%; solar 5%; increased capital requirements; small reduction in transmission losses | S2: greater share of gas (40%), half burnt using combined cycle; coal 25%; hydro 18%; geothermal 7%; solar 5%; deisel 5%<br><br>S3: same shares as S2 but with coal gasification & all coal and gas burnt using combined cycle |
| 26 | Transport services | 25% increase in motor vehicle fuel efficiency | 50% increase in motor vehicle fuel efficiency |
| Household energy consumption | | 10% electricity saving | 25% electricity saving;<br>50% savings in petroleum<br>25% savings in coal |
| Other sectors | | reductions in unit labour inputs and increases in capital requirements (see tables 14.3 & 14.4) | |

*Note*: The energy savings assumptions recorded under 'household energy consumption' have been incorporated into the projections of private consumption in the macroeconomic data -- see Chapter 5.

# CHAPTER 3

# RESULTS OF THE ANALYSIS

This chapter describes the principal results of the analysis. The first section reviews the plausibility of the Base Scenario, MS1. MS1 combines the moderate growth path that assumes an annual growth rate of around 5 per cent through to 2020 with the S1 set of projections about technological change summarised in Table 2.5 along with additional projections of changes in energy, labour and capital coefficients for sectors not the subject of case studies.

In reviewing the plausibility of MS1 we compare the labour, investment and natural resource requirements of MS1 with the potential constraints posed by the supplies of these 'factors of production'. This is the purpose of Section 3.1. We are particularly interested in exploring the extent to which the natural environment in Indonesia has the capacity to absorb the impacts of economic growth. Where a constraint, such as a labour or land shortage, becomes apparent under MS1 we examine whether an alternative scenario will allow it to be eased. The analysis of these alternatives, as well as a more detailed discussion of the MS1 results, can be found in Sections 3.2 to 3.6, covering employment, forest land, agricultural land, energy and atmospheric emissions and water use and water pollution. The final sections of this chapter (Sections 3.7 and 3.8) provide an assessment of the sector-specific changes associated with MS1 and an overview of the changes in factor requirements under the various scenarios.

## 3.1 The Plausibility of the Base Scenario (MS1)

The model and database are based on the division of the economy into 30 sectors, as shown in Appendix C. Table 3.1 shows results aggregated over the 30 sectors for GDP per capita, the trade surplus, employment demand and investment under the Base Scenario (MS1) for the years 1985 and 2020.

*Employment*

We estimate that the supply of labour will reach 134 million in 2020 (see Section 3.2). Table 3.1 shows that under the growth and technological change assumptions of MS1, employment demand is projected to reach 144.6 million jobs. Thus a 5 per cent rate of economic growth is more than enough to absorb all of the workforce in 2020. This suggests that the high growth path would run into labour shortages.

**Table 3.1 Employment and investment under the Base Scenario (MS1)**

| | 1985 | 2020 |
|---|---|---|
| GDP per capita (Rp $10^3$)[a] | 611 | 2065 |
| Trade surplus as a share of total trade (%)[b] | +16 | -1 |
| Total employment demand ($10^6$)[c] | 57.3 | 144.6 |
| Share in total employment demand (%) | | |
| agriculture | 53 | 26 |
| manufacturing | 13 | 23 |
| services | 33 | 51 |
| Cumulative investment as a share of total GDP (%) | 25.3 | 23.3 |

Notes: a. GDP per capita combines assumptions of the model (estimates of final demands other than investment) and results of the model (projections of investment requirements).
b. The trade surplus is an assumption built into the macroeconomic estimates.
c. The 1985 figures for total employment demand and sectoral shares of demand are in fact those for 1990. Please see Section 3.2 for an explanation.

*Investment*

Table 3.1 suggests that there is unlikely to be an investment constraint on the moderate growth path (MS1). However, the capital stock data used in the analysis are very preliminary and probably seriously underestimate the capital stock in 1985 and thus the investment requirements per unit of output needed for growth. Nevertheless, the results indicate a slight fall in the share of investment requirements in GDP over the period.

*Resource constraints*

Table 3.2 shows the calculated land requirements under the MS1 scenario. The demands for land by three of the four agricultural sectors in the model (Sectors 1, 2 and 3) can be compared with estimates of the maximum available land area suitable for paddy, other food crops and estate crops. Land is not a major input into livestock production, the fourth agricultural sector of the model, because intensive livestock production uses very little land directly while extensive livestock production occurs on land used principally for other purposes. The maximum areas of land for agriculture and forestry are reported in Table 3.3. They can be compared directly with the projected land requirements in 2020 shown in

the last column of Table 3.2.

**Table 3.2 Land requirements under the Base Scenario (MS1) (in million ha)**

| | 1985 | 1990 | 2020 |
|---|---|---|---|
| Paddy (Sector 1) | 7.8 | 8.3 | 8.5 |
| Other food crops (Sector 2) | 6.2 | 7.6 | 10.4 |
| Estate crops (Sector 3) | 10.0 | 10.8 | 26.9 |
| Natural forests (Sector 5) | 34.8 | 47.9 | 106.3 |
| Forest plantations (Sector 5) | 0.2 | 0.5 | 2.6 |

**Table 3.3 Maximum land area available (in million ha)**

| | Maximum land area available |
|---|---|
| Paddy (Sector 1) | 8.3 |
| Other food crops (Sector 2) | 9.8 |
| Estate crops (Sector 3) | 19.6 |
| Natural forests (Sector 5) | 61.0 |
| Forest plantations (Sector 5) | 19.8 |

*Source*: See Section 14.1.

With projected rates of growth in demand for paddy there is not a serious land constraint in that sector. Growth in rice yields is high enough to keep pace with population growth and a projected small increase in rice consumption per capita. Expansion of the Other food crops sector may run into a land constraint, although growth in yields almost keeps pace with rapid demand growth which is partly in response to booming demand for stockfeed. On the high growth path, however, a substantial increase in imports is needed to supplement domestic production if projected demand is to be met. In the case of the Estate crops sector (comprising both estates and small holders) a significant land shortage emerges under MS1 with land requirements of 26.9 million ha exceeding estimated maximum land area available by 37 per cent.

In the case of forest land, it is apparent that the 61 million ha of natural forests cannot sustain the demand for logs from natural forests under MS1, which requires an area of natural forest of over 100 million ha. However, there appears to be no constraint on the availability of land for the expansion of forest plantations. We will need to examine the results for MS2, in which a greater proportion of logs is derived from plantations, to see whether this can compensate for the shortage of natural forest land.

### 3.2 Employment

In this section we first make projections about the supply of labour in 2020. We can then compare these to the model's estimates of labour requirements in 2020. At the end of this section we also report some results about the changing requirements for labour of different skills in 2020.

Before making projections of labour demand we must decide on the correct measure of the size of the labour force in the base year. In Indonesia, there is a large pool of underemployed workers, a phenomenon known as disguised unemployment. Unless we adjust our projections for these underemployed workers we will overestimate the growth of labour requirements. We therefore convert the labour force in the base year into a 'full-time equivalent' measure.

*Full-time equivalent labour supply*

Future labour supply will depend on the size of the population, the proportion of the population that is of working age and the labour force participation rate. The participation rate is the percentage of the working age population (defined by BPS as those aged 10 years and over) that is economically active (currently employed or seeking employment). The relevant figures for 1990 and projections for 2020 are shown in Table 3.4.

Official estimates of the labour force for 1990 imply a participation rate of 57.33 per cent. Although the official figures show an unemployment rate of only 2.5 per cent, unemployment is one of the biggest economic problems facing the government. While the first column of Table 3.4 shows the official employment figures for 1990, in the second column we have attempted to better reflect the actual extent of underemployment by adjusting the official figures. The adjustment incorporates two assumptions.

**Table 3.4 Population, labour force and the participation rate, 1990 and 2020**

| Parameter | 1990 Official | 1990 Full-time equivalent | 2020 Projections |
|---|---|---|---|
| Population (millions) | 179.25 | 179.25 | 262.58 |
| Population aged 10 and over (A) | 135.71 | 135.71 | 221.99 |
| Participation rate (B) (%) | 57.33 | 54.73 | 60.36 |
| Economically active labour force (millions) (AxB/100) | 77.80 | 74.27 | 133.99 |
| . working | 75.85 | 59.15 | -- |
| . unemployed | 1.95 | 15.12 | |
| Rate of unemployment (%) | 2.50 | 20.36 | -- |

*Source*: Column 1: BPS (1991c, Table 3.2.2). Column 2: Participation rate from Gijsberts (1992 Table 2); for calculation of full-time equivalent labour force see text. Column 3: Participation rate from Gijsberts (1992 Table 2); population and population over 10 from BPS (1993).

First, a different estimate of the participation rate is used to determine the size of the labour force. Secondly, the proportion of the labour force employed has been adjusted downwards to take account of underemployment.

For the second adjustment, we have calculated the 'full-time equivalent' (FTE) labour force by subtracting from the total labour force an estimate of underemployment expressed as the equivalent number of people that would be fully unemployed if everyone were either fully employed or fully unemployed. This adjustment is made using figures on number of hours worked in 1990 (see BPS 1991c, Table 3.2.7). For example, in 1990 22.5 per cent of the workforce worked less than 24 hours per week and 39.1 per cent worked less than 34 hours. If we adjust the workforce by the number of hours worked (so that a person who worked 20 hours is regarded as being 50 per cent fully employed, with people working 40 hours or more regarded as being fully employed) then in 1990 only 79.64 per cent of the labour force was fully employed, suggesting an underlying rate of unemployment (including disguised unemployment) of 20.36 per cent.

Note that the calculation of the full-time equivalent workforce assumes that those in part-time employment would prefer full-time employment. To the extent that this is not an accurate assumption, we have overestimated the underlying rate of unemployment. On the other hand, it is likely that many of those reported as working full-time in fact are not productive for the whole time at work, especially in agriculture and the informal sectors, so that they could work fewer hours and produce the same output. It is possible that the underlying rate of unemployment is even greater than the 20.36 per cent estimated above.

The third column of Table 3.4 shows the projected workforce in 2020. For a given working-age population, the supply of labour in 2020 will depend on changes in the participation rate. As population growth slows over the next decades the population will age. In addition, a greater proportion of women will enter paid employment, raising the participation rate of women. Both of these trends will tend to increase the share of the population that works. On the other hand, people will spend more years in education which will reduce the participation rate. We have used the participation rate for 2020 estimated by Gijsberts (1992) which shows an increase from 54.73 in 1990 to 60.36 in 2020. Combining these estimates in Table 3.4, we estimate a labour supply in 2020 of 134 million.

The economic implications of the difference between the official and the adjusted estimates of the employed workforce are substantial. Between 1990 and 2020, instead of 58 million new jobs being required, the adjusted figures show that 75 million new jobs need to be created to ensure full employment.

*Labour requirements*

Growth in demand for labour depends on the following factors:

- the rate of growth of the economy and of each sector;
- base year labour requirements per unit of output; and
- growth of labour productivity in each sector.

The labour input coefficients and their rates of change for each of the 30 sectors of the model are reported in Table 14.1. Some of the projected changes in labour input coefficients between 1985 and 2020 have been developed in the case studies of technological change carried out as part of this study; these covered the four agriculture sectors (Sectors 1-4), forestry (Sector 5), five manufacturing sectors (Sectors 11, 13, 15, 16, 17) and electricity (Sector 20). Projected changes for the other sectors are based on an assumed rate of labour productivity growth of 1.5 per cent per annum in mining (Sectors 7, 8, 9 and 10), 2.5 per cent in manufacturing (Sectors 12 and 14) and 2 per cent in services (Sectors 24, 25, 26, 27, 28, 29 and 30).

To estimate growth in actual numbers of jobs we begin with the labour force in 1990 (as reported in the second column of Table 3.4) and deduct disguised unemployment from the sectors in which it occurs. It is very difficult to obtain an accurate assessment of how the underemployed are distributed across the sectors of the economy. In this analysis we have assumed that they are all in agriculture, which reduces the 1990 agricultural workforce from an official level of 38.9 million (52 per cent of the labour force) to a full-time

equivalent of 23.8 million (32 per cent of the labour force), giving an adjustment coefficient of 0.612. The NRMP-IEA case studies of the agricultural sectors (reported in Chapters 6 and 7) indicate that in 1985 the full-time labour force actually required to produce the entire output of the four agricultural sectors was in fact even lower, suggesting that 23.8 million is a conservative estimate.

Table 3.5 reports the employment demand projections of the model adjusted for disguised unemployment in agriculture using the parameter reported above (0.612). There is no appreciable difference between the technological scenarios (S1 and S2), so we report results for MS1 and HS1 only.

When we compare the total employment demand projections for 2020 of Table 3.5 with our estimate of total labour supply in 2020 of 134 million, it is apparent that the moderate growth path (with GDP growing at around 5 per cent) provides more than enough jobs to accommodate the supply of labour in 2020. All of the disguised unemployment in agriculture is absorbed and the share of agriculture in total employment demand falls from 53 per cent in 1985 (including disguised unemployment) to 26 per cent in 2020. The shares of both manufacturing and services rise substantially. Figure 3.1 shows how employment in the major sectors changes over time. The service sector grows rapidly. Figure 3.2 shows how these changes affect the shares of each major sector in total employment over time.

On the high growth path (with GDP growing at around 7 per cent) a large labour shortage emerges -- labour demand of 251 million is almost double the supply of 134 million (see Table 3.5).

It is likely that as the available supply of labour is absorbed on the moderate growth path (MS1), the high demand for labour would drive wages up and encourage greater substitution of capital for labour, reducing the labour coefficients. However it should be remembered that the model's results already incorporate expected technological changes in which labour inputs per unit output decline substantially. It seems likely that an average annual growth rate of about 5 per cent can be attained with available technology and normal adjustments in the labour market.

**Table 3.5 Employment projections by broad sector under MS1 and HS1, 2020 (millions)**

| | 1990 | | 2020 MS1 | | 2020 HS1 | |
|---|---|---|---|---|---|---|
| *Demand* | | | | | | |
| Agriculture | | | | | | |
| . FTE labour force | 23.8 | (33) | 37.7 | (26) | 45.6 | (18) |
| . disguised unemployed | 15.1 | (21) | 0.0 | (0) | 0.0 | (0) |
| Manufacturing | 9.6 | (13) | 32.6 | (23) | 76.6 | (31) |
| Services | 23.9 | (33) | 74.4 | (51) | 129.1 | (51) |
| Total labour demand | 72.4 | (100) | 144.7 | (100) | 251.3 | (100) |
| *Supply* | | | | | | |
| FTE | 57.3 | (77) | -- | | -- | |
| Disguised unemployed | 15.1 | (20) | -- | | -- | |
| Unemployed | 1.9 | (3) | -- | | -- | |
| Total labour supply | 74.3 | (100) | 134.0 | | 134.0 | |

Notes: 1. Numbers in parentheses in the demand panel show percentage shares of the total labour demand. Numbers in parentheses in the supply panel show percentage shares of the total labour supply.
2. 'Agriculture' covers Sectors 1-4 of the NRMP-IEA 30-sector classification; 'Manufacturing' covers Sectors 5-23 and includes forestry, fishing, utilities and construction; 'Services' covers Sectors 24-30.

*Skilled labour requirements*

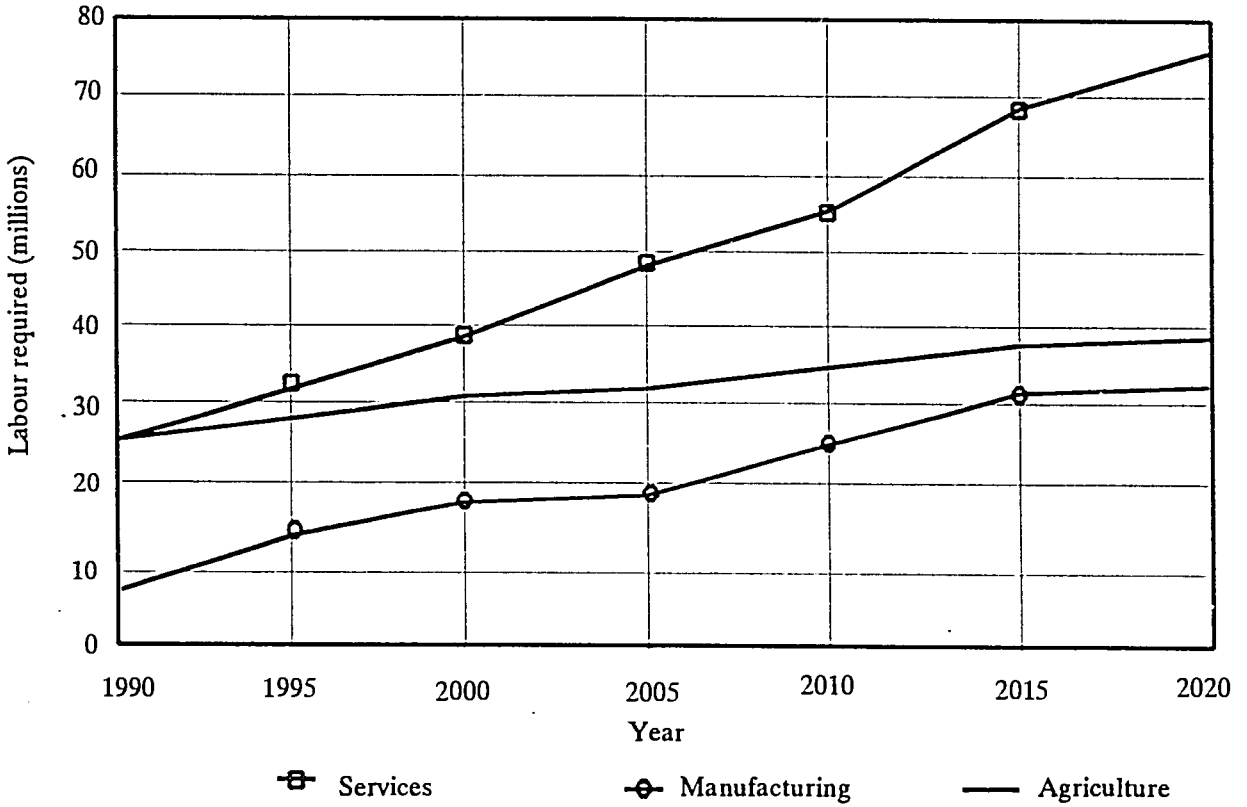
Economic growth and technological change will require a more highly skilled workforce in Indonesia and corresponding investments in education and training. The demand for labour of various skills depends on:

- the growth rate and changing sectoral structure of the economy; and
- changes in technologies used in each sector affecting the requirements for each type of labour per unit of output.

While the scenarios incorporate assumptions about changing total labour requirements in each sector, we were not able to project the labour coefficients by skill level due to time constraints on the study. However, it became very clear in the course of the case studies that managers in most industries expect technological changes that will require large increases in the proportion of the labour force with high skill levels.

Figure 3.1

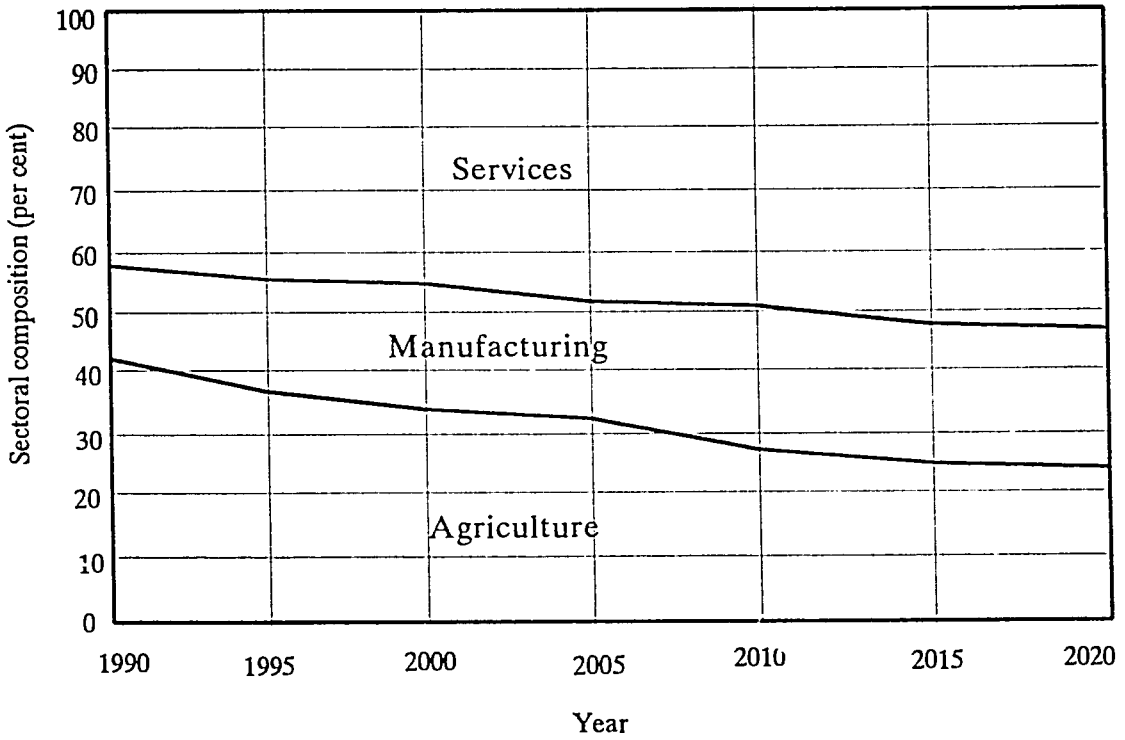
Projected labour requirements by major sector under MS1, 1990–2020




*Source:* Appendix Table D.2

Figure 3.2

Projected sectoral composition of the labour force under MS1, 1990–2020




*Source:* Appendix Table D.2

Based on a breakdown of the labour force by educational levels for 1985, the proportions of which in each sector we assumed to be unchanged over the study period, the model has been used to project demands for labour of different educational levels due to growth and structural change of the economy. These are reported in Table 3.6.

**Table 3.6 Projections of employment requirements by educational level, 2020**

| Educational level | 1985 | 2020 MS1 | 2020 HS1 |
|---|---|---|---|
| *In millions* | | | |
| 1 Primary school or less | 63.5 | 113.8 | 195.8 |
| 2 Junior high school | 5.3 | 12.8 | 23.7 |
| 3 Senior high school (general) | 2.7 | 6.9 | 12.8 |
| 4 Senior high school (vocational) | 3.6 | 9.2 | 15.5 |
| 5 Universities and academies | 0.8 | 2.0 | 3.4 |
| *Total* | 75.9 | 144.7 | 251.3 |
| *Relative to 1985* | | | |
| 1 Primary school or less | 1.0 | 1.79 | 3.08 |
| 2 Junior high school | 1.0 | 2.42 | 4.47 |
| 3 Senior high school (general) | 1.0 | 2.56 | 4.74 |
| 4 Senior high school (vocational) | 1.0 | 2.56 | 4.31 |
| 5 Universities and academies | 1.0 | 2.50 | 4.25 |
| *Total* | 1.0 | 1.91 | 3.31 |

## 3.3 Forest Land

*Supply of forest land*

As in the case of employment, in this section we will compare estimates of the future supply of forest land with projected land requirements under various scenarios. The technological scenarios for the forest products sector (Sector 5) prescribe the mix of timber coming from natural forests versus plantations. [1]

1 Please see Chapter 8 and Section 14.1 for the development of forestry scenarios and estimates of forest land availability.

The total area of natural production forest in Indonesia is approximately 61 million ha of which about 25 per cent is already logged over. There are up to 19.8 million ha of degraded *alang-alang* (grassland) and *belukar* (scrubland) areas suitable for plantation establishment. However, not all potential species will do well on all areas of these lands, and growth rates of particular species will vary substantially.

*Forest land requirements*

Growth in demand for logs responds to expansion of the sawmilling, plywood and pulp and paper industries. On the moderate growth path exports of wood products (plywood and sawn timber) are assumed to reach a peak in the year 2000 at a level 50 per cent higher than the 1990 export level and to stabilise thereafter. Exports of pulp and paper are assumed to grow rapidly, although imports also increase. In further work with the model, it may be useful to assume slower growth of imports of pulp and paper although this would mean that the industry would face an even greater land constraint in trying to meet domestic demand.

The areas of natural forest and plantation land under the different scenarios are reported in Table 3.7. Under S1, 60 per cent of logs are assumed to come from natural forests and 40 per cent from plantations; under S2, 32 per cent of logs come from natural forests and 68 per cent from plantations. In both of these scenarios, it is assumed that natural forests are logged using a more sustainable system of logging than the one currently in operation. [2]

Figure 3.3 plots forest land requirements over time under MS2. Clearly, the amount of forest area required will vary with changes in the parameters that define each scenario. If it is believed that for natural forests an average yield of 37 m3/ha can be sustained over, say, a 35-year rotation (compared to the 50-year rotation now assumed), then the area of natural forest required will be proportionally reduced. Similarly, if it is believed that the assumed average yield of plantations is too high, then the area of plantations required will be proportionally higher.

It is apparent from Table 3.7 that only the MS2 scenario requires a total area of natural forest that is below the maximum of 61 million ha actually available. The high growth scenarios (HS1 and HS2) place demands on the timber-using industries that are greater than the natural forests can sustainably supply.

2 That system and the derivation of the scenarios are described in Chapter 8.

**Table 3.7 Forest land requirements under alternative scenarios in 2020**

| | 1985 | 2020 | | | |
|---|---|---|---|---|---|
| | | MS1 | MS2 | HS1 | HS2 |
| *Production* | | | | | |
| Value of output (Rp $10^9$) | 1585 | 8227 | 8366 | 14403 | 15913 |
| Volume of logs ($10^6$ $m^3$) | 25.8 | 133.7 | 135.9 | 234.0 | 258.6 |
| *Forest land requirement ($10^6$ ha)* | | | | | |
| Natural forest | 34.8 | 106.3 | 57.6 | 186.0 | 109.6 |
| Plantation | 1.4 | 2.6 | 4.4 | 4.5 | 8.4 |
| *Relative to 1985* | | | | | |
| Natural forest | 1.0 | 3.05 | 1.66 | 5.34 | 3.15 |
| Plantation | 1.0 | 1.78 | 3.08 | 3.12 | 5.86 |

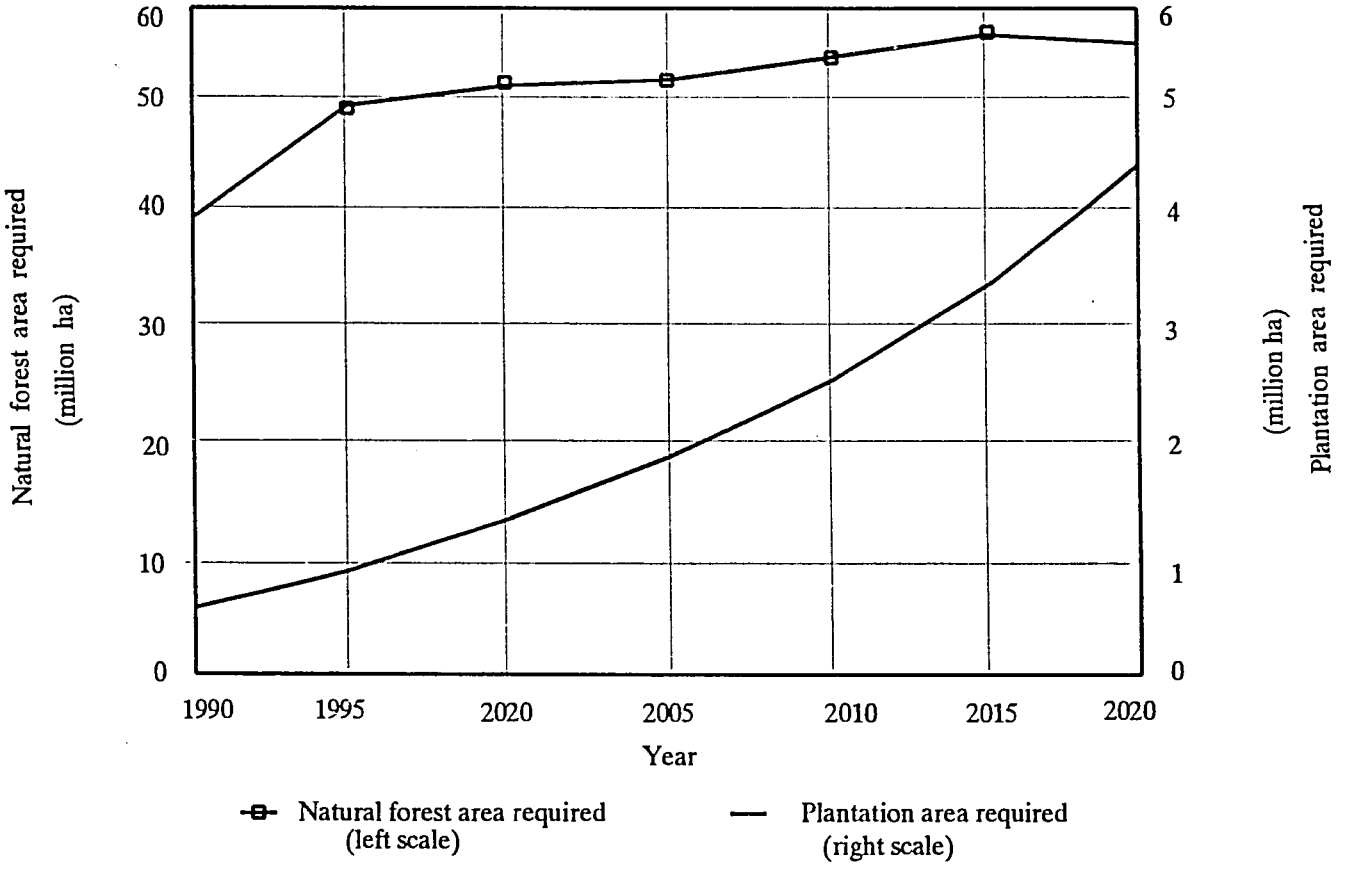
Notes: 1. The procedure has been to first convert the projected value of output into a required volume of logs by dividing by the constant 1985 price. This volume of logs is then allocated to natural forests or plantations according to the technological scenario. For natural forests we have assumed a rotation of 50 years and an average yield of 37 m3/ha (giving a land coefficient of 0.0265 ha/m3). For plantations we have assumed a rotation of 15 years with an average yield of 310 m3/ha (giving a land coefficient of 0.0032 ha/m3).
2. The figure for plantation area in 1985 represents area actually planted in 1988 (from FAO-MoFr, 1990a, Table 7.6, p178). It cannot be compared properly to projected plantation areas because the types of plantations in 1988 and projected for 2020 are very different. The existing plantations are mostly of slow-growing species (of approximately 1.44 million ha under timber plantations in 1988, 62 per cent was planted to teak) while the plantations envisaged for 2020 are fast-growing species. The area required per cubic metre of logs in 2020 will be much smaller than the area required in 1988 because growth rates are much higher and rotations are much shorter.

The MS2 scenario of sustainable yields requires that around 4.4 million ha of plantations be established. This falls within the estimated 19.8 million ha of degraded *alang-alang* and *belukar* land suitable for plantation establishment.

To allow time for plantations to become productive, such a plantation program would require approximately 200,000 ha of fast-growing plantations to be established each year for at least 20 years. The GOI currently plans to establish 6 million ha of industrial timber estates by the year 2000.

Figure 3.3

Projected forest land requirements under MS2, 1990–2020




*Source:* Appendix Table D.3

*Erosion, deforestation and employment*

The analysis provides measures of other impacts of expansion of the forestry sector under the various scenarios. These are reported in Table 3.8. The volume of soil eroded from natural forests shows a fall compared to 1985 under all scenarios except HS1 because it is assumed that under all scenarios natural forests are managed using a much more sustainable system of logging so that erosion per hectare falls from its current level of 79 t/ha to 30 t/ha. The area deforested is also lower under S2 than S1 because it has been assumed that the proportion of the logged-over area that is left deforested declines from its present level of 26 per cent using current unsustainable methods to 15 per cent under a more sustainable system of natural forest logging.

Under MS2, the only scenario that can be supported by the given area of production forest, employment reaches 7.85 million in 2020, 5.4 per cent of the projected total labour force. MS2 uses much less land and much more labour than MS1 because MS2 relies more heavily on plantations, which are very labour intensive compared to natural forest logging. Thus the shift to plantations would seem to be more consistent with Indonesia's abundance of labour and emerging shortage of forested land. However, in order to minimise environmental damage, it will be necessary to ensure that new plantations are established only on already degraded land. [3]

3 The forestry assumptions are described in Chapter 8 where plantations are represented by figures developed for a typical plot of *Acacia mangium*. A clearer picture of the options for the forestry sector in Indonesia requires a more detailed analysis of the types, growing conditions and locations of plantations, an exercise beyond the scope of the present study.

**Table 3.8 Erosion, deforestation and employment in the forest products sector under alternative scenarios in 2020**

| | 1985 | 2020 MS1 | MS2 | HS1 | HS2 |
|---|---|---|---|---|---|
| Erosion from natural forests ($10^6$ t p.a.) | 79 | 64 | 35 | 112 | 66 |
| Area deforested ($10^3$ ha p.a.) | 259 | 319 | 173 | 558 | 329 |
| Employment in Sector 5 ($10^3$) | 382 | 6171 | 7850 | 10804 | 14931 |
| Share of total labour force (%) | 0.6 | 4.4 | 5.4 | 4.8 | 6.1 |
| *Relative to 1985* | | | | | |
| Erosion from natural forests | 1.0 | 0.81 | 0.44 | 1.42 | 0.84 |
| Area deforested | 1.0 | 1.23 | 0.67 | 2.15 | 1.27 |
| Employment | 1.0 | 16.15 | 20.55 | 28.28 | 39.09 |
| Share of total labour force | 1.0 | 7.79 | 9.56 | 8.50 | 10.80 |

## 3.4 Agricultural Land

In Section 3.1 we compared our projections of land required by agriculture in 2020 under MS1 with estimates of maximum land area available. It was concluded that, taking account of growing demand for agricultural goods and increasing yields, there is unlikely to be a shortage of land for paddy. However, there may be a slight shortage of land for other food crops (Sector 2) and a more serious shortage of land suitable for estate crops (Sector 3).

Here we assess the land requirements of agriculture in 2020 under the MS2 scenario. The results appear in Table 3.9. Land requirements may be compared with the estimates of maximum land area available reported in Table 3.3. For the estate crops sector, a set of S2 assumptions was not developed so land requirements under MS2 are unchanged from MS1.[4]

4 On the high growth path, paddy land requirements are virtually the same as under the corresponding scenarios on the moderate growth path because growth in demand for paddy was assumed to be the same on

**Table 3.9 Agricultural land requirements under alternative scenarios in 2020 (million ha)**

| Sector | 1985 | 2020 MS1 | 2020 MS2 |
|---|---|---|---|
| Paddy (Sector 1) | 7.8 | 8.5 | 5.8 |
| Other food crops (Sector 2) | 6.2 | 10.4 | 11.1 |
| Estate crops (Sector 3) | 10.0 | 26.9 | 26.9 |

In the case of paddy it is apparent that land requirements fall sharply in response to the higher growth in yields and cropping intensity assumed under S2 in that sector. With the application of biotechnology, yields under S2 are assumed to rise by 82 per cent between 1985 and 2020 instead of the 35 per cent assumed under S1.

In contrast, land requirements for other food crops in 2020 increase under MS2 compared to MS1. This is because S2 for other food crops focussed on soil conservation in an effort to reduce the severity of soil erosion that will characterise this sector over the next decades. While the MS1 results show land requirements associated with the projected increases in demand, in practice the assumed growth in output of MS1 is unsustainable due to expected losses in soil fertility. Under S2, a significant portion of each hectare is devoted to soil conservation efforts, so that in aggregate more land is required to produce the same output in 2020. The output of other food crops under S2 assumptions will be much more sustainable in the long term. Under MS1 soil erosion from the other food crops sector is projected to reach 440 million tonnes annually in 2020. Under the conservation scenario MS2 it is projected to reach only 200 million tonnes.

The results of the analysis suggest that Indonesia will be able to maintain rice self-sufficiency in the next decades but that substantial investments in improving the efficiency of irrigation will be required. It is likely that the attention of the government will need to shift from rice to other food crops, for two reasons:

- maintenance of soil fertility will become increasingly difficult, threatening the long-term sustainability of yields; and
- land requirements are barely adequate to meet the demand for other food crops on the moderate growth path. On the high growth path, much greater imports of

each path. In the case of other food crops, imports were assumed to rise quickly on the high growth path so that land requirements did not substantially exceed land available.

these crops will be necessary, especially to sustain the rapidly growing intensive livestock sector.

### 3.5 Energy Use and Emissions

The projected levels of fossil fuel extraction and electricity production in 2020 under the alternative scenarios are shown in Table 3.10. The table shows that under the Base Scenario by 2020 fossil fuel extraction doubles relative to 1985 while electricity generation grows almost thirteen times. Of course, domestic use of fossil fuels more than doubles because virtually all the fuel will be consumed in Indonesia, whereas exports of petroleum were still large in 1985. In addition, the mix of fossil fuels shifts away from petroleum toward coal and gas which, although they start from very low levels, grow extremely rapidly.

**Table 3.10 Energy production under alternative scenarios in 2020**

| | 1985 | 2020 | | | | | |
|---|---|---|---|---|---|---|---|
| Energy type | | MS1 | MS2 | MS3 | HS1 | HS2 | HS3 |
| *In Rp billion* | | | | | | | |
| Fossil fuels | 15329 | 36511 | 32658 | 32392 | 67297 | 58777 | 58246 |
| Electricity | 1541 | 19737 | 15390 | 15385 | 30771 | 26634 | 26602 |
| *Relative to 1985* | | | | | | | |
| Fossil fuels | 1.0 | 2.4 | 2.1 | 2.1 | 4.4 | 3.8 | 3.8 |
| Electricity | 1.0 | 12.8 | 10.0 | 10.0 | 20.0 | 17.3 | 17.3 |

Emissions of carbon dioxide and oxides of sulphur and nitrogen depend to a large extent on levels of consumption of fossil fuels. Table 3.11 shows emissions increasing rapidly between 1990 and 2020 under all scenarios -- roughly 400 per cent on the moderate growth path and 700 per cent on the high growth path.

In many sectors emissions grow less rapidly than output largely because of extensive improvements in energy efficiency in both scenarios. No retrofitted emission controls for sulfur or nitrogen are assumed under either scenario. There are, however, significant differences between the scenarios.

Scenario S2 assumes greater gains in fuel efficiency in a number of key sectors, notably electric power generation, transportation and household energy use. It also assumes greater reliance on natural gas by households and the electric utilities sector. These assumptions result in reduced requirements for energy and consequently emissions of carbon, sulfur and nitrogen are about 20 per cent lower under S2 relative to S1 in 2020 for both growth paths. Emissions of nitrogen oxides are especially sensitive to assumptions about fuel efficiency gains in the transportation services sector, which accounted for 50 per cent of all nitrogen emissions in 1985. If emission controls such as catalytic converters are added to motor vehicles in the future, nitrogen emissions could fall even further.

**Table 3.11 Emissions of carbon, sulphur dioxide and nitrogen oxides under alternative scenarios in 2020**

| Pollutant | 1985 | 2020 MS1 | MS2 | MS3 | HS1 | HS2 | HS3 |
|---|---|---|---|---|---|---|---|
| *In thousands of tonnes* | | | | | | | |
| CO2 | 34157 | 171343 | 143139 | 140585 | 310585 | 253881 | 249129 |
| SOx | 383 | 1966 | 1569 | 1498 | 3743 | 2982 | 2853 |
| NOx | 608 | 2980 | 2356 | 2322 | 5015 | 3948 | 3887 |
| *Relative to 1985* | | | | | | | |
| CO2 | 1.0 | 5.0 | 4.2 | 4.1 | 9.1 | 7.4 | 7.3 |
| SOx | 1.0 | 5.1 | 4.1 | 3.9 | 9.8 | 7.8 | 7.4 |
| NOx | 1.0 | 4.9 | 3.9 | 3.8 | 8.2 | 6.5 | 6.4 |

The reduction in emissions attributable to increased fuel efficiency is tempered by a moderate increase in the use of coal by the electric utilities sector, households and a few industrial sectors such as cement. Coal has a higher carbon content per unit of energy than other fuels and most coals, even Indonesian ones, have a higher sulfur content per unit of energy than other fuels. Their use is, therefore, accompanied by higher rates of emission of these pollutants.

Scenario S3 differs from S2 only by the increased use of coal gasification and combined-cycle technology in the electric utilities sector (see Chapter 9). Given the large volumes of fossil fuels used by households and other sectors, especially transportation services, the impact of this policy alone on economy-wide production of energy is relatively small.

Nonetheless, carbon and nitrogen emissions are 2 per cent lower under S3 than S2, and sulfur emissions are 4 per cent lower.

Carbon is a global pollutant because it mixes very quickly in the atmosphere. For sulphur and nitrogen, by contrast, the geographic distribution of emissions is of greatest importance. The regional concentration of pollutants cannot be directly assessed from these national-level calculations; regional models would be required. However, based on the current distribution of industrial activities and motor vehicle use, some observations can be made. Today, most industrial activity, use of motor vehicles and the associated pollution occurs on Java and in cities on Java the concentration of atmospheric pollutants is already high. Though industry is expected to spread to other islands in the future, Java will continue to dominate industrial production and provide a home to the majority of the population. Hence it may be assumed that most of the increases in sulphur and nitrogen emissions will be concentrated in Java.

Although in this study we have not undertaken to make a direct link between emissions and atmospheric concentrations of pollutants, there is no doubt that the increases in air pollution projected by the analysis would cause serious health problems for the increasingly urbanised Indonesian population. A World Bank report notes that children in Bangkok lose an average of 4 or more IQ points by the age of seven because of exposure to high levels of lead in the air (World Bank 1992b, p53). While the present study has not measured lead levels, air pollution in Jakarta is almost as serious as it is in Bangkok (World Bank, 1992b, Table A.5) and will certainly be several times worse than at present under the projections madc by the model.

## 3.6 Water Use and Water Pollution

*Water use*

Under all scenarios, water withdrawals actually fall over the period 1985 to 2020. This is true despite steep rates of increase in water uptake in a number of manufacturing sectors and a doubling of household use of water. This economy in water uptake is made possible by the assumption of improved efficiency in paddy irrigation under both sets of technological assumptions, S1 and S2. The savings are achieved through both less use of water per unit of paddy and, especially, a great improvement in the ratio of water used to water withdrawn. It is assumed that in 1985 only 25 per cent of water taken up for paddy irrigation is actually delivered to the fields and that in 2020 this increases to 50 per cent.

Water withdrawals for the principal water-using sectors in 1985 and projections for 2020 are shown in Table 3.12 under both the MS1 and HS2 scenarios. Under MS1, water withdrawals for paddy fall by 70 per cent over the period despite a 70 per cent increase in paddy output. Under HS2, paddy output is a few percent higher than under MS1, but water withdrawals for paddy fall even more because of the assumed higher growth of yields per unit of land area.

**Table 3.12 Water withdrawals under alternative scenarios in 2020**

| Sector | 1985 | 2020 MS1 | MS2 | HS1 | HS2 |
|---|---|---|---|---|---|
| *In millions of cubic metres* | | | | | |
| 1 Paddy | 363251 | 112255 | 81476 | 116993 | 83806 |
| 4 Estate crops | 4 | 24 | 24 | 34 | 34 |
| 11 Food & beverages | 124 | 121 | 121 | 170 | 169 |
| 13 Pulp & paper | 164 | 429 | 418 | 823 | 773 |
| 15 Chemicals | 1 | 19 | 18 | 50 | 46 |
| 17 Other manufacturing | 339 | 688 | 383 | 5601 | 4729 |
| Households[a] | 8757 | 18494 | 18494 | 18494 | 18494 |
| *Total* | 372640 | 132030 | 100934 | 142165 | 108053 |
| *Relative to 1985* | | | | | |
| 1 Paddy | 1.0 | 0.3 | 0.2 | 0.3 | 0.2 |
| 2 Estate crops | 1.0 | 6.0 | 6.0 | 8.5 | 8.5 |
| 11 Food & beverages | 1.0 | 1.0 | 1.0 | 1.4 | 1.4 |
| 13 Pulp & paper | 1.0 | 2.6 | 2.5 | 5.0 | 4.7 |
| 15 Chemicals | 1.0 | 19.0 | 18.0 | 50.0 | 46.0 |
| 17 Other manufacturing | 1.0 | 2.0 | 1.1 | 16.5 | 13.9 |
| Households[a] | 1.0 | 2.1 | 2.1 | 2.1 | 2.1 |
| *Total* | 1.0 | 0.3 | 0.3 | 0.4 | 0.3 |

a. Household demand for water is exogenous.

The manufacturing sectors will be subject to two offsetting trends in their use of water. With the growth of manufacturing -- especially in water-intensive sectors like pulp and paper, chemicals and metal-processing -- the demand for water will clearly grow. At the same time, technologies for conserving water will be adopted both in response to pollution control legislation and for economic reasons. Under MS1, the net outcome is a doubling in water use whereas under HS2 it increases nine-fold.

While the numerical results are rather crude, as they are based on an incomplete coverage of water use and very rough estimates of parameters and parameter changes, nonetheless the major sectors have been covered and the estimates are of a realistic order of magnitude. Based on these results, it is clear that the growing demand for water for manufacturing, household use, and crops other than paddy can be accommodated if strenuous efforts are made to achieve the economies that are technically possible in the use of water for paddy irrigation.

*Water pollution*

Calculations have been made for the content of biological oxygen demand (BOD), chemical oxygen demand (COD)and total suspended solids (TSS) in water discharged from the manufacturing sectors based on changes in the parameters governing these pollutants over the period from 1985 to 2020. Due to the scarcity of reliable data, only one set of parameters has been projected for both S1 and S2. While there are a number of other considerations in addition to the aggregate quantity, it is clear that water pollution is bound to be greater under the high growth path than under the moderate one. Water pollution associated with agriculture is not examined in this study. Volumes of BOD, COD, and TSS in 1985 and projections for 2020 are shown for MS1 and HS2 in Table 3.13.

Under MS1 suspended solids fall to less than half the 1985 amounts because of technological changes in food processing, pulp and paper, and other manufacturing, mainly metal processing. BOD hardly changes over the entire period, despite significant increases in output, because of technological controls. There is an 18 per cent increase in COD, however, due mainly to the growth of the pulp and paper sector.

Under scenario HS2, on the other hand, growth in all three forms of water pollution is dramatic, about four-fold for BOD and COD and 3-fold for TSS. This result reflects the heavy emphasis on certain manufacturing sectors, especially pulp and paper and metal-processing, under the high growth assumptions. The rates of increase of output far outstrip the techniques that have been assumed for reducing pollution on a per-unit-of-output basis.

**Table 3.13 Water pollution under alternative scenarios in 2020**

| Pollutant & sector | 1985 | 2020 MS1 | MS2 | HS1 | HS2 |
|---|---|---|---|---|---|
| *In thousands of tonnes* | | | | | |
| BOD | | | | | |
| 11 Food & beverages | 24 | 6 | 6 | 9 | 9 |
| 13 Pulp & paper | 42 | 76 | 74 | 147 | 137 |
| 17 Other manufacturing | 68 | 55 | 31 | 448 | 378 |
| *Total BOD* | 134 | 137 | 111 | 604 | 524 |
| COD | | | | | |
| 11 Food & beverages | 35 | 9 | 9 | 12 | 12 |
| 13 Pulp & paper | 142 | 299 | 291 | 574 | 539 |
| 17 Other manufacturing | 271 | 220 | 123 | 1792 | 1513 |
| *Total COD* | 448 | 528 | 423 | 2378 | 2064 |
| TSS | | | | | |
| 11 Food & beverages | 59 | 8 | 8 | 11 | 11 |
| 13 Pulp & paper | 49 | 25 | 24 | 48 | 45 |
| 17 Other manufacturing | 339 | 172 | 96 | 1400 | 1182 |
| *Total SS* | 447 | 205 | 128 | 1459 | 1238 |
| *Relative to 1985* | | | | | |
| Total BOD | 1.0 | 1.0 | 0.8 | 4.5 | 3.9 |
| Total COD | 1.0 | 1.2 | 0.9 | 5.3 | 4.6 |
| Total SS | 1.0 | 0.5 | 0.3 | 3.3 | 2.8 |

These results suggest that with a moderate rate of growth in the manufacturing sectors accompanied by some pressure on manufacturers to reduce water pollution, adequate control of water pollution can readily be achieved with available technologies. However, if very rapid growth takes place in major water-polluting sectors, sector-specific monitoring will be necessary to make certain that these sectors make greater efforts -- beyond those of the technologies assumed under S2 -- to reduce water use and to recover pollutants from their effluents.

## 3.7 The Changing Structure of the Economy

The Base Scenario represents an effort to achieve certain growth targets while satisfying both explicit and implicit constraints regarding labour, capital, land, water and pollution. But for more detailed planning purposes the Second Long-Term Development Plan also needs to be concerned with the changing structure of the economy. In the scenarios that have been analysed, we have not prescribed objectives with regard to structural change, although this could be done in future analyses. We are, however, able to examine the implications of the Base Scenario for the changing relative importance of the different sectors of the Indonesian economy.

Table 3.14 shows the growth rates of individual sectors of the economy arranged in three groups in descending order. The table distinguishes six sectors for which there is reason to believe that their growth has been underestimated. These sectors are marked with an asterisk.

The fastest growing are the energy sectors and the electricity and water utilities. Many of these sectors will probably grow even faster than is indicated in the table. The other industries of increasing relative importance are chemicals and pulp and paper. When we consider also the fact that growth of the fertilizer sector has probably been underestimated (because fertilizer exports have been simply extrapolated from past values), it is clear that the chemical sectors will constitute an important growth area over the next 25 years.

While pressure on land will continue as efforts to maintain food self-sufficiency continue, it is clear that there will be increasing air quality problems associated with the growth of energy use and increasing water pollution problems associated with the production of chemicals.

## 3.8 Summary of Factor Use Under Alternative Scenarios

In many of the sections of this chapter, the factor requirements associated with the six alternative scenarios have been compared. Factors are here considered to include not only the traditional factors of production of land, labour and capital, but also use of fossil fuels and water, the atmosphere as a sink for air pollutants and rivers and other water sources as mechanisms of waste disposal. Table 3.15 summarises these findings.

**Table 3.14 Rates of growth of individual sectors under the Base Scenario (MS1)**

| Sector | Output 1985 | Output 2020 | Annual rate of growth 1985-2020 (%) |
|---|---|---|---|
| Coal | 78 | 3314 | 11.3* |
| Chemicals | 2043 | 26270 | 7.6 |
| Electricity | 1541 | 19737 | 7.6 |
| Liquified natural gas | 3945 | 47987 | 7.4 |
| Gas utilities | 183 | 1852 | 6.8 |
| Natural gas | 852 | 7516 | 6.4* |
| Paper and products | 933 | 7618 | 6.2* |
| Water utilities | 133 | 1068 | 6.1* |
| Social & other services | 9344 | 69889 | 5.9 |
| Public administration | 6375 | 46028 | 5.8 |
| Business services | 8232 | 59107 | 5.8 |
| Transport & communication | 10420 | 74717 | 5.8 |
| Wood products | 2602 | 18162 | 5.7 |
| Livestock | 4842 | 31215 | 5.5 |
| Wholesale & retail trade | 14323 | 86501 | 5.3 |
| Restaurants & hotels | 5826 | 33374 | 5.1 |
| Fisheries | 2123 | 12134 | 5.1 |
| Construction | 19446 | 101336 | 4.8 |
| Forest products | 1585 | 8201 | 4.8 |
| Other food crops | 5380 | 25842 | 4.6 |
| Cement & limestone | 730 | 3114 | 4.2 |
| Food, beverages & tobacco | 16414 | 63819 | 4.0 |
| Fertiliser & pesticides | 1093 | 4015 | 3.8* |
| Other mining | 1317 | 4833 | 3.8 |
| Petroleum refining | 7075 | 23268 | 3.5 |
| Other food crops | 7429 | 17523 | 2.5 |
| Other manufacturing | 17044 | 34579 | 2.0* |
| Crude oil | 14477 | 25681 | 1.7 |
| Paddy | 7040 | 11756 | 1.5 |

* Growth of these sectors may be underestimated.

Table 3.15 shows that the use of most factors of production increases substantially between 1985 and 2020 under the Base Scenario. One striking exception is water uptake in agriculture which falls because of the assumed increased efficiency of paddy irrigation. Another exception is the case of forest land which is economized by the shift from natural forest to plantations. Total dissolved solids in water discharged by industry also fall because of anticipated improvements in pollution controls.

On the medium growth path with the technological assumptions of S2 (MS2), virtually all factor inputs and pollutants fall relative to the Base Scenario. Labour requirements are slightly higher, and there is reason to believe that capital requirements have been underestimated. The technical assumptions of S3 make it possible to reduce coal requirements, and emissions, at very little additional cost.

On the high growth path, all factor requirements and all pollutants grow significantly relative to MS1. Even the technical assumptions of S2 and S3 make the scenario appear infeasible in terms of constraints to factor supplies and environmental carrying capacities.

**Table 3.15 Summary of factor use under alternative scenarios in 2020 (MS1 in 2020 = 1)**

| Factor | 1985 | 2020 MS1 | MS2 | MS3 | HS1 | HS2 | HS3 |
|---|---|---|---|---|---|---|---|
| Capital | 0.20 | 1.0 | 0.99 | 0.99 | 1.82 | 1.72 | 1.72 |
| Labour | 0.48 | 1.0 | 1.02 | 1.02 | 1.67 | 1.83 | 1.83 |
| Land | | | | | | | |
| . agricultural | 0.31 | 1.0 | 0.95 | 0.95 | 1.58 | 1.49 | 1.49 |
| . natural forest | 0.33 | 1.0 | 0.54 | 0.54 | 1.75 | 1.03 | 1.03 |
| . plantation | 0.54 | 1.0 | 1.73 | 1.73 | 1.75 | 3.28 | 3.28 |
| Energy | | | | | | | |
| . all fossil fuels | 0.42 | 1.0 | 0.89 | 0.89 | 1.84 | 1.61 | 1.60 |
| . coal | 0.02 | 1.0 | 0.77 | 0.70 | 1.60 | 1.22 | 1.10 |
| Air pollution | | | | | | | |
| . CO2 | 0.20 | 1.0 | 0.84 | 0.82 | 1.81 | 1.48 | 1.45 |
| . SOx | 0.19 | 1.0 | 0.80 | 0.76 | 1.90 | 1.52 | 1.45 |
| . NOx | 0.20 | 1.0 | 0.79 | 0.78 | 1.68 | 1.33 | 1.30 |
| Water uptake | | | | | | | |
| . agriculture | 3.23 | 1.0 | 0.73 | 0.73 | 1.04 | 0.75 | 0.75 |
| . manufacturing | 0.48 | 1.0 | 0.75 | 0.75 | 5.29 | 4.55 | 4.55 |
| . total | 2.82 | 1.0 | 0.76 | 0.76 | 1.08 | 0.82 | 0.82 |
| Water pollution | | | | | | | |
| . BOD | 0.98 | 1.0 | 0.81 | 0.81 | 4.41 | 3.77 | 3.77 |
| . COD | 0.85 | 1.0 | 0.80 | 0.80 | 4.50 | 3.91 | 3.91 |
| . TSS | 2.19 | 1.0 | 0.62 | 0.62 | 7.12 | 6.04 | 6.04 |

Note: Except for the first column, ratios for capital and labour cover investment and employment, respectively, accumulated over the period 1990 to 2020. Other variables are reported for the year 2020.

# CHAPTER 4

# POLICY IMPLICATIONS AND FURTHER WORK

## 4.1 Policy Implications

### *4.1.1 Employment*

The results indicate that an annual growth rate of 5 per cent on the moderate path will be enough to absorb the unemployed and new entrants to the labour market through to the year 2020. However, large increases in the supply of skilled and highly skilled workers will be required due to both:

- the structural shift to industries that use more highly skilled labour; and
- increasing application of technologies that require skilled workers.

The results show that due to structural shifts alone, on the moderate growth path Indonesia will require two and a half times more workers educated at the senior high school and university levels. Further, casual evidence from the case studies suggests that use of more advanced technologies will more than double that figure.

There is no doubt that continued growth and development will be more intensive in human resources. While our projections suggest that the available workforce will not be fully employed until towards the end of the study period (2020), there is little doubt that shortages of skilled workers will emerge much sooner. Overcoming these bottlenecks will require large investments in education, both the expansion of facilities and the upgrading of teaching. This should receive very high priority for government investment.

### *4.1.2 Forestry*

The results suggest that even with moderate growth, the limited area of natural forests means that domestic demand for timber will be met only if at least two thirds of logs are provided by plantations. The alternative is for Indonesia to import most of its timber needs.

The GOI needs to consider methods of encouraging the establishment of plantations on land that is already degraded. It was shown in Chapter 3 that there is enough land available for the purpose although a great deal of research needs to be carried out on the suitability of sites and species. As there is currently inadequate silvicultural information on

forest plantations under tropical conditions, the GOI should consider funding an extensive research program to determine the most suitable species, sites and management systems for tropical timber plantations in Indonesia.

As much of the land suitable for plantations is subject to traditional community ownership rights, the GOI should investigate ways of integrating the need to develop plantations with the needs of local communities to develop sustainable methods of increasing income, employment and welfare.

In addition, the analysis indicates that the damage now being done to natural forests by current logging practices can be substantially reduced by a shift to a more sustainable system of natural forest logging. This requires a new set of guidelines governing road construction, logging practices and the volumes and species of timber cut, as well as strict enforcement of these guidelines. The current Indonesian Selective Cutting and Planting System (TPTI) is being widely flouted. The GOI could consider the following methods of ensuring more sustainable natural forest logging practices: introducing an independent forestry inspection and enforcement service, imposing a moratorium on granting new concessions, making renewal of concessions subject to an independent review of past logging practices and raising the reforestation fund and forest fee to a combined $40 per cubic metre.

### *4.1.3 Energy use and air pollution*

The results of the study indicate that atmospheric emissions will increase four or five-fold even with a moderate rate of GDP growth. While all sectors produce some atmospheric pollution, sectoral results indicate that three sectors are responsible for most of the air pollution: transportation services, electric utilities and households. These sectors offer the best prospects for significantly reducing air pollution through increased use of cleaner, more energy-efficient technologies and through more fundamental changes in production and consumption to reduce the need for goods and services produced by energy-intensive sectors. A far-reaching, coordinated set of policies such as those discussed below will be required to deal with the growing air pollution problem; no single technology or policy will solve the problem. [1]

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1 The economy-wide model used for this study indicates that in general industrial sectors are not the most important sources of atmospheric pollution. However, a more disaggregated, regional model may reveal unhealthy concentrations of industrial emissions even though the aggregate levels may be lower than those of other sectors on a national basis.

*Transportation*

Transportation is the single largest source of air pollution in Indonesia. Greater fuel efficiency for all transportation equipment would cut emissions significantly, and could be achieved by the establishment of higher fuel efficiency standards, higher fuel prices or some combination of the two. The introduction of catalytic converters for motor vehicles and a reduction in the sulphur content of diesel oil would also reduce emissions.

Even with greater fuel efficiency and the widespread adoption of catalytic converters, atmospheric emissions are likely to be high and relatively concentrated geographically. Measures to provide alternatives to private transport may be required to reduce pollution to tolerable levels in the future. Clean, efficient mass transit systems could make a major contribution to reducing urban air pollution.

*Households*

In developed countries, energy efficiency standards for household appliances were established in the wake of the large oil price increases in the 1970s. These have resulted in improvements in the energy efficiency of major appliances such as refrigerators and air conditioners by 50 per cent or more over the past 15 years; even more efficient appliances are currently being developed. Many household electrical appliances are produced or assembled in Indonesia. The current design of these appliances is roughly equivalent to Japanese design of 10 years ago (Schipper and Meyers, 1991). Significant energy savings and a reduction in the associated pollution could be achieved if domestic appliance design is continually updated, particularly if lags in updating the designs were reduced.

This is a critical time for encouraging the introduction of new, more efficient designs because the rate of appliance ownership in Indonesia is rather low and is expanding rapidly. Once ownership approaches a saturation point, new, more energy-efficient appliances will only be introduced as old ones are replaced, locking the country into the use of low-efficiency appliances for a considerable time to come. The establishment of energy efficiency standards (or taxes on less efficient appliances) which would gradually tighten over the next decade is one important means of achieving significant energy savings.

*Electric power*

Faced with the prospect of depleted oil reserves, the GOI is encouraging use of other domestically available fuels, especially natural gas and coal. From an environmental perspective, natural gas is preferable to coal as it produces less carbon, sulphur and nitrogen emissions per unit of energy delivered. Renewable forms of energy, such as

geothermal and hydroelectric power, provide even cleaner energy but have received less emphasis in Indonesia's energy plans.

Nowhere is the choice of fuel more important than in the electric power industry, which is planning to expand its use of coal rapidly in the next decades. Currently cleaner coal burning technologies, such as the coal gasification and fluidised-bed combustion used in combined-cycle plants, are not expected to account for a large share of electric power capacity by 2020. The application of these technologies is worthy of serious consideration by the GOI.

Furthermore, there are no plans for the use of flue-gas desulphurisation equipment in conventional coal-fired plants. The imposition of emission standards for electric power plants and the provision of financial incentives for achieving them, including penalties for exceeding standards and subsidies for the investment necessary to meet them, would go a long way towards ensuring the use of cleaner technologies and cleaner fuels.

Nuclear power is an option that is being considered. The substantially higher costs of generating a unit of electricity by nuclear power has not deterred plans for a full program of nuclear power. There is a clear need for an independent assessment of the full life-cycle costs of the proposed nuclear plants including the costs of decommissioning retired plants, storage of spent fuel, establishment of an effective regulatory agency and the additional construction measures needed to ensure safety in a country that is seismically active. While flue-gas desulphurisation of conventional power plants has been dismissed as too expensive, investment in these environmental measures may be much cheaper than meeting the additional costs of nuclear power plants.

### *4.1.4 Water Use and Water Pollution*

Economic growth over the next few decades will require integrated water planning to provide the high-quality water required by agricultural, industrial and household sectors and to deal with their discharge of pollutants. The two sectors that use the most water are paddy and households. Significant improvements in the efficiency of water use for irrigation in paddy have been assumed under all scenarios in the analysis. These improvements, however, require substantial changes in farmer behaviour which will not occur without government intervention. To provide an incentive for conserving water, it will be necessary to price access to water appropriately. Considerable investment will be required to improve irrigation infrastructure, reduce the loss of water and permit greater control and metering of water flows.

With higher-than-average growth anticipated for the chemical sectors, the volume of water pollutants, including toxic wastes, will increase very steeply. A comprehensive set of regulations need to be put in place before new factories are locked into technological choices. In addition, the GOI should give unambiguous signals that it intends to enforce environmental protection regulations.

Both intake and outflow of water by households will need to be more carefully regulated if the health problems associated with contaminated water are to be reduced. Construction of sewage treatment plants at least for major cities should be a high priority and this will require large investments in public water utilities.

## 4.2 Cautions in Interpreting the Results

A study of this sort can always be improved by further data development and refinement. The principal areas which require further work are discussed below.

Projections of investment requirements are heavily dependent on the rather weak underlying capital stock data for 1985. While the estimation of the overall magnitude of increases in investment over the period 1985-2020 is probably fairly accurate, the weaknesses of the capital stock data suggest that sectoral investment projections may not be very accurate.

The macroeconomic projections for several sectors (notably coal, natural gas, pulp and paper and other manufacturing) would benefit from closer scrutiny especially with respect to exports and imports, an area which received comparatively little attention in this study.

In interpreting the results, the distinction between pollutant emissions and pollutant concentrations must be kept in mind. In some circumstances the two may not be closely related. Currently, there is no mechanism in the dynamic input-output model to relate emissions to concentrations. A more disaggregated, regional model of the Indonesian economy would be a necessary first step toward making this link. A regional model would also be suited to more accurate appraisal of demands and supplies of water.

The technological projections developed for this study may be too conservative. Many projections were based on the opinions of experts who tended to focus on the period to around 2005 and not much beyond. Thus this study has perhaps underestimated the extent of technological change from 2005 to 2020.

All of the potential difficulties mentioned above are particularly applicable to Sector 17 (other manufacturing), the highly aggregated nature of which conceals many changes in a number of important, diverse and rapidly growing industries.

Large changes in relative prices, especially for natural resources, will affect final demands and technological choices in the future. The model does not explicitly account for price changes, although the modelled technological changes reflect the views of experts on major changes in relative prices.

### 4.3 Priorities for Further Work

First, an economic model such as the one used in this study would benefit from being integrated with other types of models to investigate the feedbacks from environmental change on economic activity and human welfare. The dynamic input-output model and database used in this study provide the appropriate starting point for a full-scale modelling effort because the modelling of environmental impacts depends on capturing physical stocks and flows. Most economic models deal in money values only.

Other priorities for further work are suggested by the caveats mentioned in the previous section. Among them, the data could be revised to reduce some of the larger uncertainties about the results of the current model. For example, a substantial improvement in the capital stock data would make the model a valuable tool for the investment planning process required for the next Repelitas. In collaboration with BAPPENAS planners, the model could be used to generate greater sectoral detail. Further disaggregation of sectors such as other manufacturing, pulp and paper, wood products and forest products would allow much more detailed and accurate evaluation of alternative development paths for those sectors.

The development of improved employment data -- particularly more accurate assessments of the extent of underemployment by sector and of skill requirements by sector -- would permit more accurate assessments of the implications of alternative development paths for employment creation, training and the priorities for investment in education.

Disaggregation of the economy-wide model and data base into a series of interrelated regional models would make it feasible to explore specific local issues of resource use and pollution. Since regional input-output tables and associated static models already exist for Indonesia, this would entail extension of existing work only rather than development of entirely new models. The linkage of regional models into an interregional model could follow the principles used in the world model of Duchin and Lange (in press). Specifically,

together with the price and income versions of the present model, an interregional model of the Indonesian economy would allow investigation of economy-wide and interregional issues of income distribution.

# PART 2

# THE CASE STUDIES

## Preface

Part 2 of this report provides descriptions of the case studies that have been undertaken to provide information on technological change in a range of agricultural and industrial sectors. These are reported in Chapters 6-13. In addition, Chapter 5 provides details of the macroeconomic projections used in the model. Chapter 14 presents the data on land, labour and capital per unit of output and projected changes in those parameters. Chapter 15 provides the parameter estimates for atmospheric emissions, water use and water pollution per unit of output.

The case studies were undertaken by a team of researchers in Jakarta. For the manufacturing sectors, much of the information was drawn from personal interviews with production managers, engineers and industry experts. The case studies were conducted over a brief four-month period and the projections should therefore be considered to be preliminary only. A thorough assessment of likely technological change would require a great deal more time and resources. In most cases only one scenario (S1) specifying technological change between 1985 and 2020 has been developed.

It became apparent in the course of the case studies that managers in Indonesian industry are not well informed about technological developments at home and abroad. In some major industries, information about technological developments overseas is very scarce and there appears to be a distinct role for government in helping to provide it. Perhaps of more concern is that managers and engineers do not appear to view technological development as a high priority but are content to try to maximise output from older and often out-dated industrial processes. These older technologies are generally responsible for much higher levels of pollution than newer ones.

It also became apparent in the course of the case studies that industrial managers expect the GOI to impose stricter environmental standards in the future. Some of them, such as in the pulp and paper industry where large investments are involved in establishing new plants, are building flexibility into their facilities to make it easier to meet stricter standards. On the other hand, while many factories have installed some pollution abatement equipment, it is often not used or not used effectively. Regrettably, its main purpose appears to be material proof that standards are being met should the government or the local community ask questions.

# CHAPTER 5

# MACROECONOMIC PROJECTIONS*

## 5.1 The Method

The dynamic input-output model has been implemented for the period 1985 to 2020. The starting year of 1985 was chosen because it is the most recent year for which BPS has prepared a full input-output table and other supporting material, and the ending point of 2020 was chosen because the Second Long-Term Development Plan will extend over the period 1994 to 2019. A time horizon this long reflects the length of time some investment projects take to come to fruition. In addition, many environmental impacts make themselves fully apparent only after some decades.

The study requires projections of all categories of final deliveries except investment for the period 1986-2020, although wherever possible all figures for 1986-1990 use actual data. These projections reflect expected developments in the Indonesian economy at both an aggregate and a sectoral level. As with any projections about the future, it is impossible to attain precision in anticipating detailed outcomes 20 or 30 years hence. The objective is to develop alternative projections that are feasible and incorporate the most likely range of outcomes.

This chapter presents macro projections which describe the projected final demands in each of the 30 sectors of the dynamic model at constant 1985 prices at five year intervals for the period 1985-2020. The components of final demand are private consumption, government consumption, exports and imports. (Investment is determined within the dynamic model). There are two macro paths, a Moderate Growth Path and a High Growth Path. In addition, private consumption projections incorporate two different sets of assumptions about household energy use.

The Moderate Growth Path is shown in Table 5.1. It projects annual growth rates of GDP less investment of around 5.0 per cent. [2] For the period up to the year 2000, the growth rates of the components of GDP are similar to the forecasts of the World Bank (1992b, Chapter 2). For the period 2001-2020 the aggregate growth rates have been developed by NRMP-IEA to reflect a similar growth trajectory.

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* This chapter draws on Hamilton and Hulu (1993)

2 Note that we calculate growth rates of GDP excluding investment because levels of investment are endogenous to the model. Throughout this chapter references to 'GDP' should be understood as GDP less investment.

**Table 5.1 Moderate Growth Path: Projected real annual growth rates of macroeconomic aggregates, 1991-2020 (per cent)**

| | 1991-95 | 1996-00 | 2001-05 | 2006-10 | 2011-15 | 2016-20 |
|---|---|---|---|---|---|---|
| GDP (less investment) | 5.4 | 5.0 | 5.0 | 4.8 | 5.0 | 5.0 |
| Private consumption | 5.3 | 5.4 | 5.0 | 5.0 | 5.0 | 5.0 |
| Government consumption | 7.3 | 6.8 | 5.6 | 5.0 | 5.0 | 5.0 |
| Exports[a] | | | | | | |
| . non-oil | 11.7 | 7.6 | 7.2 | 6.7 | 6.7 | 6.6 |
| . oil & gas[b] | 0.4 | 1.2 | 5.2 | 5.3 | 4.2 | 4.1 |
| . Total | 6.6 | 5.4 | 6.6 | 6.3 | 6.0 | 6.0 |
| Imports | | | | | | |
| . non-oil | 8.0 | 7.3 | 7.0 | 6.8 | 6.1 | 6.1 |
| . oil & gas | 1.4 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 |
| . Total | 7.6 | 7.1 | 6.8 | 6.7 | 6.0 | 6.0 |

a. See the discussion of exports in the text.
b. Oil prices are assumed to rise from US$ 18.3 per barrel in 1991 to US$ 20.5 in 1995 and US$ 30.6 in 2000. The growth of oil and gas exports after the year 2000 is accounted for by exports of natural gas.
*Sources:* For 1991-2000, estimates are similar to those in World Bank (1992b, Chapter 2); for 2001-2020 estimates are the authors'.

**Table 5.2 High Growth Path: Projected real annual growth rates of macroeconomic aggregates, 1991-2020 (per cent)**

| | 1991-95 | 1996-00 | 2001-05 | 2006-10 | 2011-15 | 2016-20 |
|---|---|---|---|---|---|---|
| GDP (less investment) | 7.1 | 6.9 | 7.0 | 7.0 | 7.0 | 6.3 |
| Private consumption | 6.0 | 6.0 | 6.5 | 7.0 | 7.0 | 6.5 |
| Government consumption | 7.5 | 7.0 | 7.0 | 7.5 | 7.0 | 6.5 |
| Exports | | | | | | |
| . non-oil | 15.3 | 10.8 | 7.9 | 7.3 | 7.6 | 7.0 |
| . oil & gas[a] | 3.6 | 4.2 | 6.6 | 6.6 | 5.7 | 5.1 |
| . Total | 10.0 | 8.5 | 7.5 | 7.1 | 7.1 | 6.5 |
| Imports | | | | | | |
| . non-oil | 8.4 | 7.3 | 6.7 | 7.6 | 7.1 | 7.1 |
| . oil & gas | 1.8 | 1.2 | 1.3 | 1.7 | 1.9 | 1.9 |
| . Total | 8.0 | 7.0 | 6.5 | 7.5 | 7.0 | 7.0 |

a. Reflects high growth of natural gas exports. See note b. in Table 5.1.

The High Growth Path is shown in Table 5.2. It projects annual growth rates of GDP less investment between 1991 and 2020 in the range 6.3 to 7.1 per cent. These aggregate growth rates have been developed after discussions with BAPPENAS.

Projections of real GDP per capita for the High and Moderate Growth Paths are shown in Figure 5.1. The starting level of GDP per capita in 1985 is Rp 593,125 (US$ 524) and this has been extrapolated using the growth rates of GDP less investment of Tables 5.1 and 5.2 based on estimates of future population growth. Per capita GDP is reported both in constant 1985 rupiah and in constant dollars (converted at the 1985 exchange rate of US$ 1 = Rp 1131). It can be seen from Figure 5.1 that the Moderate Growth Path leads to a per capita GDP (excluding investment) in 2020 of Rp 1.58 million (US$ 1393) while the High Growth Path brings about a more than six-fold increase in per capita real income, rising to Rp 2.67 million (US$ 2,360). While this is only a crude index of changes in real income, as it does not take account of changes in relative prices and the composition of consumption, the figure nevertheless shows that the higher growth rates lead to real per capita incomes in 2020 almost double those that would be achieved at the lower growth rates.

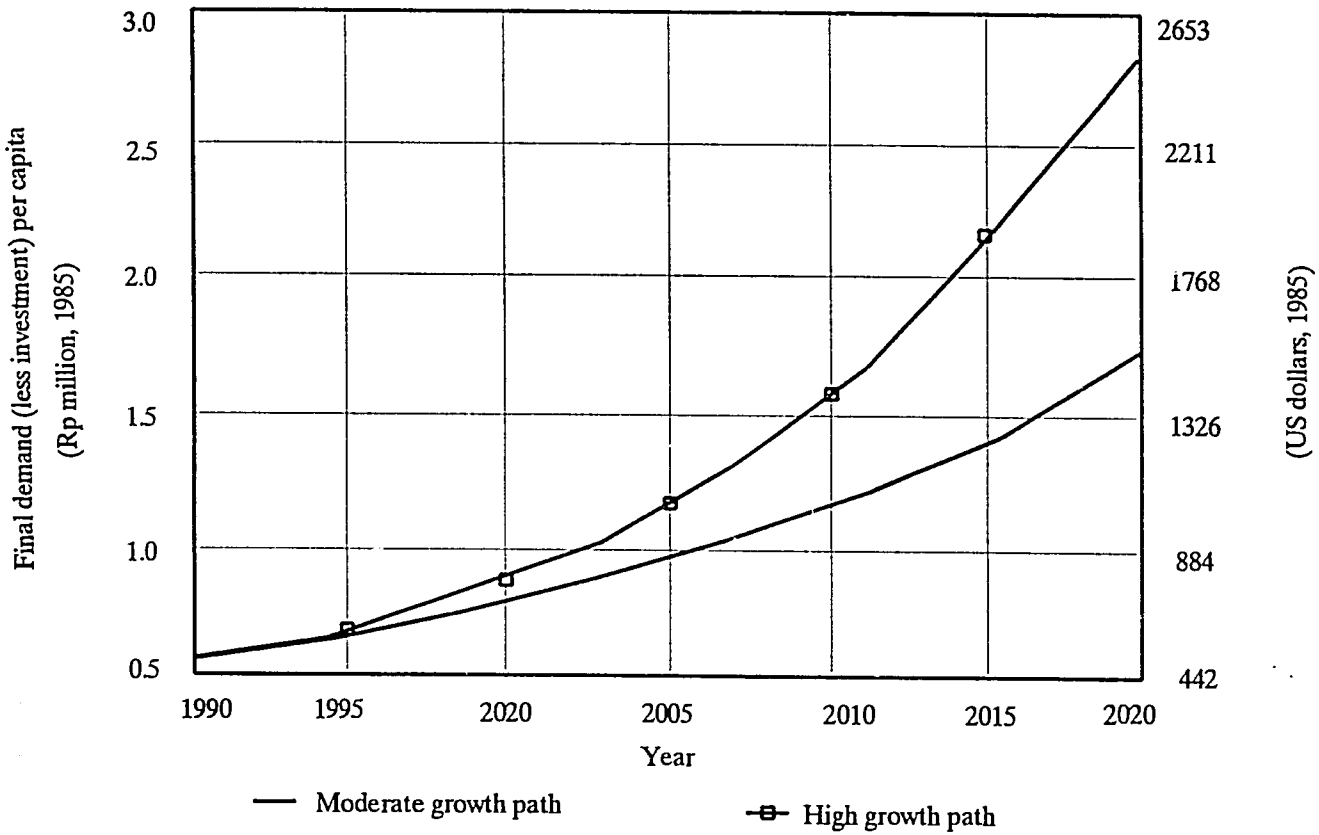
After the aggregate growth rates of GDP were estimated, the detailed growth rates for the components of GDP were developed for the Moderate Growth Path. These were then adapted for the High Growth Path.

For the Moderate Growth Path we have relied on World Bank projections of growth rates for the period 1990-2000 of consumption, exports and government consumption. A considerable amount of additional detailed work has been necessary to allocate the growth rates for each component of GDP to the 30 input-output sectors and to extend the projections beyond the year 2000.

There are two areas of data development that could be improved upon. The first is in the use of income elasticities to make projections about private consumption (described below). Although we have carried out some detailed sectoral projections for food and energy consumption, we recognise that the elasticities approach has shortcomings. An alternative might be to carry out a cross-country analysis of changes in the composition of private consumption. The second area of potential improvement would be a more complete analysis of growth rates of exports and imports for several important sectors. It has not been possible to examine each sector carefully, but several important sectors have been the subject of individual attention. In principle it would be better to close the model for both imports and exports, but that would require work well beyond the scope of the present study.

Figure 5.1

Final demand (less investment) per capita, 1990–2020 (constant 1985 prices)



## 5.2 Private Consumption

For 1985, private consumption by sector is taken from the input-output table. For the period 1986-2020, the general procedure for estimating private consumption by sector has been to allocate the total growth of private consumption using sectoral income elasticities of demand. These widely used parameters measure the growth in demand for a sector's product in response to a one per cent growth in income. However, for some important sectors described below, estimates have been made for growth of consumption based on more sector-specific information. We first describe the procedure for estimating aggregate consumption on the two paths; then we describe the procedure for allocating this growth among the 30 sectors.

For the Moderate Growth Path, the growth rate of real aggregate consumption for the five-year period 1985 to 1990 has been calculated from the statistical relationship between growth of GDP and growth of aggregate private consumption to estimate a marginal propensity to consume. For the period 1991 to 2000 growth rates of real aggregate consumption are taken from the World Bank's macro model estimates (World Bank, 1992b). For the period 2001 to 2020 we have used our own estimates based on a similar version of the World Bank forecasts for the period to the year 2000.

For the High Growth Path, we have again used the statistical relationship between growth of GDP and growth of aggregate private consumption to estimate a marginal propensity to consume for 1990, which was assumed to remain constant through to 2020.

To estimate consumption by sector, the income elasticities have been applied to per capita income. It was therefore necessary first to calculate total income per capita using estimates of population through to 2020. After estimating sectoral consumption per capita using the income elasticities of demand, total private consumption in each sector is derived by multiplying per capita consumption by population.

Population growth rates are taken from BPS (1993). Some of the income elasticities are taken from an unpublished BAPPENAS analysis of regional consumption patterns among different income classes, normalised so that their weighted average each year is 1. The elasticities appear in Table 5.3.

Income elasticities are generally crude and unreliable measures. We have therefore checked that the sectoral shares of private consumption in 2020 implied by the elasticities are consistent with other sources of information, including extrapolations of growth rates of consumption for the period 1985 to 1990. In several important sectors -- the energy sectors (Sectors 7, 18, 19, 20, 21) and the food, beverages and tobacco sector (Sector 11) -- we have

replaced the elasticity-based estimates with estimates based on other sources of data on likely growth rates of private consumption demand. The procedure for projecting household energy consumption is described separately in Chapter 9. The food, beverages and tobacco sector is particularly important because of its size and its impact on agricultural employment. The share of this sector in 2020 has been estimated from data contained in a World Bank analysis of agriculture in Indonesia (World Bank 1992a, especially Annex IV, Table 4.12).

### 5.3 Government Consumption

For the Moderate Growth Path, growth rates of total government consumption are similar to the World Bank forecasts reported in Table 5.1. These are extended to the year 2020 in the way described above for projecting the growth of aggregate private consumption. The composition of government consumption, in terms of the mix of goods and services, is assumed to remain as it was in 1985. In 1985, 76 per cent of government consumption was delivered by only two sectors -- the public administration sector itself (Sector 28) and social and other services (Sector 29), which includes health and education.

For the High Growth Path, projected government consumption for the period 1991-2020 is based on a marginal propensity for the government to consume from calculated GDP. This parameter, which reflects the change in government's share of GDP as GDP changes, was estimated from national accounts data for the period 1983-1991. Otherwise, the procedure is the same as for the Moderate Growth Path.

### 5.4 Exports

For both growth paths, the values of exports in 1990 (at 1985 prices) were derived principally from BPS data on physical quantities of exports (BPS 1987, BPS 1991c). From these data real growth rates for 1985-1990 have been calculated. The commodity classification has been matched with input-output sectors as closely as possible.

For the Moderate Growth Path, the projections for export growth for 1991-2020 have been developed as follows. Real growth rates for textiles, plywood and other manufactures and for agriculture and metals and minerals for the period 1991-2000 are taken from the World Bank forecasts (1992b) and extended for the years beyond 2000 (see Table 5.4). For other sectors (and for some sectors within the broad category of other manufacturing, Sector 17) estimates based on real growth rates for the 1985-1990 period have been used.

## Table 5.3 Per capita income elasticities of demand

| Sector | | Income elasticity |
|---|---|---|
| 1 | Paddy | 0.546 |
| 2 | Other food crops | 0.546 |
| 3 | Estate crops | 0.777 |
| 4 | Livestock, poultry & products | 1.480 |
| 5 | Forest products | 1.162 |
| 6 | Fisheries | 0.869 |
| 7 | Coal | -- [a] |
| 8 | Crude oil | 0.777 |
| 9 | Natural gas | 0.777 |
| 10 | Other mining | 0.777 |
| 11 | Food, beverages & tobacco | 0.488[a] |
| 12 | Wood products | 2.323 |
| 13 | Pulp, paper & products | 1.625 |
| 14 | Fertilizer & pesticides | 1.393 |
| 15 | Chemicals | 1.393 |
| 16 | Cement & limestone | 1.000 |
| 17 | Other manufacturing | 2.190 |
| 18 | Petroleum refining | 0.540 (0.120)[a] |
| 19 | Liquified natural gas | 3.250 (3.060)[a] |
| 20 | Electricity | 6.370 (4.500)[a] |
| 21 | Gas utilities | 3.420 (3.430)[a] |
| 22 | Water utilities | 1.162 |
| 23 | Construction | 1.000 |
| 24 | Wholesale & retail trade | 1.298 |
| 25 | Restaurants & hotels | 1.298 |
| 26 | Transport & communications | 1.625 |
| 27 | Real estate, finance & business services | 1.671 |
| 28 | Public administration & defence | 1.295 |
| 29 | Social & other services | 1.295 |
| 30 | Unspecified | 1.295 |

Notes: a. For these sectors alternative estimates of consumption growth have been used (see text). For the energy sectors (Sectors 7, 18, 19, 20 and 21) the reported elasticities are for the moderate growth path over the period 1990-2020 under household energy Scenario 1 (described in Chapter 9). Household energy Scenario 2 elasticities, reflecting greater energy conservation, are shown in parentheses. There are no figures for coal because household consumption of coal in 1990 was zero. Note that the low elasticity for petroleum products is dominated by the substitution of electricity for kerosine. The consumption elasticity for all fossil fuels (Sectors 7, 18, 19 and 21) is 0.950 (0.520).

*Source*: NRMP and BAPPENAS estimates. Elasticities have been normalised in projecting private consumption.

Crude oil exports are projected to continue to decline at the rate that prevailed in the period 1985-1990 through to the year 2015 when exports reach zero. This reflects expected declining reserves of crude oil and increasing domestic demand. Domestic demand for petroleum will continue to grow squeezing out exports such that exports of refined petroleum reach zero in 2005, when current contracts for petroleum exports expire. . Exports of liquified natural gas (LNG) are forecast to continue to grow at the 1985-1990 growth rate, calculated from figures in Directorate Jenderal Minyak dan Gas Bumi (1991). Reserves of natural gas are large and new contracts for the export of LNG have recently been signed.

For the High Growth Path, the procedure was as follows. The growth rates of total exports were projected by calculating the relationship between the growth rate of GDP and the growth rate of total exports for the period 1983-1991 and applying the projected ratio to projections of GDP. The sectoral export growth rates were projected by assuming that the composition of exports calculated for the Moderate Growth Path remained unchanged. They were applied to the higher growth of total exports. As a result of this procedure, the growth rate of oil and gas exports in the period 1991-95 rose from 0.4 per cent on the Moderate Growth Path to 4.5 per cent on the High Growth Path because the initial share of oil and gas exports in 1991 was very high (21.4 per cent). Projected growth rates of sectoral exports on the High Growth Path appear in Table 5.5.

## 5.5 Imports

Imports in 1990 have been estimated by calculating growth rates of import volumes for the main commodities using BPS import data (BPS 1987, BPS 1991c). We have assumed that the growth rates of imports of services are equal to the growth rate of aggregate consumption.

For the Moderate Growth Path, the projections for 1991-2000 of total import growth are taken from World Bank estimates (1992b) and are extended for the period 2001-2020, as in Table 5.1. Sectoral import growth rates for the period 1991-2020 are assumed in the first instance to be equal to the growth rates calculated for 1985-1990. However, sectoral import growth rates were then adjusted proportionally so that the growth rate of total imports equals the rate separately estimated and reported in Table 5.1.

**Table 5.4 Moderate Growth Path: Estimated growth rates of exports, 1991-2020 (per cent)**

| | 1991-95 | 1996-00 | 2001-05 | 2006-10 | 2011-15 | 2016-20 |
|---|---|---|---|---|---|---|
| Wood products | 6.3 | 2.0 | -1.6 | -0.7 | -0.1 | 0.0 |
| Other manufacturing | 21.0 | 10.6 | 10.2 | 7.3 | 6.4 | 6.0 |
| Agriculture | 7.8 | 5.4 | 3.3 | 4.3 | 4.9 | 5.0 |
| Coal | 6.3 | 6.2 | 4.5 | 5.5 | 6.1 | 6.2 |
| Other mining | 5.1 | 5.0 | 3.3 | 4.3 | 4.9 | 5.0 |
| *Total non-oil exports* | *11.7* | *7.6* | *7.2* | *6.7* | *6.7* | *6.6* |
| Oil & gas | 0.4 | 1.2 | 5.2 | 5.3 | 4.2 | 4.1 |
| *Total exports* | *6.6* | *5.4* | *6.6* | *6.3* | *6.0* | *6.0* |

*Sources*: World Bank (1992b) and NRMP estimates.

**Table 5.5 High Growth Path: Estimated growth rates of exports, 1991-2020 (per cent)**

| | 1991-95 | 1996-00 | 2001-05 | 2006-10 | 2011-15 | 2016-20 |
|---|---|---|---|---|---|---|
| Wood products | 10.7 | 6.0 | 1.1 | 2.3 | 2.8 | 2.4 |
| Other manufacturing | 26.0 | 14.9 | 13.2 | 10.5 | 9.4 | 8.5 |
| Agriculture | 12.3 | 9.5 | 6.1 | 7.1 | 7.9 | 7.5 |
| Coal | 10.7 | 10.3 | 7.3 | 8.7 | 9.1 | 8.7 |
| Other mining | 9.5 | 9.1 | 6.1 | 7.5 | 7.9 | 7.5 |
| *Total non-oil exports* | *15.3* | *10.8* | *7.9* | *7.3* | *7.6* | *7.0* |
| Oil & gas | 3.6 | 4.2 | 6.6 | 6.6 | 5.7 | 5.1 |
| *Total exports* | *10.0* | *8.5* | *7.5* | *7.1* | *7.6* | *7.0* |

*Source:* See text

For the High Growth Path, the growth rate of total imports was estimated in the same way as total exports, by calculating a marginal propensity to import from the data for the period 1983-1991. The sectoral import growth rates were projected by assuming that the composition of imports calculated for the Moderate Growth Path remained unchanged and were applicable to the higher growth of total imports.

# CHAPTER 6

# FOOD CROPS*

## 6.1 Paddy: Current Technology

The first two sections of this chapter describe current and future technologies in the Indonesian irrigated rice production sector (Sector 1 in the NRMP-IEA 30-sector classification system). This sector includes the cultivation and harvesting of rice (*padi* and *gabah*) but not the processing of rice to an edible form (*beras*). Estimates are also made of natural resource demands (land and water) and of some impacts on the natural environment associated with rice production.

In the case of the agricultural sectors discussed in this and the next chapter, by 'technologies' we mean the ways in which natural resources, intermediate inputs, capital equipment, labour of various skill types and knowledge are combined to produce agricultural products. The technologies described here also include some of the impacts on the natural environment of different cultivation and harvesting methods.

Most rice in Indonesia is grown in irrigated fields (*sawah*) on landholdings averaging 0.25 ha each. This irrigated rice production, which accounted for 95 per cent of total rice production in 1985, the remainder coming from upland rice, will be most affected by changes in production technology. Traditional, sustainable technology has been largely replaced since the introduction of new seed-fertiliser technology in the 1970s (the Green Revolution). The current technology depends on a changing range of fertiliser-responsive rice varieties, based on seed types developed by the International Rice Research Institute (IRRI). The new varieties' high yields require carefully timed applications of nitrogen and phosphate fertilisers, skillful pest control and more reliable and timely irrigation.

The great majority of farmers still rely on human and draft labour for land preparation, transplanting, crop maintenance (fertilising and weeding) and harvesting. Mechanisation of field operations is limited to land preparation, for which some farmers hire hand-tractor services to reduce time required. Despite attempts by the government to encourage use of hand tractors, including through subsidised credit, their use is limited by steeply terraced terrain and small field size. Tractors are widely used only in regions with extensive areas of flat land ( where plot sizes are also generally larger) and where availability of irrigation water is tightly scheduled, requiring rapid land preparation.

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* This chapter draws on NRMP-IEA Input-Output Working Papers Numbers 6 and 7 (Foley 1993a and 1993b).

In 1985 total national production of unmilled rice was 39 million tonnes, and approximately 94 per cent of this total was grown on lowland ricefields (irrigated and rainfed) with an average yield for each crop of 4.2 tonnes/ha (t/ha). By 1990, total production had risen to 45 million tonnes, 93 per cent of which was grown on lowland ricefields, with an average yield of 4.6 t/ha. Production on irrigated lowland ricefields, about 80 per cent of total production, achieved markedly higher yields, in the range 4.5-5.5 t/ha in 1985 and 4.8-5.8 t/ha in 1990 (BPS 1991a), with the highest yields achieved on Java. During this period, the number of crops per year (cropping intensity) on Java increased from 1.44 to 1.48, while off Java there was a slight decline in intensity. The area of lowland rice harvested grew from 8.8 million ha in 1985 to 9.4 million ha in 1990 (1.36 per cent p.a.).

Studies by the World Bank (1992a), Winrock International (1991) and the Centre for World Food Studies (SOW) (1991), all anticipate gradual increases in both land and labour productivity in this sector. Discussions with local experts confirm this expectation, with Indonesia anticipated to remain self-sufficient in rice production on average (trend self-sufficiency), given expected increases in population and very slowly increasing average per capita consumption of rice. This outcome will be explored in the scenarios developed below.

Indonesia increasingly faces constraints on the area of land available for agriculture. While new agricultural land is being developed off Java, existing land, particularly irrigated ricefields, is being lost to urbanisation and industrialisation, especially on Java. In 1985 some 7.5 million ha were used for lowland (irrigated and rainfed) rice production. By 1990 the area had increased to about 8.2 million ha. According to recent estimates, approximately 0.96 million ha of additional land off Java are potentially suitable for rice cultivation (RePPProT 1990). By 2020 it is estimated that some 1.1 million ha of lowland ricefields, mainly on Java, will have been converted to other uses (SOW 1991). If the potentially suitable land is developed in the future, the area of land under lowland ricefields in the year 2020 will be about the same as in 1990, 8.2 million ha. This means growth in production will have to come almost entirely from increases in yields and cropping intensity.

The base technological scenario (S1) described in the next section projects a growth in yield averaging 0.85 per cent p.a. (taking output from 4.2 t/ha in 1985 to 5.7 t/ha in 2020), which would result in production from lowland ricefields (irrigated and rainfed) of about

62 million tonnes. [2] The World Bank (1992a) analysis, extended to 2020, anticipates faster growth in yields of 1.23 per cent p.a. over 1988-2020, resulting in an average yield for lowland (irrigated and rainfed) rice of about 6.9 t/ha by 2020 (and total production of about 64 million tonnes). Yields for lowland irrigated rice alone would be higher (about 7.5 t/ha), but would grow less rapidly (1.16 per cent p.a.). The increases in average yields could be achieved by more efficient crop management and use of fertiliser and water, rather than by greater use of these inputs per unit area.

The High Technology Scenario (S2) described in the next section -- which anticipates yields on lowland irrigated ricefields increasing to a national average of about 9.4 t/ha by the year 2020 -- would allow the same total production from irrigated ricefields (55 million tonnes) to be achieved using less land; it uses the World Bank (1992a) study as a starting point but envisages more rapid growth in yields after the year 2000, resulting in substantial increases in both land and labour productivity for irrigated rice by 2020.

The principal intermediate inputs to production of paddy according to the 1985 input-output table are listed in Table 6.1. These inputs are dominated by fertiliser and pesticide (Sector 14) and paddy (for seed), with financial intermediaries and trade having less significance. Other intermediate inputs each account for less than 1.5 per cent of total intermediate inputs. This mix of inputs serves as a point of departure for the projections.

**Table 6.1 Paddy: Principal intermediate inputs, 1985**

| Sector | name | Coefficient (Rp/Rp) |
|---|---|---|
| 14 | Fertiliser & pesticide | 0.0688 |
| 1 | Paddy | 0.0182 |
| 27 | Financial intermediaries | 0.0082 |
| 24 | Retail & wholesale trade | 0.0058 |

Source: BPS 1989

Before developing the technological scenarios it will be useful to present the arithmetical relationships for the parameters to be calculated. This will help readers translate the parameters as they are usually defined by agricultural specialists into the forms of the parameters used in the present model. The definitions and relationships are presented in Table 6.2.

2 This would be sufficient to meet anticipated demand of 154 kg/capita p.a. for a population in 2020 of 273

**Table 6.2 Parameters used in the agricultural case studies**

Parameters as usually defined

| *Definition* | *Name* | *Unit* |
|---|---|---|
| $t_1$ | yield | output/ha/crop |
| $t_2$ | cropping intensity | crops/annum |
| $t_3$ | labour inputs | person years/ha (for a given $t_2$) |
| $t_4$ | chemical inputs | chemicals/ha/crop |
| $t_5$ | water use | water used/ha/crop |
| $t_6$ | water withdrawals | water withdrawn/water used |

Parameters as used in the model

| *Definition* | *Name* | *Unit* |
|---|---|---|
| $1/t_1t_2$ | land coefficient | ha/output/annum |
| $t_3/(t_1t_2)$ | labour coefficient | person/output/annum |
| $t_4/t_1$ | fertiliser coefficient | fertilisers/output |
| $(t_6t_5)/t_1$ | water withdrawals | water/output |

## 6.2 Paddy: Changes in Technological Coefficients to 2020

Two scenarios are developed for the year 2020. The Base Scenario (S1) describes a continuation of current trends in improvements in use of inputs to production and slowly rising yields; no substantial increase in mechanisation is anticipated. The High Technology Scenario (S2) examines the potential for increasing labour and land productivity by exploiting the yield potential of new rice varieties which, according to IRRI, should be available by about the year 2000.

### *6.2.1 Base Scenario (S1): Continuation of Current Trends*

With a continuation in current trends, yields are expected to improve by 35 per cent by 2020. The cropping intensity is expected to increase by 14 per cent. Estimated changes in technological coefficients for intermediate inputs, labour, land and environmental impacts are discussed below and summarised in Table 6.3. Table 6.3 is a useful intermediate step in developing the final data sheet for the sector because it presents physical coefficient data for 1985. In this case study, as in the others, projections of coefficient change are expressed as percentage changes applied to the 1985 coefficient. Estimates of percentage changes in

million (Winrock International, 1991), before taking into account upland rainfed rice production.

coefficients have been made using physical input data derived from a range of other sources.

Yield increases result from incremental improvements in the use of inputs (e.g. fertiliser and water) and cause a general decline in inputs required per unit of production. The increase in yields is wholly responsible for increases in land and labour productivity.

*Intermediate inputs*

More efficient use of fertilisers (better placement and slow release formulations) and the growing adoption of integrated pest management result in a decline in the amounts needed per unit of production.

It is estimated that requirements for fertiliser per unit of output will decline by some 13 per cent by 2020 and pesticide use will decline by 66 per cent. These per unit declines reflect both more efficient input use and increasing yields; the volume and value of fertilisers and pesticides is dominated by the former.

**Table 6.3 Paddy: Base Scenario (S1) technological coefficients**

| Input | 1985 level (input/t) | Change in coefficient 1985-2020 (%)[a] |
|---|---|---|
| Fertiliser & pesticide | | -13 |
| . urea (kg) | 43.725 | |
| . other fertilisers (kg) | 18.376 | |
| . pesticides (kg) | 0.611 | -66 |
| Paddy | | -26 |
| . seed (kg) | 9.366 | |
| Labour | | -26 |
| . human labour (person-years) | 0.0885 | |
| (person-days) | 26.542 | |
| . draft labour (cattle-days) | 0.149 | |
| . tractors (machine-days) | 0.007 | |
| Water use (m3) | 2,367 | -63 |
| Land (ha) | 0.2367 | -35 |
| Methane gas (kg) | 42-84 | -35 |
| 1985 unit price (Rp)[b] | 182,941 | |

Notes: a. For more detailed derivation of some of these estimates see Foley (1993a).
b. The 1985 unit price has been estimated because the environmental coefficients used in the model are presented as per tonne of output while the model generates output projections in Rupiah.

Incremental price increases for fertiliser, caused by a progressive removal of subsidies, are already encouraging more efficient use of fertiliser, as is verified by data contained in BPS (1991b). The complete elimination of subsidies on pesticides since 1986 is having a similar effect, and is being further stimulated by a national integrated pest management program.

Increases in yields will reduce the amount of seed paddy required to produce a tonne of rice at about the same rate as yields increase. An improvement in yields of 35 per cent implies a decline in paddy (seed) requirements per unit production of some 26 per cent, (1 - 1/1.35) x 100.

*Labour requirements*

Labour requirements per unit output in rice production are closely related to yields. It is assumed that in the absence of greater mechanisation the amount of labour per hectare remains constant, so that labour requirements per tonne of output will fall at the same rate as land requirements, i.e. 26 per cent by 2020.

*Natural resource impacts*

Land requirements depend on crop yields and cropping intensity. With yields rising by 35 per cent (reducing land per tonne of output by 26 per cent) and cropping intensity rising by 14 per cent, land requirements per unit of output will be reduced by some 35 per cent by the year 2020, [1 - 1/(1.35 x 1.14)] x 100.

Irrigation requirements per unit of output will be reduced by increases in yields and improvements in irrigation delivery efficiency. Improvements in irrigation delivery efficiency from the current level of about 25 per cent (World Bank 1992a) decrease the volume of water uptake needed per tonne of output. However, to some extent the efficiency gains in existing systems are likely to be offset by declining efficiencies caused by greater infiltration rates and leakages as irrigation is extended to new areas. Overall, it is estimated that irrigation delivery efficiency will double to 50 per cent by 2020. In conjunction with yield increases, this implies a reduction in water uptake per tonne of production of 63 per cent ([1 - 1/(1.35 x 2)] x 100). Water delivered declines by only 26 per cent ([1 - 1/(1.35)] x 100).

Soil erosion is not considered to be an important issue for irrigated rice production under current technological trends (Euroconsult 1989). Intense, short-term erosion will occur during the establishment of new ricefields, but we are currently unable to quantify this impact.

### *6.2.2 High-Technology Scenario (S2)*

Under the Base Scenario (S1), agriculture in Indonesia will continue to absorb a very large share of the workforce because rates of labour productivity growth in rice (and the other agricultural sectors) are slower than in the rest of the economy. A large decline in the share of agriculture in total employment would require rapidly increasing yields after the year 2000 and may require greater mechanisation.

IRRI's research program aims to increase yields by 20-30 per cent by developing hybrid rice not requiring additional inputs (next 10 years), reduce the number of tillers (stems) from 20-15 to 4-5 productive ones with larger seed-bearing panicles (10-15 years), markedly improve inbred disease and pest resistance and improve crop management practices, including fertiliser applications (deep placement, slow release) and use of fertility maintaining crop rotations (World Bank 1992a). The long-term goal is to achieve yields of 15 t/ha.

Mechanisation of field operations (land preparation, planting, weeding and harvesting) could possibly double human labour productivity. However, given the limited success of previous efforts to extend mechanisation of land preparation, it is hard to envisage how this might be achieved. Mechanisation of weeding and harvesting would be confront by both technical problems (getting the equipment into steeply terraced fields and, for weeding, ensuring that weeds and not rice plants are removed) and social barriers, as high-paying manual harvesting and threshing is still an important method of income redistribution in many areas.

Nominally, some 16,000 two-wheeled tractors were available for land preparation in 1985 (BPS 1986c). With a per tractor capacity of approximately 29.4 ha per season and three crops cultivated per annum, this results in a maximum estimate of 1.4 million ha of land prepared by tractors, leaving some 7.4 million ha (or about 84 per cent) requiring draft cattle. This means mechanised land preparation played a minor role nationally, despite its importance in some areas where cropping intensity was much higher than average, e.g. the coastal plains of Java. This pattern is very unlikely to change dramatically.

The World Bank (1992a) study anticipates irrigated lowland rice yields increasing from 4.8 t/ha to 7.00 t/ha on Java and 6.20 t/ha off Java by 2010, wholly through improved management in the use of the current range of inputs. Continuing these rates of increase to 2020, based on the same methods, would result in average yields of about 7.5 t/ha for lowland irrigated rice. If human labour inputs per hectare remain constant, this would result in output per unit of labour increasing by 45 per cent or a 31 per cent decline in labour requirements per unit output between 1985 and 2020.

In order to achieve a doubling of output per unit of labour yields for irrigated lowland rice production in the period 2000-2020 need to increase by 2.5 per cent p.a. (a very high growth rate to sustain over 20 years), resulting in an average yield in 2020 of about 9.4 t/ha (10.2 t/ha on Java and 8.9 t/ha off Java). Land productivity would increase by 82 per cent and cropping intensity by 24 per cent, reducing land required per tonne of annual production by 56 per cent. Assuming labour inputs per hectare remain constant, labour required per tonne of output falls by 45 per cent. The increases in yields of irrigated rice, on which this scenario depends, are the goal of the current research programme at IRRI.

To summarise the impacts of the High Technology Scenario (S2), labour requirements will decline by about 45 per cent per unit of output (although the remaining labour will need to be more skilled). Fertiliser requirements will decline, but by less than the increase in yield; a decline of 25 per cent per unit of production may be feasible. The land area per tonne of output will decrease by around 56 per cent due to increased yields and cropping intensity. Water consumption per unit of output will decline by about 73 per cent. The intense, short-term soil erosion caused by establishing new irrigated areas will be almost completely eliminated. Changes in the technological coefficients for rice under both scenarios are presented in Table 6.4.

The problems associated with a mechanical as opposed to a biological (yield-increasing), approach to increasing output per unit of labour favour the latter. In addition, the biological approach goes a long way towards developing an active, as opposed to reactive, response to the loss of irrigated land to other non-agricultural uses and towards increasing land area available for meeting rapidly increasing demand for vegetables, fruit and meat.

**Table 6.4 Paddy: Changes in technological coefficients, 1985-2020**

| | | | Change between 1985 and 2020 (%) | |
|---|---|---|---|---|
| | | | S1 | S2 |
| *Intermediate inputs* | | | | |
| 1 Paddy | | | -26 | -45 |
| 14 Fertiliser & pesticides | | | -13 | -25 |
| *Labour inputs* | | | | |
| Total employment per unit output | | | -26 | -45 |
| *Capital inputs* | | | | |
| Total new capital requirements | | | 0 | 0 |
| *Natural resource impacts* | | | | |
| | Unit | 1985 level | S1 | S2 |
| Water uptake | m3/t | 9,568 | -63 | -73 |
| Water delivered | m3/t | 2,367 | -26 | -45 |
| Land area | ha/t | 0.2367 | -35 | -56 |

Note: Intermediate inputs are expressed in terms of the NRMP-IEA 30-sector classification.

## 6.3 Other Food Crops: Current Technology

The next two sections describe current and future technologies in the other food crops sector (Sector 2 in the NRMP-IEA 30-sector classification system) which covers all non-plantation and non-rice food crops. Three main types of agricultural products make up the sector: staple crops (maize, cassava, sweet potato, groundnuts and soybeans), vegetables and fruit. This combination of a broad range of non-rice food crops, grown under widely differing conditions and with varying physical and labour requirements, makes the analysis difficult. Currently available data on physical and labour inputs to non-rice food crops are extremely limited, both with regard to the number of crops for which data can be found and the quality of available data. The sector covers only on-farm production of these crops and not further processing.

Production methods are small-scale (farms averaging less than one hectare), almost completely unmechanised (except for equipment used to apply pesticides) and rely on human and draft labour for all steps in production. Hand hoeing and cattle-drawn ploughs

are used for land preparation, and seed or cuttings (cassava and sweet potato) are planted by hand. Weeding, fertilising, other crop maintenance activities and harvesting are also performed using human labour.

Most of these crops are grown under rainfed conditions on sloping or undulating land; only a minor proportion are grown on unirrigated ricefields in rotation with rice. Most production within this sector is for own-consumption by farm families and only a relatively small proportion is grown commercially to meet urban demand. However, growing urban populations and income-derived demand will increase both the scale and proportion of commercial production by 2020, especially for vegetables and fruits (World Bank 1992a).

Except for cassava, none of these crops is currently exported and demand is primarily influenced by domestic factors such as population and income. Some studies foresee the possibility for future exports of maize (Winrock International, 1991). There may also be opportunities for small-scale exports of specialty high-value, low-volume fruit (World Bank 1992a).

By volume in 1985, staple crops accounted for some 78 per cent of sectoral production and 87 per cent of area, vegetables for 7 per cent of production and 4 per cent of area, and fruit for the remaining 15 per cent of production and 9 per cent of area. Average yields for each type of crop were 4.07 t/ha for staples, 7.23 t/ha for vegetables and 7.19 t/ha for fruit (BPS 1986a). It can be seen from Table 6.5 that in 1985 these crops occupied a total of some 6.23 million hectares, of which approximately 3.51 million ha are on Java and 2.15 million ha are off Java (see Foley 1993b).

Because 1989 is the latest year for which data are available for vegetables and fruit, the data of Table 6.5 have been extrapolated at the 1985-89 growth rates to give approximations for 1990. By 1990, based on these assumptions, vegetable production had increased to 2.70 million tonnes (an increase of 9.45 per cent p.a.) and fruit production to 4.33 million tonnes (1.05 per cent p.a.), with average yields for vegetables of 9.35 t/ha (6.64 per cent p.a.) and fruit 7.22 t/ha (0.10 per cent p.a.).

The share of staples in sectoral production remained stable at about 78 per cent in 1990 while the share of vegetables had increased slightly to 8 per cent and fruit declined slightly to 13 per cent of the total. By 1990 total area harvested had increased by 3.91 per cent p.a. to 7.55 million ha, some 4.18 million ha (3.56 per cent p.a.) on Java and 2.76 million ha (5.19 per cent p.a.) off Java (Foley 1993b).

**Table 6.5 Other food crops: Area, production and yields, 1985 and 1990**

| Crop | Area $10^3$ ha | Output $10^3$ t | Yield t/ha | Share of total area | Share of total output |
|---|---|---|---|---|---|
| *1985* | | | | | |
| Staples | 5,394 | 21,946 | 4.07 | 86.5 | 78.4 |
| Vegetables | 260 | 1,882 | 7.23 | 4.2 | 6.7 |
| Fruit | 578 | 4,155 | 7.19 | 9.3 | 14.9 |
| Total or weighted mean | 6,232 | 27,983 | 4.49 | 100.0 | 100.0 |
| *1990 (est.)* | | | | | |
| Staples | 6,647 | 26,673 | 4.01 | 88.0 | 78.2 |
| Vegetables | 289 | 2,701 | 9.35 | 3.8 | 7.9 |
| Fruit | 600 | 4,332 | 7.22 | 7.9 | 12.7 |
| Total or weighted mean | 7,550 | 34,115 | 4.52 | 100.0 | 100.0 |

*Source:* Foley (1993b)

A recent study by the World Bank (1992a) suggests that demand for staple crops (except as stock feed) is likely to grow very slowly to 2010, while there will be a significant increase in demand for vegetables and fruit as incomes rise. Several studies (Winrock International 1991, Centre for World Food Studies 1991, World Bank 1992a) anticipate steady increases in land and labour productivity for these crops during this period.

As with rice production, Indonesia faces limits on the area of land suitable for cultivation for this range of crops. According to estimates by RePPProT (1990), off Java there are an additional one million ha potentially suitable for dryland arable crops and another 1.2 million ha for mixed arable and tree crops. Changes in land use on Java, particularly in areas adjacent to major urban markets, are resulting from expansion of vegetable and fruit production (World Bank 1992a). However, expansion of production on Java will generally result in the replacement of irrigated rice cultivation by intensive cultivation of vegetables on a commercial basis. In addition, increases in demand for stock feed (maize and soybeans) will result in expansion of production both on Java and off Java, but soybeans are often planted in rotation with rice.

The main intermediate inputs to production in 1985 are listed in Table 6.6. Fertiliser and pesticide account for nearly one third of intermediate inputs by value, and over one third of intermediate inputs to this sector come from within the sector itself. Paddy, retail and wholesale trade, livestock products and financial intermediaries are the only other sectors

which individually account for more than 2 per cent of intermediate inputs.

**Table 6.6 Other food crops: Principal intermediate inputs, 1985**

| Sector | name | Coefficient (Rp/Rp) |
|---|---|---|
| 2 | Other food crops | 0.0405 |
| 14 | Fertiliser & pesticide | 0.0380 |
| 1 | Paddy | 0.0172 |

Source: BPS 1989

## 6.4 Other Food Crops: Changes in Technological Coefficients to 2020

Two scenarios have been identified. Only the base technological scenario (S1) has been fully developed for this sector. The second scenario (S2), known as the 'Conservation Scenario', is developed for upland staple crops. In addition to the yield gains under S1, S2 is designed to maintain land productivity by reducing soil erosion. It has been developed only in outline for the purposes of discussion. For the reasons given below, it appears unlikely that major increases in average productivity of land or labour will be achieved in this sector. Rather, the main task to be confronted in this sector will be to maintain the productivity of the land in the face large-scale soil erosion and soil nutrient losses.

Except for maize, the crops in this sector are grown by smallholders mainly for own-consumption, with a relatively small but increasing proportion entering commercial markets. There appears to be little stimulus or opportunity for intensification of production (e.g. major increases in fertiliser use) or mechanisation (e.g. land preparation) to achieve markedly higher levels of land and labour productivity. In addition, as many of these crops (particularly staples) are grown on sloping land with high rates of soil and nutrient loss through erosion, farmers will face a struggle just to maintain current yields. New areas that may be opened for cultivation have generally poorer soil or more steeply sloping land than existing areas since they would otherwise have been put under cultivation already, so that yields from these areas are unlikely to be as high as those achieved in existing areas.

### *6.4.1 Base Scenario (S1) -- Continuation of Current Trends*

Technological changes in this scenario will be reflected in increases in yields of the various crops that make up the sector. However, there will be changes in the shares of various

crops in the sector and this will be taken into account in calculating average yields for future years. Changes in shares will be determined by changes in demands as incomes rise. Changes in demands for different crops will result in changes in the areas and proportions of land planted with various crops and this too will affect yields because of variations in land quality.

These various factors have been incorporated into models of food demand and supply by the World Bank (1992a) and this has formed the basis for the estimates of parameter change developed below. The details may be found in Foley (1993b).

In this scenario crop production area and productivity expand to supply the growing demand for food, with most expansion occurring in production of vegetables and fruit. It should be noted that production and anticipated demand for staples includes a growing proportion of maize and soybeans used as stock feed (about half by 2020) rather than for direct consumption. By the year 2020, the share of staples in the diet is expected to have declined from 78 per cent to 59 per cent of the total; the shares of vegetables and fruit will have risen to 15 per cent and 26 per cent, respectively.

With a continuation of current trends in yields, and with the estimated changes in the proportion of staples, vegetables and fruit produced, improvements in cultivation will result in a 40 per cent increase in yields by 2020 (0.97 per cent p.a.). Within the sector, increases in staple crop yields are estimated at 14 per cent over 1985-2020, in vegetable yields by about 138 per cent and in fruit yields by about 60 per cent. These increases in yields result from gradual improvements in the crop varieties available to farmers, particularly maize, groundnuts and soybeans, and in the use of inputs, particularly fertiliser.

*Intermediate inputs*

Changes in intermediate inputs, labour inputs and natural resource impacts under S1 are shown in Table 6.7. Fertiliser use per hectare for maize, groundnut and soybean crops will rise more slowly than yield increases (due to increasing efficiency of use), while its use for cassava and sweet potato crops will remain negligible. Fertiliser use per hectare on vegetables will rise more slowly than yields (again, due to increasing efficiency of use), but the proportion of area of vegetables on which fertiliser is used will increase due to more intensive commercial production. Fertiliser use for fruit will remain negligible. Inputs of pesticide per hectare, currently very low, are expected to decline per unit of output for staples in line with yield increases, but they are likely to increase for vegetables and fruit unless integrated pest management is adopted more widely. Overall, no change is expected in the application of fertilisers and pesticides per tonne of output of the sector.

Use of seed per unit of production is estimated to decline at the same rate as land requirements, i.e. by 29 per cent over 1985-2020. [3]

**Table 6.7 Other food crops: Base Scenario (S1) technological coefficients**

| Input | 1985 level (input/t) | Change in coefficient 1985-2020 (%) |
|---|---|---|
| Fertiliser & pesticide | | 0 |
| . urea (kg) | 15.122 | |
| . other fertilisers (kg) | 17.769 | |
| . pesticides (kg) | 0.095 | |
| Seed (other food crops) (kg) | 5.839 | -29 |
| Labour | | |
| . human labour (person-years) | 0.0804 | -29 |
| (person-days) | 24.112 | |
| . draft labour (cattle-days) | 3.638 | |
| Land (dryland) (ha) | 0.2227 | -29 |
| Soil erosion (t) | 6.088 | +10 |
| 1985 unit price (Rp) | 75,833 | |

Notes: Details on estimation procedures and data may be found in Foley (1993b), Annex 2.

*Labour requirements*

Overall, increasing yields will reduce labour requirements per unit output by the same amount (-29 per cent) over 1985-2020 because labour per hectare is expected to remain constant. For staple crops the decline in labour requirements per unit of output is likely to be minor (in line with the small increase in yields). However, for vegetables and fruit, increases in yield will result in substantially less labour being required per unit of output (-60 per cent and -38 per cent, respectively).

*Natural resource impacts*

Unirrigated and undulating or sloping land is the main natural resource input to production in this sector, except for the minor proportion of these crops grown on unirrigated ricefields in rotation with rice. Land requirements reflect yields which are expected to increase overall by 40 per cent by 2020. As a result the average land requirement per unit of production will decline by about 29 per cent by 2020 with more

3 Derived as follows: 29 = [1 - (1/1.4)] x100 where 1.4 reflects the assumed 40 per cent improvement in yields.

substantial declines for vegetables (-60 per cent) and fruit (-33 per cent) than for staples (-12 per cent).

The main environmental impact of crop production in this sector is soil erosion, resulting in loss of soil mass and reductions in soil fertility. Downstream effects include siltation of waterways, dams and harbours and increased probability of flooding during the wet season. Dryland staple crop production is undoubtedly responsible for both the high rate and great majority of soil and nutrient loss within this sector because of its scale (87 per cent of total area) and the fact that cultivation commonly takes place on land with slopes of over 7 per cent. Vegetables are usually cultivated on flat to slightly sloping land; fruit production is extensive with little disturbance of the soil after crop establishment.

Because of the extension of cultivation onto more marginal and sloping land, and more intensive cultivation of some staples and vegetables, it is expected that soil erosion will increase per unit of output unless there is a large-scale change to more conservation-orientated cultivation techniques.

Estimation of soil erosion per unit of production in 1985 was based on an assumption of an annual loss of between 44 tonnes (mildly sloping land) and 200 tonnes (steeply sloping land) per ha (Euroconsult 1989), and an average crop duration of 100 days. Using an average figure of 100 t/ha/annum results in per crop losses of 27 tonnes per crop/ha. With average yields in 1985 of 4.5 t/ha, soil losses were 6.088 tonnes per tonne of production.

Based on this general (but conservative) evaluation, and despite an increase in yields, an initial estimate of an increase in erosion of 10 per cent to 6.697 tonnes of soil per tonne of production is proposed. However, this estimate may be too low, given the extension of cultivation into ever more marginal and sloping lands.

### *6.4.2 Conservation Scenario (S2)*

The widespread adoption and practice of soil-conserving crop cultivation methods will probably be the most important and positive change in production technology for this sector, particularly for staple crop production on sloping lands. Without major efforts to reduce soil and nutrient losses, it will be difficult to sustain both yields and the extent of area under cultivation. For example, Repetto *et al.* (1989) suggest that if active soil conservation practices are not followed soil fertility losses may reach 7 per cent p.a. for crops cultivated on sloping land, i.e. that soil fertility is halved every 10 years, resulting in a major decline in yields.

The short-term and medium-term costs of implementing farm-level soil conserving cultivation practices need to be set against the long-term decline in land and labour productivity due to soil and nutrient losses. In addition, there are off-site erosion costs (e.g.

siltation of rivers, dams and harbours) that would be reduced by an effective soil conserving approach.

Soil conservation on hillsides relies on developing crop terraces to reduce runoff and increase water infiltration, ploughing and planting along contours, and ensuring that there is continuous vegetative cover. The traditional approach requires major earthworks to construct terraces. This approach is labour-intensive and often results in increased rates of erosion during and after terracing. An alternative approach is to plant deep-rooting grasses, shrubs or trees at appropriate intervals along the contour and use the build-up of soil behind them to gradually create a terrace; the species used can be selected with a view to providing additional income, stock fodder or fuel. This method is slower but it requires less labour and does not risk major soil losses during construction.

In addition to terracing, farmers will need greatly improved information on, and assistance in selecting, crop species and cultivation techniques that minimise soil losses. This requires a radically improved dryland research and extension system (World Bank 1992a). In addition, given the small farm size (especially on Java), active cooperation between farmers working on a hillside or within a minor catchment is essential; land consolidation may be necessary.

A combination of appropriate terracing, cultivation practices and crop selection can reduce soil losses to about one tonne per hectare per annum, increase water availability and improve yields (Euroconsult 1989). We estimate conservatively that this strategy would reduce soil erosion per tonne of output by 50 per cent of its level per hectare in 1985.

It is extremely difficult to establish the amounts of labour and other inputs required and the changes in yields that might result from an active conservation scenario, given the wide range of conditions under which dryland crops are grown in Indonesia. Assuming that approximately 15 per cent of the land area will need to be devoted to terraced vegetation, this will result in a short-term loss of production. Hence, in the short- to medium-term (1-5 years), land required per tonne of output will increase by about 15 per cent, and in the medium- to long-term term (5-10 years) increasing yields due to improved soil fertility and water retention will result in a decline in this land coefficient of 24 per cent. Medium-term improvements in soil fertility will also result in a reduction in the use of manufactured fertiliser required per unit of output by around 15 per cent.

Establishing terrace vegetation will require a major once-off investment of labour, with minor amounts required each season for maintenance and harvesting. Very roughly, it is estimated that labour requirements per tonne of production will increase by about 10 per cent in the short-term and decline by a similar (or possibly greater) amount in the medium-

and long-term due to increased yields. However, the level of skill required to practice soil-conserving farming successfully will increase requirements for skilled labour.

The technological coefficients for both scenarios are summarised in Table 6.8.

**Table 6.8 Other food crops: Changes in technological coefficients, 1985-2020**

| | Change between 1985 and 2020 (%) | |
|---|---|---|
| | S1 | S2 |
| *Intermediate inputs* | | |
| 2 Other food crops | -29 | -24 |
| 14 Fertiliser & pesticides | 0 | -15 |
| *Labour inputs* | | |
| Total employment per unit output | -28 | -14 |
| *Capital inputs* | | |
| Total new capital requirements | 0 | 0 |

*Natural resource impacts*

| | Unit | 1985 level | S1 | S2 |
|---|---|---|---|---|
| Land area | ha/t | .2227 | -29 | -24 |
| Soil erosion | tonnes/t | 6.088 | +10 | -50 |

Note: Intermediate inputs are expressed in terms of the NRMP-IEA 30-sector classification.

# CHAPTER 7

# ESTATE CROPS AND LIVESTOCK*

## 7.1 Estate Crops: Current Technology

This chapter describes current and future technologies in the Indonesian estate crops and livestock sectors (Sectors 3 and 4 in the NRMP-IEA 30-sector classification system). The first two sections deal with estate crops and the second two sections deal with the livestock sector.

Estate crops are perennial and are grown under rainfed conditions, generally on land that is not suitable for annual crops, except for sugar cane, a seasonal crop grown on irrigated land in Java and Sumatera. Overall, because yields on estates are generally two to three times those achieved by small holders, in 1985 total production was about evenly divided between smallholders and estates despite their significant differences in land area.

The estate crops sector covers 10 species of tree crops plus two groupings of 'other crops'. These are rubber, sugar cane, coconut, oil palm, tobacco, coffee, tea, cloves, pepper and nutmeg, other estate crops (cocoa, vanilla, kapok, cinnamon, cotton, cashew) and other minor tree crops. Rubber, coconut, palm oil, coffee, tea, pepper and nutmeg are important export crops.

Between 1985 and 1990 there was a rapid increase in the output of the sector, from 7.03 to 9.27 million tonnes (5.7 per cent p.a.). The area planted, which includes tree crops which are not yet productive, grew from 9.97 to 11.51 million ha (2.91 per cent p.a.), and average yield increased from 0.705 to 0.806 t/ha (2.70 per cent p.a.).

By volume, output was dominated by sugar cane (27 per cent), coconut (27 per cent), oil palm (18 per cent) and rubber (15 per cent) in 1985 (see Table 7.1). By area, coconut (31 per cent), rubber (28 per cent), coffee (9 per cent) and oil palm (6 per cent) were the most important crops. In 1990 the pattern was similar, with the notable difference that the share of oil palm in total sectoral production had risen to 26 per cent and its share of total area planted had increased to 10 per cent.

As part of the government's policy for increasing non-oil exports, rubber and palm oil in particular are recipients of various production, processing and export stimulation

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* This chapter is drawn from *NRMP-IEA Input-Output Working Papers* Numbers 8 and 9 (Foley 1993c and 1993d). The estate crops analysis has benefitted greatly from advice from Dr Chris Bennett.

programs. In the last few years the per tree (and hence per ha) productivity of these two tree crops has been greatly increased by the application of cloning techniques for the mass reproduction of superior planting stock, both for estates and small holders.

**Table 7.1 Estate crops: Area, yield and production, 1985**

| Crop (sector)[a] | Area $10^3$ ha | Yield t/ha | Output $10^3$ t |
|---|---|---|---|
| Rubber (7) | 2,776 | 0.380 | 1,055 |
| Sugar cane (8) | 526 | 3.603 | 1,895 |
| Coconut (9) | 3,050 | 0.630 | 1,920 |
| Palm oil (10) | 538 | 2.080 | 1,243 |
| Tobacco (11) | 288 | 0.571 | 165 |
| Coffee (12) | 920 | 0.337 | 310 |
| Tea (13) | 123 | 1.040 | 123 |
| Cloves (14) | 643 | 0.063 | 41 |
| Pepper and nutmeg (15) | 137 | 0.401 | 55 |
| Other estate crops (16) | 46 | 0.741 | 34 |
| Other tree crops (17) | 864 | 0.215 | 186 |
| Total | 9,969 | 0.705 | 7,031 |

Note: a. BPS 66-sector classification
*Sources:* BPS 1987 and Direktorat Jenderal Perkebunan 1992

The two modes of production, smallholders and estates, have differing technologies, mainly with respect to the quality of planting materials, rates of use of fertiliser and pesticides, and patterns of planting. These differences account for most of the differences in yields. Smallholders plant a relatively small number (10-20) or area (1-3 ha) of trees as cash crops, perhaps intercropped with other annual or perennial crops, and these trees are only a portion of total farm production, which may also include annual crops and livestock. The farm family provides all labour. The farmer often also has off-farm sources of income. Both physical and labour inputs to crop maintenance are generally lower than on estates.

On estates, tree crops are usually grown as monocultures, with relatively high levels of fertiliser and pesticide use. Land preparation, crop establishment and maintenance are undertaken by hired labour; in some of the more modern estates tractors and other mechanical equipment are used for under-tree grass and shrub cutting and for transporting the harvested crops.

The principal intermediate inputs to production in this sector, based on data from the 1985 input-output table, are listed in Table 7.2.

**Table 7.2 Estate crops: Principal intermediate inputs, 1985**

| Sector | | Coefficient (Rp/Rp) |
|---|---|---|
| 3 | Other food crops | 0.1050 |
| 14 | Fertiliser & pesticide | 0.0459 |

*Source:* BPS 1989

## 7.2 Estate Crops: Changes in Technological Coefficients to 2020

Only one scenario (S1) is described for the year 2020. Because of the long period to maturation (4-7 years) and long productive life (20-35 years) of estate crops, changes in this sector are much slower than in other sectors of agriculture. The consensus of opinion (including World Bank 1992a and Winrock International 1992) is that changes in the sector will be gradual, with increases in yields accounting for a large proportion of production increases although land planted will also rise.

To develop the scenario our own estimates of rates of change in area and yield were compared with the econometric estimates of both the World Bank (1992) and Winrock International (1992). In general, rates of change used here lie between those estimated by the two sources above, the World Bank generally being more conservative in projections of production growth than Winrock International. The scenarios are described below; full details can be found in Foley (1993c, Annex 2).

*Base Scenario (S1)*

In 1985, tree crops occupied nearly 10 million ha, of which estates accounted for some 1.5 million ha. By 2020, the scale of the tree crops sector is expected to expand by nearly 50 per cent and the share of estates in area planted is expected to rise from 10 to 22 per cent.

Between 1985 and 2020 average yields in the sector are estimated to increase from 0.705 t/ha to 1.256 t/ha; the land requirement per tonne of production will fall by 44 per cent to 0.796 ha/t. Compared to smallholders, the decline in land requirements per unit output for estates is slower due to the more rapid increase in average yields for smallholders. Thus while the smallholders' share of total area planted will decline, yields for smallholders will rise more than those of estates. Overall the balance of production between estates and

smallholders is expected to remain constant at about 50-50 over 1985-2020, except for oil palm where the smallholder share of area and output grows.

Much of the increase in average yields will be due to the increased proportion of total area planted to oil palm. Oil palm is expected to account for 33 per cent of sectoral output in 2020 (up from 18 per cent in 1995). The yield increases for major tree crops -- rubber (1.97 per cent p.a.), coconut (1.59 per cent p.a.) and oil palm (1.18 per cent p.a.) -- will come from widespread replacement of existing trees and planting of new areas with superior monoclonal planting materials (rubber) or hybrids (oil palm and coconut) and increased use of fertilisers by smallholders in particular.

There are only limited opportunities for smallholder production to be mechanised given both the layout of smallholdings and the cost of capital equipment in relation to an individual family's earnings. On estates, where monocultures are dominant, mechanisation of land preparation and under-tree clearance may become more common, but only for crops planted in an open-lattice pattern, such as oil palm, rubber and coconut. It is unlikely that mechanical harvesting, even of estate crops, will significantly reduce demand for human labour.

The estimated technological changes for the sector to 2020 are summarised in Table 7.3. Table 7.3 is a useful intermediate step in developing the final data sheet for the sector because it presents physical coefficient data for 1985.

*Intermediate inputs*

Apart from inputs from the sector itself, fertiliser dominates the intermediate inputs used by this sector. In 1985 the rate of fertiliser use per hectare on estates was approximately twice that of smallholders, and the rate of pesticide use was about 10 times that of smallholders.

It is estimated that by 2020 smallholders will double the amount of fertiliser used per hectare, due to both higher rates of use and an extended period of application. This will increase their use to 40 kg/ha/annum, and result in an increase in use per tonne of production by 7 per cent. Because use of fertilisers on estates is already at levels sufficient to achieve maximum economic yields, use per hectare is not expected to increase. However, an increase in yields due to improved planting materials and cultivation techniques leads to a decline in fertiliser use of 30 per cent per tonne of production.

For the sector as a whole, fertiliser use in 2020 is expected to decline by about 12 per cent (from 49.6 to 43.6 kg per tonne of output).

**Table 7.3 Estate crops: Base Scenario (S1) technological coefficients**

| Input | 1985 level (input/t) | Change in coefficient 1985-2020 (%) |
|---|---|---|
| Fertiliser & pesticide | | -15 |
| . fertiliser (kg) | 4.96 | -12 |
| . pesticides (kg) | 1.7 | -46 |
| Labour (person-years) | 0.047 | -41 |
| (person-days) | 14.093 | -41 |
| Land (ha) | 1.418 | -46 |
| Soil erosion (t) | 6.1 | -39 |
| 1985 unit price (Rp) | 533,426 | |

Source: Foley 1993c

No major change in rates of pesticide use per hectare is expected for smallholders or estates. Thus use per unit output will decline at the same rate as land requirements per tonne of output, i.e. a fall of 46 per cent over 1985-2020. Overall, the use of fertiliser and pesticides is expected to fall by around 15 per cent per tonne of output.

*Labour inputs*

Labour inputs per unit of production are expected to decline less than the decline in land requirements due to increased labour for harvesting larger yields, especially for rubber, coconut and oil palm. In 1985, on average, harvesting absorbed approximately 10 per cent of total labour inputs (i.e. about 0.76 days/ha). Yields almost twice as high in 2020 are likely to result in a doubling of harvest labour requirements (i.e. to 1.52 days/ha), 18.3 per cent of a total average labour requirement of 8.32 person-days/ha. However, the increase in yields results in overall labour inputs falling by 41 per cent per tonne of output.

*Natural resource impacts*

Average sectoral requirement for land per tonne of production in 1985 was 1.418 ha per tonne, the reciprocal of yield (Table 7.1). For estates, with an average sectoral yield of 2.33 t/ha, the land requirement was 0.429 ha per tonne, while for smallholders, with an average yield of 0.419 t/ha, the land requirement in 1985 was 2.387 ha per tonne of production. By 2020 increased yields are estimated to have reduced average land requirements by 46 per cent, to 0.769 ha/tonne of output.

Based on RePPProt (1990) estimates, a realistic maximum of the additional land available for tree crops is 5.35 million ha plus some proportion of an addition 1.71 million ha for mixed tree and annual crops. The great majority of this land is in Kalimantan with a smaller proportion in Irian Jaya. By 2020 there will be little if any suitable land available for further expansion, and increases in production will depend almost entirely on improvements in yields.

All tree crops in Indonesia are grown under rainfed conditions, and it is not possible or useful to partition tree crop water demand between that supplied by rainfall and groundwater or, given the open-spacing of tree crops, between water used by the trees and that used by other vegetation. In general these crops require an annual rainfall of 2,000 to 1,200 mm (Euroconsult 1989).

Soil erosion is potentially a serious environmental problem associated with estates. Large-scale plantations are usually established on flat to undulating land, while smallholder crops are to be found on land ranging from flat to fairly steep. For the purposes of this study, it is optimistically assumed that tree crops are grown on land with slopes of an average 7 per cent, for which soil erosion is estimated as 4.3 tonnes/ha/annum (Euroconsult 1989). Given an average crop production of 0.705 tonnes/ha in 1985, this is equivalent to an average of 6.1 tonnes of soil erosion per tonne of output.

Establishment of new estates and expanding smallholder production will result in the destruction of existing forests and is estimated to involve expansion onto some 5.8 million ha of less suitable, more steeply sloping land. This will lead to short-term increases in soil erosion to a level equivalent to soil losses on bare soil on a 7 per cent slope for one year (39 t/ha/annum). Over an average 25-year productive life, this is equivalent to an additional 1.56 t/ha/annum of soil erosion on the area brought into production. Assuming yields increase to an average of 1.256 t/ha, this is equivalent to 3.7 tonnes of soil loss per tonne of production, a decline of 39 per cent.

Changes in technological coefficients for estate crops are presented in Table 7.4.

**Table 7.4 Estate crops: Changes in technological coefficients, 1985-2020**

| | | | Change between 1985 and 2020 (%) |
|---|---|---|---|
| *Intermediate inputs* | | | |
| 14 Fertiliser & pesticides | | | -15 |
| *Labour inputs* | | | |
| Total employment per unit output | | | -41 |
| *Capital inputs* | | | |
| Total new capital requirements | | | 0 |
| *Natural resource impacts* | | | |
| | Unit | 1985 level | |
| Land area | ha/t | 1.418 | -46 |
| Soil erosion | t/t | 6.1 | -39 |

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

## 7.3 Livestock: Current Technology

The next two sections cover the production of livestock and poultry products, including milk and eggs (Sector 4 in the NRMP-IEA 30-sector classification). The processing of livestock and livestock products are excluded from consideration.

Traditionally (pre-1970) the land, labour and manufactured goods required by this sector were relatively insignificant because of the simple methods of livestock production and the small amounts of livestock products consumed. In addition, the majority of production was for own-consumption, and commercial production for urban markets represented a minor part of total production.

Under traditional conditions animal products were by-products of a range of other farm activities, making use of otherwise unused resources from local food production and the local environment. In addition, livestock manure, especially from cattle, was, and remains, essential for maintaining soil fertility for dryland agriculture. Cattle and duck manure

contributed to ricefield fertility, and pig and chicken manure helped maintain house-garden soil fertility.

Cattle and buffalo were grazed on such local land as was available and farmers hand-cut grass for stall-feeding at night. Exhausted draft animals were slaughtered for meat. Dairy cattle were almost non-existent, and cow's milk was not a normal part of the diet. Pork production, in areas where eating pork was acceptable, was a household affair using local feedstuffs (banana trunks, rice bran and leafy greens). Poultry production (chickens and ducks) was extensive, with a diet from scavenging supplemented with rice bran, maize and cassava. Goat production was extensive, commonly with tethered grazing.

Until the late-1970s production of meat and livestock products was generally a non-specialised farming activity operating in parallel with the production of other food crops. The early 1980s saw the appearance of small-scale battery production using low technology (bamboo cages) for production of poultry (eggs and broilers), importation of dairy cattle (mainly from Australia) and the beginnings of specialised beef production (fattening in feedlots). Since the late 1980s, low-technology chicken egg and meat production has declined in importance due to competition from intensive production methods. The rapid expansion of commercial production during the 1980s has employed up-to-date methods imported from industrial countries, resulting in a parallel rise of large-scale stockfeed importation, milling and formulation enterprises.

A 'dual economy' operates within this sector -- the traditional sector, with extensive production largely for own-consumption, and the rapidly expanding modern, intensive sector which is highly capital-intensive and wholly commercial in orientation. These two modes of production have almost no interaction at the level of production technology, except for the use of some processed stockfeed by small-scale farmers. There is also little complementarity in the market place, with traditional producers supplying their own needs and those of adjacent rural communities, and modern intensive producers focused on supplying the household, restaurant and fast-food markets in towns and cities. Traditional production methods are changing very slowly while intensive producers are keen to use the most advanced methods available. It is also clear that traditional production methods are not going to disappear as they make good use of otherwise unused local resources, help maintain soil fertility and provide a source of income and a savings bank 'on the hoof' that can be tapped in times of financial need. Thus, changes in average technological coefficients for the sector conceal a widening gulf between traditional and modern livestock production techniques.

According to government data, total meat production was 808 thousand tonnes in 1985 and had risen to 1,027 thousand tonnes by 1990. During the 1985-1990 period, production of

non-poultry meat (beef, buffalo, goat, sheep, pork and horse) increased at only 1.13 per cent p.a., and its share in estimated total meat consumption, which declined from 61 per cent to 50 per cent, is projected to decline further in coming years. However, there has been a slow increase in the proportion of beef produced (fattened) in feedlots, mainly to meet the demand for higher quality meat by the wealthier segment of the population.

The most significant change in the last 20 years has been the rapid growth of intensive (battery) poultry production, both for eggs and meat. Intensive production of chicken eggs and meat began in the early 1980s, and over 1985-90 grew at an annual rate averaging 19 per cent. By 1990 it accounted for over half total poultry meat production (311,000 of 509,000 tonnes). From about the same time, production of hen's eggs (increasingly from modern battery production) and cow's milk have increased rapidly, growing at 5.5 per cent and 12.0 per cent p.a. respectively between 1985 and 1990. Hen's eggs and milk alone accounted for almost half the volume of animal products in 1990 (see Table 7.5).

**Table 7.5 Livestock: Production of meat, milk and eggs, 1985 and 1990 (thousand tonnes)**

| Product | Output 1985 ($10^3$ t) | Share of total (%) | Output 1990 ($10^3$ t) | Share of total (%) | Annual growth rate (%) |
|---|---|---|---|---|---|
| Beef | 227.4 | 16.6 | 259.2 | 14.0 | 2.65 |
| Buffalo | 48.6 | 3.5 | 44.3 | 2.4 | -1.84 |
| Goat | 49.5 | 3.6 | 58.3 | 3.1 | 3.33 |
| Sheep | 29.8 | 2.2 | 31.7 | 1.7 | 1.24 |
| Pork | 133.2 | 9.7 | 123.3 | 6.6 | -1.53 |
| Horse | 1.7 | 0.1 | 1.7 | 0.1 | 0.00 |
| Village chicken | 178.0 | 13.0 | 176.6 | 9.5 | -0.15 |
| Intensive layer | 15.8 | 1.2 | 36.3 | 2.0 | 18.08 |
| Intensive broiler | 114.5 | 8.4 | 274.3 | 14.8 | 19.09 |
| Ducks | 9.9 | 0.7 | 21.5 | 1.2 | 16.73 |
| Milk | 191.9 | 14.0 | 345.6 | 18.6 | 12.49 |
| Eggs | 369.9 | 27.0 | 484.0 | 26.1 | 5.52 |
| Total meat | 808.4 | 59.0 | 1,027.2 | 55.3 | 4.91 |
| Total animal products | 1,370.2 | 100.0 | 1,856.8 | 100.0 | 6.27 |

Note: Total animal products is the sum of meat, milk and eggs.
*Source*: Direktorat Jenderal Peternakan 1992

As a consequence of the rapid increase in intensive poultry (meat and eggs) and milk production, per capita consumption of animal products (meat, milk and eggs) increased at

an average rate of 4.34 per cent p.a. over 1985-90, growing from 8.3 kg to 10.3 kg per capita/annum (Direktorat Jenderal Perternakan 1992).

As incomes increase there will be a rapidly rising demand for animal products in the years to 2010, with an increasing proportion supplied from intensive poultry and dairy production. Industry experts (including the World Bank) anticipate only a relatively slow growth in total demand for beef, of which intensive feedlot beef will make up a small but increasing proportion. Milk and eggs are expected to make up a steadily increasing proportion of the output of this rapidly growing sector.

The change to intensive production methods has resulted in the rapid expansion of a specialised poultry sub-sector within the livestock sector with large production and processing facilities located close to major urban centres. In addition, the demand for stockfeed has stimulated the production of maize and soybeans and required importation of additional soymeal and other stockfeeds.

*Intermediate inputs*

In 1985 intermediate inputs from only four sectors (livestock products, other food products, poultry and products, and retail and wholesale trade) accounted for 83 per cent of total intermediate inputs (Table 7.6). However, despite the concentration of intermediate inputs from a few sectors, the livestock sector is unlike the other three agricultural sectors in that it requires inputs from many other sectors of the economy. In this respect, it has more in common with some industrial sectors than with food and tree crop agriculture, and this similarity (intensive production in 'animal factories') is expected to increase in the future.

**Table 7.6 Livestock: Principal intermediate inputs, 1985**

| Sector | name | Coefficient (Rp/Rp) |
|---|---|---|
| 4 | Livestock products | 0.2922 |
| 11 | Food, beverages & tobacco | 0.0782 |
| 24 | Wholesale & retail trade | 0.0558 |

*Source:* BPS 1989

The proportion of intermediate inputs coming from within the sector (some 46 per cent) is high because the BPS classification combines both livestock production and slaughtering. Of the 46 per cent two-thirds are accounted for by slaughtering alone. The inputs from Sector 11 (Food, beverages & tobacco) are in fact animal stockfeed. Similarly, for the poultry sub-sector some 57 per cent of its inputs are stockfeed.

*Labour requirements*

Available data on labour use in intensive livestock production are fragmentary. Because of the extensive nature of semi-traditional livestock production, it is not practicable to estimate the amount of labour required to produce one tonne of meat or eggs, the main traditional products. In any case, the use of cattle for draft labour makes it impossible to partition labour required for animal care and feeding into portions producing draft labour, meat and milk.

Although the 1985 labour input coefficient, as for all sectors, is taken from the input-output tables (BPS 1989), projections of changes in labour requirements require us to establish base year labour and physical output data for the sector from consistent data sets, because this is the best method of projecting changes in labour coefficients. These projected changes will then be applied to the 1985 coefficient derived from BPS.

According to BPS (1989) in 1985 some 1.51 million people produced a total of 1.37 million tonnes of animal products (meat, milk and eggs). This includes production from both semi-traditional and intensive production methods. On this basis, labour required per tonne of production was 1.1 person-years, for the sector as a whole. Estimates by Alirahman *et al.* (1992) of livestock production in 1991 suggest that total production (meat, milk and eggs) of 1.71 million tonnes was achieved by an input of 1.42 million person-years of labour, resulting in an estimate of 0.829 person-years per tonne of production.

Data from a study of relatively small-scale, intensive chicken egg production (Simatupang *et al.* 1992) suggest that 42.019 tonnes of eggs and 4.998 tonnes of chicken meat from *over-age* laying hens (total 47.017 tonnes) required 475 days of human labour. This is equivalent to 0.038 person-years per tonne of eggs (for a 300-day year). To simplify calculations in this instance, the meat is regarded as a 'labour-free' by-product of egg production. Data from PT Cipendawa, a major meat and day-old chick producer, suggests a figure of 0.028 person-years per tonne of output of eggs.

In view of these data and the unreliable nature of the aggregate employment estimates, this case study estimates labour requirements at 0.03 person-years per tonne of intensively produced chicken meat and 0.04 person-years per tonne of chicken eggs in 1985. On this

basis, nation-wide intensive chicken meat production of 130,000 tonnes required a labour force including supervisory and administrative staff of 3,900 persons; and intensive chicken egg production, estimated at 227,000 tonnes, required a labour force of 9,080 persons.

Intensive production of other livestock products (milk and intensive pork) is known to be more labour-demanding than intensive production of chicken meat and eggs. Milk production requires labour on a daily basis for both herding and milking. Labour needed for supplementary feeding is minimal as it occurs during milking. Intensive pork production requires labour for feed preparation and distribution and substantial amounts of labour for cleaning stalls and tending piglets. For lack of other data, we assume that milk and intensive pork require twice as much labour per unit of production as intensive chicken egg production, i.e. 0.08 person-years per tonne. On this basis, milk production in 1985 (192,000 tonnes, half of which is assumed to be intensive) required a labour force of about 7,680 persons and pork production (133,000 tonnes, half of which is assumed to be intensive) required an estimated labour force of 5,320 persons.

To provide a basis for projecting 2020 labour requirements per unit of output we assume the 'average' farmer counted in this sector spent 25 per cent of his or her work time looking after livestock. This assumption is based on the fact that non-intensive, semi-traditional livestock production is for most farmers a part-time activity used to generate supplementary income. Combining this estimate and employment data from the BPS input-output table (BPS, 1989, Volume II, Table 8) for labour employed in the traditional livestock sector (i.e. the full-time labour of 25 per cent of 1.51 million persons) with production of 0.805 million tonnes gives an average figure of 0.47 person-years per tonne of production. This is still more than ten times the per unit labour requirements for intensive chicken production where capital (in the form of buildings) and stockfeed are substituted for labour. If total full-time employment in the sector in 1985 was 0.37[illegible] million and total production 1.370 million tonnes, this gives an average figure of 3.64 tonnes of output per person-year, or 0.28 person-years per tonne for the sector as a whole.

In summary, in 1985 intensive production of livestock products provided relatively little additional employment in the sector -- possibly 26,000 person-years of work. A comparison with estimated total full-time labour in the sector (377,000 persons) indicates that the continuing shift to intensive livestock production shows little promise of providing substantial employment opportunities despite rapidly rising output.

*Stockfeed requirements*

Since no data on traditional requirements for stockfeed are available, and because the technology of production in the unmodernised sector is expected to remain largely

unchanged, attention is focused on estimating stockfeed requirements for modernised, intensive production.

Based on World Bank (1992a) calculations of the composition of rations for livestock and estimates of livestock production, one tonne of livestock products required 3.802 tonnes of mixed stockfeed. For intensive poultry meat production the ratio was similar at 3.953 tonnes of feed per tonne of production. For intensive egg production the World Bank estimates that 3.817 tonnes of mixed feed are required per tonne of eggs.

Standard parameters for modern, intensive production give an average feed-to-growth conversion factor of 2.25:1 under tropical conditions (Euroconsult 1989). The average live weight of mature female chickens ready for slaughter is 1.7 kg, with a *dressing-out* proportion of 80 per cent (the proportion of live weight to carcass weight). This implies that one kg of prepared meat requires 2.813 kg of mixed feed. Thus, one tonne of feed is sufficient to produce 0.356 tonnes of chicken meat. To allow for lower production efficiencies in less advanced or less well-managed facilities, a figure of 3.5 kg of feed per kg of meat produced is used in calculations, i.e. one tonne of feed is sufficient to produce 0.286 tonnes of edible meat.

For egg production a figure of 3.5 kg of feed per kg of eggs is assumed. Thus, one tonne of eggs requires 3.5 tonnes of mixed feed, or one tonne of mixed feed is sufficient to produce 0.286 tonnes of eggs.

Milk production is less demanding of intensive, processed inputs from other sectors than intensive chicken production as it relies largely on cattle foraging for themselves, supplemented by processed stockfeed rations.

Efficiency of conversion of feed to milk in dairy cattle is not expected to change substantially as it is limited by biological factors. Based on World Bank (1992) estimates, and assuming one half of the dairy herd received supplementary stockfeed in 1985, one tonne of total milk required approximately 0.271 tonnes of supplementary stockfeed.

*Water requirements*

In addition to high protein feed, chickens under intensive management also require an adequate supply of clean water to achieve rapid rates of growth and high levels of egg production. In these conditions, water requirements are estimated at an average of 0.25 litres/day (Euroconsult 1989). It is estimated that one tonne of water is sufficient to produce 0.15 tonnes of chicken meat. In intensive egg production, it is estimated that one tonne of water is sufficient to produce 0.16 tonnes of chicken eggs (for detailed calculations see Foley 1993d).

*Waste generation*

According to standard parameters (Euroconsult 1989), some 20 per cent of feed supplied to chickens is excreted as waste. For this case study, a figure of 0.4 tonnes of waste per tonne of production for both chicken meat and eggs is used. Industry sources claim that there is a ready market for chicken manure for use in intensive vegetable production and that its disposal is not a problem. Nor does it have adverse environmental impacts if used as fertiliser.

## 7.4 Livestock: Changes in Technological Coefficients to 2020

One scenario (S1) is developed for the livestock sector based mainly on the growing portion of output provided by intensive methods. The technology of non-intensive (i.e. semi-traditional) production of livestock products is not expected to change over 1985-2020. Furthermore, the conversion of stockfeed into meat, milk and eggs is limited by biological factors, and is not amenable to significant changes. Estimates, based on World Bank (1992) projections of demand for livestock products, indicate that there will be little change in the amount of stockfeed required to produce one tonne of meat, milk and eggs over 1985-2020 although the mix of products will change. Further technological changes in intensive livestock production, in terms of stockfeed requirements, largely depend on unknowable changes resulting from future application of bio-technology to improving the metabolic conversion efficiencies of livestock.

The most obvious change in livestock production technology is the increasing importance of intensive production, particularly for chicken meat and eggs. The impact of these changes on the range of inputs required is as follows: processed high-energy and high-protein feeds will replace fodder from grazing or cut-and-carry methods; additional, clean (possibly filtered) water will be required for maximising growth rates and for cleaning production facilities; additional energy will be required for lighting and cooling production facilities; additional, more sophisticated materials will be required for constructing production facilities; and additional, more highly trained labour will be required to operate intensive, increasingly automated production facilities.

The World Bank (1992a) projections for 1988-2010 envisage a very rapid increase in output of livestock products. Of particular importance in making estimates of increased demand for stockfeed is the radical increase in intensive production of chicken meat because of its dependence on maize and soymeal for feed and the land area needed to grow these crops. World Bank (1992a) estimates show feed demand increasing at a constant annual rate of about 10.4 per cent over 1988-2010. Based on recent interviews with industry sources,

however, this appears to be an overestimate. More realistic estimates are 9.5 per cent p.a. over 1991 2000 and 9.0 per cent p.a. over 2001-2020. More generally, we have reduced rates of growth in demand for all other types of meat for the 2011-2020 period by 0.5-1.0 per cent p.a. compared to the World Bank's 1988-2010 estimates to make allowance for slowing population growth and possible production limitations due to lack of land for extensive pasture and growing stockfeed. (Refer to Foley 1993d, Annex 3, for details).

If livestock production using traditional methods grows relatively slowly in the years 1985 to 2020, the great bulk of livestock products (meat, milk and eggs) in 2020 will come from intensive production. In 2020, total production from semi-traditional methods is estimated at about 16 per cent of total production, the remainder coming from intensive and semi-intensive production. Thus the share of intensive production in total output is expected to rise from 41 per cent in 1985 to around 84 per cent in 2020.

*Stockfeed requirements*

It is estimated that in 1985 0.565 million tonnes or 41 per cent of total livestock products were produced under intensive conditions. Total stockfeed consumption in 1985 is estimated as 2.515 million tonnes, which if averaged over total livestock production (1.370 million tonnes), gives an estimate of 1.835 tonnes of stockfeed for each tonne of output. Thus, overall, one tonne of stockfeed was required to produce 0.545 tonnes of livestock products.

Livestock production in 2020 under intensive conditions is estimated to account for 84 per cent of total production. For 2020 we estimate a requirement of 3.159 tonnes of stockfeed for every tonne of output such that one tonne of stockfeed will be required to produce 0.317 tonnes of livestock products.

These estimates suggest that the shift to a greater dependence on intensive production will result in a significant increase in stockfeed requirements per tonne of production. Over 1985-2020 it is estimated there will be an increase of about 72 per cent per tonne of production over the study period.

*Labour requirements*

The difficulty in estimating labour requirements for semi-traditional livestock production has already been raised, and an estimate of 0.42 person-years per tonne was made. This is assumed to remain constant over 1985-2020. Widespread automation of intensive chicken meat and egg production is highly probable by 2020, and would result in an approximate halving of 1985 labour requirements per unit of output (PT Cipendawa personal

communication). This implies that production of one tonne of chicken meat will require only 0.015 person-years and one tonne of eggs 0.02 person-years.

In 1985, a labour force of some 26,000 produced an estimated 0.520 million tonnes of livestock products in intensive production (about 38 per cent of total production), equivalent to 19.994 tonnes per person-year, or 0.05 person-years per tonne. We estimate that by 2020 this will grow to 43.443 tonnes per person-year or 0.023 person-years per tonne.

With semi-traditional labour requirements remaining at 0.47 person-years per tonne, the labour requirements for the sector as a whole are estimated to be 0.093 person-years per tonne in 2020 (10.79 tonnes of output per person-year) compared to 0.28 for 1985. This is equivalent to a reduction of 66 per cent in labour per tonne of production. As should be clear however, the increase in labour productivity will be wholly concentrated in intensive livestock production, especially poultry.

*Water requirements*

The massive increases estimated for intensive chicken meat and egg production suggest that there will be substantial increase in total demand for water. Although requirements per tonne of intensive production are unlikely to change significantly, the increased share of intensive production in total output will increase the average amount of water required per tonne of output by around 105 per cent. In the normal course of events this is not an especially large water requirement. However, in this case it represents an additional demand on clean water resources close to major urban areas where fierce competition for available resources is already apparent.

*Land use implications*

The recent trend towards intensive livestock production will require significant increases in the amount and proportion of staple crop production (primarily maize and soybean) used as stockfeed. These land requirements will be reflected in the calculated land requirements of Sector 2 (other food crops).

Changes in technological coefficients for the livestock sector are summarised in Table 7.7.

## Table 7.7 Livestock: Changes in technological coefficients, 1985-2020

| | | Change between 1985 and 2020 (%) |
|---|---|---|
| *Intermediate inputs* | | |
| 4 | Livestock and products | 0 |
| 11 | Food, beverages & tobacco | +72 |
| 18 | Petroleum refining | +30 |
| 20 | Electricity | +30 |
| *Labour inputs* | | |
| Total employment per unit output | | -66 |
| *Capital inputs* | | |
| Total new capital requirements | | +105 |

| *Natural resource impacts* | Unit | 1985 level | |
|---|---|---|---|
| Water input | m3/tonne | 2.575 | +105 |

Note: Intermediate inputs are expressed in terms of the NRMP-IEA 30-sector classification.

# CHAPTER 8

# FOREST PRODUCTS AND PULP AND PAPER*

## 8.1 Forest Products: Introduction

This chapter describes current and future technologies in the Indonesian logging industry (forest products) and in the pulp and paper industry (Sectors 5 and 13 in the NRMP-IEA 30-sector classification system). It has not been possible in this study to develop technological scenarios for the sawmilling and plywood industries.

In the case of the forest products industry, by 'technologies' we mean the ways in which intermediate inputs, capital equipment, labour of various skill types and knowledge are combined to produce and extract logs. The technologies described here also include some of the impacts on the natural environment of different logging methods.

The forest products sector (Sector 5) covers the process of extracting logs from forests and delivering them to the 'mill door'. In addition to the current method of extracting logs from natural forests, two log production and extraction methods are defined:

- a more sustainable system of logging in natural forests; and
- the establishment of plantations on degraded land using mechanical techniques.

These logging practices are quantified in terms of both their economic inputs -- intermediate, capital and labour inputs -- and their impacts on the natural environment. Changes to the current logging practices are used as a basis for defining two technological scenarios for the logging industry:

S1 a shift to more sustainable logging in natural forests and reliance on plantation timber for 40 per cent of log supply; and

S2 a shift to more sustainable logging in natural forests and reliance on plantation timber for 68 per cent of log supply.

Logs drawn from natural forests and from plantations are aggregated into a single sector. It would have been more satisfactory to divide the forest products sector into

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* This chapter draws on *NRMP-IEA Input-Output Working Papers* Numbers 5 and 10 (Hamilton, 1993a and Hamilton and Iskandar, 1993a)

two, especially given the very different technologies used in each. However, the technology we describe for the single sector represents an average for the two methods of log production.

## 8.2 Forest Products: Forest Types and Technologies

In Indonesia there are several different forest types. The principal forest types that are now or will be the main sources of logs are as follows:

*Natural forests*
mixed hill forests
peat swamp forests

*Plantations*
tropical hardwoods and softwoods
estate crops (coconut wood, rubber wood, oil palm wood).

Each of these has its own logging technology; within a forest type there may also be several different logging technologies. Peat swamp logging, for example, often involves the construction of small-gauge railways in the swamps for log extraction. For the purposes of this study, however, only three technologies will be defined, two for natural mixed hill forests (current practices and a more sustainable system) and one for timber plantations.

Natural mixed hill forests and plantations now provide and will continue to provide the great bulk of commercial timber in Indonesia but the proportion of timber supply from plantations is expected to increase sharply over the next decades as output from natural forests declines and plantations come on stream. This shift towards plantations is the key to the definition of our scenarios because the scenarios will be defined as different mixes of natural forest and plantation logging. In addition, when we come to analyse the results of the model we will calculate the land area required by the forest products sector using the proportions of logs from natural forests and plantations specified below.

The FAO and the Ministry of Forestry (FAO-MoFr 1990a) have made log output projections based on an optimistic scenario specifying investments in plantations and improved log recovery from natural forests. Their estimates appear in Table 8.1. Between 1990 and 2020 the proportion of logs supplied by plantations is expected to rise

from 28 per cent to 68 per cent. The projected decline in total log volume from natural forests reflects high rates of deforestation and forest degradation as well as declining yields as the more productive forests are logged out.

**Table 8.1 Potential industrial wood supply by source, 1990-2020 (million cubic metres)**

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|
| Natural forests[a] | 33.02 | 29.80 | 24.98 | 24.59 | 24.43 | 23.99 | 23.19 |
| Plantations[b] | 13.16 | 17.60 | 23.17 | 31.96 | 33.56 | 44.18 | 48.39 |
| Proportion from plantations | 0.28 | 0.37 | 0.48 | 0.57 | 0.58 | 0.65 | 0.68 |

a. Includes conversion forests.
b. Includes estate crops.
*Source*: FAO-MoFr 1990a, Table 9.13, p230

In defining both Scenario S1 and Scenario S2, projected changes in the technology for producing logs will take two forms:

- a shift to more sustainable methods of harvesting natural forests involving more environmentally sensitive road construction and felling practices; and
- a shift in the composition of total log supply away from logs extracted from natural forests and towards logs grown in plantations (using mechanised techniques).

It is first necessary to describe the current production technology for logs derived from natural forests and logs from plantations. These are very different. In the former case, where the trees are already standing, the principal input costs are those of labour and machinery for road building, harvesting and haulage. In the case of plantations, the principal costs are for the establishment of plantations, including machinery and labour for land preparation, planting and weeding as well as labour for harvesting and haulage. There is a crucial difference relating to the timing of inputs and outputs. In the case of natural forest logging, investments in equipment begin to be repaid more or less immediately because the trees are already standing. In the case of plantations, there are large initial investments followed by a delay of between 9 and 50 years.

In the following sections we first describe the current system of natural forest logging and its environmental impacts. Next we describe a technology for establishing and harvesting plantations. We then describe a more sustainable system of natural forest logging which we will assume applies in the future. Lastly, we combine the future systems of natural forest and plantation logging to define the scenarios themselves.

## 8.3 Forest Products: Natural Forest Logging Technology

There are five main stages to logging: taking an inventory, laying out of roads, road building, tree felling and log transport. The values of some important parameters used in this analysis are reported in Table 8.2 and the values of inputs into the forest products sector according to the 1985 input-output tables appear in Table 8.3.

**Table 8.2 Forest products: Values of some important parameters, 1985**

| Parameter | Unit | Value |
|---|---|---|
| Output of logs | $10^6$ $m^3$ | 24.082 |
| Value of log output | Rp $10^6$ | 1,482,206 |
| Unit log price | Rp/$m^3$ | 61,548 |
| Average yield of production forest | $m^3$/ha | 21.2 |

*Sources:* Log output and yield are from FAO-MoFr (1990a Table 5.1, p128 and Table 3.10, p74); value of output is from BPS (1989); unit price is derived from value and volume of output; average yield is from FAO-MoFr 1990a, Table 3.10, p74.

It is worth noting the very large share of total intermediate inputs accounted for by 'operating surplus' in the BPS input-output tables. This share is not explained by imputed wages and probably reflects the very high rents being accumulated by concession holders.

Table 8.3 illustrates that the principal intermediate inputs are from the petroleum sector, machinery (repairs and maintenance) and other services.

**Table 8.3 Forest products: Principal intermediate inputs, 1985**

| Sector | | Coefficient (Rp/Rp) |
|---|---|---|
| 17 | Other manufacturing | .0274 |
| 18 | Petroleum refining | .0238 |
| 29 | Other services | .0225 |

*Source*: BPS (1989)

Scattered information is available on equipment and other costs in a number of logging concessions. These data are summarised in Table 8.4.

**Table 8.4 Forest products: Input coefficients in logging activities, 1992**

| Type of input | | Value |
|---|---|---|
| *Intermediate inputs* | | *Rp $10^6/10^3$ $m^3$ of logs* |
| 17 | Other manufacturing | 13.00 |
| 18 | Petroleum refining | 12.67 |
| *Capital stocks* | | |
| 17 | Other manufacturing | 18.00 |
| *Employees* | | *person-years/$10^3$ $m^3$ of logs* |
| Supervisors | | 0.36 |
| Drivers | | 0.34 |
| Labourers | | 2.28 |
| Total employees | | 2.98 |

*Source*: NRMP survey of concessions in West Kalimantan. Note that the volumes of logs may have been understated in which case the per unit costs reported here would be too high.

The data of Table 8.4 will be used to develop estimates of unit labour inputs and capital stocks for natural forest logging and to help estimate changes in other coefficients to reflect the new technology.

In principle, the dynamic input output model requires estimates of the amount of capital required to expand capacity by one unit using the newest technology. Information on required capital in the logging industry using the More Sustainable System is not readily available but it is possible to obtain a rough approximation by estimating the value of capital stock currently used in the natural forest logging industry. Extrapolation from a survey of concessions in West Kalimantan by NRMP in 1992 suggests a value of capital stocks in the industry as a whole (including tractors, skidders, trucks, chainsaws and furniture) of around Rp 434 billion (Hamilton 1993a). This represents a capital stock of around Rp 18,000 per cubic metre of natural forest logs. Each cubic metre of logs is valued at Rp 61,548.

## 8.4 Forest Products: Environmental Impacts of Natural Forest Logging

The current system of natural forest logging has various negative environmental impacts including:

- deforestation;
- erosion and siltation;
- changes in water flow rates and water quality;
- pollution of forest lands from fuel oils, chemicals and human garbage; and
- impacts on wildlife including habitat fragmentation, depletion of food sources and loss of biodiversity.

It is possible to make reasonable numerical estimates for two of these, deforestation and erosion. We begin, however, with an estimate of the total area of natural forest land available.

*Land availability*

In Chapter 14 it is reported that the total area of production forest in Indonesia is approximately 61 million hectares.

*Deforestation*

FAO-MoFr (1990a, Table 3.3, p61) estimate that between 1982 and 1990 236,000 ha of *production forest*, areas reserved for selective logging, were deforested each year. (This figure rises to 407,000 ha p.a. if the East Kalimantan fires of 1982-83 are included.) This deforestation is due to road construction, forest degradation as a result of poor logging practices and shifting cultivation. The FAO also reports that in recent years around 900,000 ha of production forest have been logged each year (FAO-MoFr 1990a, p61). Thus around 26 per cent of logged-over production forests are deforested as a result of logging. In other words, under the current system, for every 4 ha of production logged, one ha is left deforested. Several studies confirm these figures. One indicates that around 20 per cent of land area is deforested because it is covered with roads, and if skid trails are included the percentage rises to 30 (Hendrison 1992, p23).

Unlike deforestation on land designated as conversion forest, this deforestation of production forests is unplanned. It not only reduces the ability of the forest to replace the biomass lost through logging, but it also interferes with the ecological processes of the forests including disturbance of water flows and increased risks of fire, habitat loss, disturbance to wildlife corridors and soil degradation.

*Soil erosion*

According to the FAO-MoFr (1990b, p80):

> The increased soil erosion rates caused by commercial forest harvesting are mainly attributable to the disturbance of the soil by logging techniques, mainly from log landings, skid trails, and roads. On steep slopes and with high intensity rain patterns, the erosion can be quite serious and persist for many years.

The report quoted suggests that the quality and planning of logging roads is inadequate.

Estimation of the rates of erosion as a result of logging in mixed species hill forests is difficult and only order-of-magnitude estimates are possible. While soil loss from undisturbed forests is almost nil, one study of Indonesian forests (Hamilton and Pearce 1988) measured soil loss from a newly constructed skid road at 12.9 tonnes per hectare per month. Three years after the road had been abandoned soil losses persisted at 3.2 tonnes per hectare per month. The figure of 12.9 tonnes/ha/month converts to 154.8 tonnes/ha/yr from roads. Repetto *et al.* (1989, Table II.7, p45) report a series of studies

2 The estimates of deforestation made here exclude clearing of conversion forests.

in Java which indicate rates of soil erosion on degraded forested land (both under roads and not under roads) of 88.3 tonnes/ha/annum.

It was reported above that around 26 per cent of logged-over production forest is left deforested, largely due to roads and log landings. Hamilton and Fearce (1988) report that the percentage of a logging concession under track and trail can range from 16 to 30 per cent.[3] We take 16 per cent as a conservative estimate of area under roads and landings. We assume soil loss from roads to begin at 154.8 tonnes/ha in the first year and to fall asymptotically through 38.4 tonnes/ha/an (i.e. 3.2 tonnes/ha/month) in year four until year ten.

Using these estimates, we can calculate that each year 70.8 million tonnes of soil are eroded from roads built over the previous 10 years. Assuming that around 900,000 ha of production forest are logged annually, erosion occurs at an average rate of 79 tonnes/ha/an (i.e. 70.8 million tonnes divided by 900,000 ha.). This amounts to around 39 million cubic metres as the total annual volume of soil erosion from production forests, equivalent to a mound of soil one metre high covering an area of 1 by 39 km each year. These estimates cover only erosion due to roads and landings and exclude erosion from soil disturbance off roads and landings; they also exclude soil erosion from conversion forests.

## 8.5 Forest Products: Logging Technology in Plantations

According to the FAO-MoFr (1990a, Chapter 7), a major program of forest plantation establishment is necessary to meet the deficit in timber supply from natural forests that will occur in the next few years. Plantations are also necessary to rehabilitate critical watersheds that have been extensively degraded by increasing population pressure. The Government's ambitious plan is to establish about 6 million hectares of industrial timber estates by the year 2000.

The FAO argues that the social returns from the establishment of industrial timber estates are higher than private returns (because of the environmental benefits and the shorter investment horizons of private logging companies) and that therefore subsidies are justified to encourage plantation establishment. Plantations producing pulpwood

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3 Weir and Manan (1989, p66) report studies that indicate that selective logging leaves up to 50 per cent of the ground surface affected by machinery.

alone, saw/veneer logs alone and mixed saw/veneer logs plus pulpwood are all expected to be profitable.

The key difference in logging technology between natural forests and plantations is that in the latter a large part of the input costs are devoted to establishing the plantation (in addition to the costs of harvesting and transportation) and that investors must wait several years before they see a return on their investments.

Data on physical inputs into plantations are difficult to obtain. Moreover, there are many feasible types of plantations varying according to species planted, the planned rotation, the site quality and the size of the plantation. Each has a different cost structure. The example developed here of a plot of *Acacia mangium* -- a fast-growing exotic hardwood that is suitable for pulpwood, sawlogs and veneer logs -- could be considered a typical plantation of the future. In this example, taken from an FAO report, it is assumed that the plantation is established on *alang-alang* (grassland) using mechanical land preparation and weeding (but not planting). The plantation is aimed at producing pulpwood, sawlogs and veneer logs and has a rotation of 15 years, with pulp thinnings harvested in year 9. Over a fifteen-year rotation each hectare produces 310 m3 of logs. These figures imply a mean annual increment of a little under 21 m3/ha/an, a fast growth rate which is apparently achievable with this species. (PT Indah Kiat reports an achieved mean annual increment of 40 m3/ha/an for *Acacia mangium* in its Riau plantations (Pk Soebardjo, personal communication).) The yield of 310 m3/ha from this plantation compares to a yield of 37 m3/ha from more sustainably managed natural production forests (with a 50-year rotation). The yields for this regime are reported in Table 8.5.

**Table 8.5 Forest products: Yields from** Acacia mangium **plantation**

| Age | Product | Yield ($m^3$/ha) |
|---|---|---|
| Year 9 | Pulpwood | 60 |
| Year 15 | Veneer logs | 50 |
| | Sawlogs | 125 |
| | Pulpwood | 75 |
| | TOTAL | 310 |

*Source:* Davis 1989, Appendix XVII

Table 8.6 provides cost estimates for a hectare of representative plantation of *Acacia mangium*. The division between labour and other purchases is crude. The figures of Table 8.6 will be translated into the input-output sectoral classification.

Mechanised establishment and maintenance of plantations offers several advantages over manual systems including better suppression of alang-alang grass and other noxious weeds, increased ploughing volume and depth of soil for rooting, full benefit of applied fertiliser and faster growth in the first year. Overall, mechanised systems use about half of the labour of manual ones and have lower costs. In the mechanised system described in Table 8.6 establishment of each hectare of plantation requires over the first four years 124 days of labour. Note that the total days of labour convert to 400 person days/1000 m3 for establishment of mechanised plantations compared to around 894 person days/1000 m3 for logging in natural forests.

**Table 8.6 Forest products: Plantation costs,** Acacia mangium **(Rp 000/ha)**

| | Years | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| Cost item | 1 | 2 | 3 | 4 | 5 | 6-10 | 11-15 | 1-15 |
| Capital and other inputs | 249 | 99 | 99 | 99 | 99 | 495 | 495 | 1635 |
| Labour inputs | 558 | 20 | 23 | 35 | 42 | 1181 | 3515 | 5374 |
| TOTAL COSTS | 807 | 119 | 122 | 134 | 141 | 1676 | 4010 | 7009 |

*Source:* Davis 1989, Appendix XVII, p203 and Appendix XXII, p226.

From Table 8.6 it can be seen that only 11.8 per cent of total labour costs per ha occur in the first four years of the 15-year cycle. Most of the costs (76 per cent) are incurred at the times of harvest in years 9 and 15. This implies that 1048 days of labour are required per ha over 15 years or 11.27 person years (3381 person days) per 1000 m3. The figure of 11.27 person years per 1000 m 3(converted to person years per Rp million of output) will be used as the labour input coefficient for plantations.

Plantations of the future may use around 150 kg of fertiliser (mainly triple superphosphate and urea) per hectare (Davis 1989, p 213). In 1985, the cost of a

kilogram of fertiliser was around Rp 200. A tractor (with appropriate attachments) takes around 3 hours per hectare to carry out ripping, clearing, ploughing and weeding on alang-alang land. Allowing for downtime, this suggests that each tractor could prepare around 600 ha each year (Davis 1989, pp73-74).

The environmental impacts of plantation logging must now be assessed. The impacts will depend crucially on what sort of land is used to establish plantations. If naturally forested lands are cleared for plantations, then the environmental consequences -- in terms of erosion, siltation, changes in water flows and impacts on biodiversity -- will be very severe. If alang-alang and *belukar* (scrubby) sites are used, the environmental impacts are likely to be less severe because the impact of initial deforestation has already been absorbed and may even be partly reversed by the plantation. In terms of environmental impact, then, decisions regarding location of future plantations are critical.

*Land availability*

Mechanised plantations require reasonably flat terrain with minimal stumps; a high proportion of such land will be belukar or alang-alang sites according to Davis (1989, p85). At the risk of underestimating the ecological impact of plantations, it is consequently assumed that they are developed on *alang-alang* or *belukar* sites.

Davis estimates (1989, Appendix XXIV, p247) that in the Outer Islands (beyond Java and Bali) there are about 5.2 million ha of *alang-alang* dry grassland and 14.6 million ha of *belukar* shrub land suitable for plantation establishment, a total of 19.8 million ha.

*Soil erosion*

On alang-alang and belukar land, the principal ecological impact is likely to be erosion and siltation due to road building (especially on slopes of more than 5 degrees) and ripping and ploughing in preparation for planting. It is likely that after high rates of erosion in the first years, once the plantations are established soil loss will be less than it was when the land was under alang-alang or belukar. No quantitative information appears to be available on the impact of plantation establishment on soil erosion. Basing our estimates on the sources cited above, Repetto *et al.* (1989) and FAO-MoFr (1990b), we postulate the impacts specified in Table 8.7. These can be compared with the erosion figures reported in Chapter 7 for establishment of agricultural estates.

According to figures in Table 8.7, in the longer term plantations will have a net positive impact on erosion as long as natural forests are not cleared to establish plantations. (A further environmental problem from plantations may be a small amount of pollution of waterways from fertilizer runoff.)

**Table 8.7 Forest products: Erosion from plantation establishment on alang-alang land**

| | Soil loss (tonnes/ha) |
|---|---|
| Before plantation | 15 |
| Due to plantation | |
| - first year | 40 |
| - years 2-4 | 20 |
| - subsequent years[a] | 5 |

a. Note that Repetto et al. (1989) report an erosion rate of 6 tonnes/ha for forested land on Java. That land is liable to be steeper than the plantation land in question.
Source: For development of these estimates see Hamilton (1993a).

## 8.6 Forest Products: Future Logging Technology in Natural Forests

Although it is assumed that the mechanical plantation technology will be used over the whole of the study time horizon (i.e. to the year 2020), the influence of plantation technology on timber extraction will increase as a rising proportion of the total volume of timber is sourced from plantations. If plantations are established on alang-alang and belukar land then the substitution of plantation timber for naturally grown timber will have a major positive impact on the environment, including:

- a sharp reduction in the rate of soil loss and associated siltation;
- a reduction in flooding and ecological damage to waterways; and
- a declining rate of deforestation and a marked reduction in threats to wildlife habitat and biodiversity.

We turn our attention next to potential changes in logging technology in natural forests. Hendrison (1992, pp 22-23) has proposed a series of improvements to current practices aimed at reduction in vegetation damage, soil damage and erosion. His scheme 'C' has

the following characteristics, all of which can be achieved with only minor alterations to the existing system of natural forest logging:

- improved planning and organisation of roading, felling and transportation;
- the introduction of directional felling and controlled skidding;
- partial replacement of branch roads by trails for wheeled skidders; and
- log extraction by winching.

Hendrison estimates that these changes would reduce the total area of forest affected by logging from about 52 per cent to 30 per cent. They would increase felling costs by around 10 per cent but reduce transport costs by 15 per cent and skidding costs by 5 per cent. Jonsson and Lindgren (1990, p51) report that trials in Sarawak using similar methods and emphasising careful planning reduced logging costs by 20 per cent compared to a conventional operation.

In addition, we extend Hendrison's changes by requiring road construction that is more sensitive to the risks of erosion. Roads must be constructed only on slopes of less than 25 degrees and must allow for adequate drainage. Landings must be sited on level ground and roads and landings must be at least 100 metres from streams. This system we call the More Sustainable System of natural forest logging.

We postulate that the impact of these changes will be to:

- reduce the affected area from 52 to 30 per cent;
- reduce annual average erosion from 79 tonnes/ha to 30 tonnes/ha;
- reduce the incidence of damage to remaining stems from around 60/ha to 40/ha (Jonsson and Lindgren 1990, p53); and
- reduce the rate of deforestation due to roading and careless logging from 26 to 15 per cent of the area subject to logging.

The reduction in impact on biodiversity and wildlife numbers will be small because the proposed changes still involve intensive logging.

The shift from the current system of natural forest logging to the More Sustainable System involves the following changes:

- unskilled labour requirements per unit of output fall by 10 per cent in view of the evidence of Hendrison (1992) and Jonsson and Lindgren (1990);

- training in road building, felling techniques and extraction methods is represented by a 50 per cent increase in requirements, per unit output, for the most skilled (supervisory) workers;

- upgrading of management skills is required in addition to more supervision of forest operations and this is represented by another 50 per cent increase in the requirements for the most skilled workers; and

- machinery requirements may change slightly with greater use of wheeled skidders. These could be introduced gradually and are represented by a 10 per cent increase in the stock of transport equipment required per unit increase in capacity.

These changes, and some important parameters, are reported in Table 8.8 below. The table summarises the assumptions in the form in which they will be used in the input-output model. The first column of the table shows the values of intermediate and capital inputs used in the production of 1000 m3 of logs from natural mixed hill forests under the current system. It also shows the amount of labour in person days per 1000 m3 of logs and the deforestation and soil erosion impacts of logging.

The second column of Table 8.8 shows changes in inputs and in impacts on deforestation and erosion using the More Sustainable System of logging natural forests. The third column shows the inputs and natural resource effects of plantations.

**Table 8.8 Forest products: Inputs and natural resource impacts of natural forest and plantation logging, 1985 and 2020**

| Input/parameter | | Natural forest 1985[a] | Natural forest 2020[b] | Plantation 2020 |
|---|---|---|---|---|
| *Intermediate inputs (Rp/Rp of output)*[a] | | | | |
| 14 | Fertiliser & pesticides | 0 | 0 | .0016 |
| 17 | Other manufacturing | .0226 | .0226 | .0244 |
| *Labour (person years/ Rp million of output)*[c] | | | | |
| Total labour | | .0492 | .0499 | .1855 |
| *Capital stocks (Rp/Rp of output)*[d] | | | | |
| Total capital stocks | | .2925 | .3210 | .5634 |
| *Environmental impacts* | | | | |
| Deforestation (proportion of land area) | | .26 | .15 | 0 |
| Soil erosion (tonnes/ha) | | | | |
| - before logging/establishment | | 0 | 0 | 15 |
| - after logging/establishment | | 79 | 30 | 10 |
| *Other parameters* | | | | |
| Yield ($m^3$/ha) | | 21.1 | 37.0 | 310 |
| Rotation (years) | | 35 | 50 | 15 |
| Area required (ha/$10^3$ $m^3$) | | 47.4 | 26.5 | 3.22 |
| Unit price (Rp/$m^3$) | | 61,548 | 61,548 | 61,548 |

Notes: a. Current system of logging
b. More Sustainable System of logging
c. Labour coefficients can be converted into person years/1000 m3 of log output by multiplying by 61.548.
d. Coefficients can be converted into million Rp of input/1000 m3 of log output by multiplying by the unit price, 61.548.
*Sources:* Tables 8.4, 8.6, 8.7 and text.

## 8.7 Forest Products: Description of the Scenarios

The technological scenarios can now be defined in Table 8.9 where they are represented by mixes of the current system of natural forest logging, the More Sustainable System of natural forest logging and mechanised plantations. The percentage distribution between logs from natural forests and plantations are based on the assumptions of Table 8.1.

The actual implementation of these scenarios depends critically on effective enforcement of government policy. In particular, policies on use of forest land need to be strictly enforced to prevent further environmental damage. In the case of plantations it is especially important to ensure that they are established on genuinely degraded land so that existing forests are not cleared for plantations.

The shifts to supplying logs from plantations and to more sustainable natural forest logging are likely to lead to a very marked fall in soil erosion and deforestation and alleviation of the impact of current logging on biodiversity and carbon fixation.

Table 8.10 shows the input-output coefficient changes as well as the 1985 coefficients for natural resource impacts and their projected changes under the two scenarios.

**Table 8.9 Forest products: Definition of Scenarios 1 and 2**

| *Scenario* | S1 | S2 |
|---|---|---|
| *Percentage of logs from:* | | |
| Natural forests (more sustainable) | 60 | 32 |
| Plantations | 40 | 68 |

**Table 8.10 Forest products: Changes in technological coefficients, 1985-2020**

| | Change between 1985 and 2020 (%)[a] | |
|---|---|---|
| | S1 | S2 |
| *Intermediate inputs*[a] | | |
| 14 Fertiliser & pesticides[b] | .00064 | .00109 |
| 17 Other manufacturing | +3 | +5 |
| *Labour inputs* | | |
| Employment | +211 | +289 |
| *Capital inputs* | | |
| Capital requirements | +45 | +68 |

| *Natural resource impacts* | | | | |
|---|---|---|---|---|
| | Unit | 1985 level | S1 | S2 |
| Land area | ha/$10^3$ $m^3$ | 26.5 | -35 | -60 |
| Soil erosion | tonnes/ha | 79 | -80 | -92 |
| Deforestation | ha/ha logged | .26 | -65 | -81 |

Notes: a. Intermediate inputs use the NRMP-IEA 30-sector classification.
b. In the case of inputs of fertiliser and pesticides the absolute value of the coefficient is given (i.e. Rp/Rp) since inputs were 0 in 1985.

## 8.8 Pulp and Paper: Current Technology

The pulp and paper industry (Sector 13 in the NRMP-IEA 30-sector classification) is likely to be one of the fastest growing sectors in Indonesia over the next 30 years. Plans for several new mills are in process. The major categories of paper are newsprint, printing and writing paper (also known as 'cultural paper') and others. The last includes papers for packaging and industrial uses.

In Indonesia, pulp making and paper making have generally not been integrated, with most paper mills located on Java and most pulp mills off Java. In 1992 there were 12 integrated pulp and paper mills, 33 paper mills and one mill that produced pulp only in

Indonesia (Soetikno, 1992, Annex 2). Paper production substantially exceeds pulp production although the difference is likely to narrow in the future.

In paper making, some mills use recycled paper for manufacturing industrial papers. Some mills continue to use rice straw and bagasse (the residue from sugar cane) for fibre suitable for newsprint but there is a trend to switch to hardwoods from fast-growing plantations. Indonesia's climatic conditions are not very suitable for softwood plantations and imports of long-fibre pulp for sack kraft paper, which are produced from softwood, are projected to increase with the growth of industry. At present Indonesia imports long-fibre pulp for making industrial papers such as cement bags from Canada, Finland and New Zealand, among others.

In pulp making, the principal raw materials used as fibre are bagasse, rice straw, hardwood, softwood and waste paper. Only 6 of the 13 pulp mills in Indonesia use wood exclusively for their raw material. In future, it is expected that wood will form an increasing proportion of raw material as plantations are established with government encouragement and bagasse is phased out for environmental reasons. The major intermediate inputs to the pulp and paper sector in 1985 were from the pulp and paper, chemicals and road transport sectors. Table 8.11 shows the principal intermediate inputs for Sector 13.

**Table 8.11 Pulp and paper: Principal intermediate inputs, 1985**

| Sector | | Coefficient (Rp/Rp) |
|---|---|---|
| 13 | Pulp and paper | 0.323 |
| 14 | Chemicals | 0.045 |
| 26 | Road transport | 0.028 |
| 18 | Petroleum refining | 0.015 |

*Source*: BPS (1989)

### *8.8.1 Pulp production*

There are three types of pulping process: chemical, semi-chemical and mechanical. Currently, most of the pulp mills in Indonesia use the kraft process, a chemical process.

Other chemical processes include the acid sulphite and soda methods. The kraft and soda methods are suitable for pulping hardwoods. At present 77 per cent of pulp in Indonesia is produced using the chemical method, and this will continue to be the case in future (Duchin and Lange, 1992b, Table 8 and Soetikno 1992, p8).

Before wood is pulped in the mills, it is prepared by debarking in a drum barker, chipping to cut logs into small pieces and chip screening to obtain the right size of chips. Chips that are too big or too small are used as fuel. The chips then go into the cooking process for pulp making.

The stages of pulp making using the kraft process are cooking, bleaching and chemical recovery. The usual stages in the bleaching process are chlorination and oxidative extraction, followed by a brightening sequence consisting of bleaching with chlorine dioxide ($ClO_2$), extraction and a final bleaching with $ClO_2$ (usually summarised as CD-Eo-D-E-D).

Increasingly, chlorine dioxide has been substituted for elemental chlorine, replacing up to 70 per cent of chlorine in the first bleaching stage. Chlorine dioxide does not release chlorine ions that may form dioxin so the substitution of it for chlorine is environmentally safer (Bettis 1992, p23).

*8.8.2 Paper production*

There are several kinds of paper and cardboard products, each of which may use its own proportions of raw materials. Production of writing and printing paper requires 10-15 per cent long fibre and 85-90 per cent short fibre pulp. Sack paper 100 per cent long fibre, packaging paper uses 50 per cent short fibre and 50 per cent long fibre, corrugated medium 100 per cent waste paper (sometimes with added short fibre), and newspaper up to 100 per cent waste paper.

Currently, most of the paper produced in Indonesia is writing and printing paper. The process to produce this paper has two main stages, stock preparation and paper production. To produce writing and printing paper, the proportion by weight of raw materials used is 80 per cent pulp (long and short fibre) and 20 per cent chemicals.

### *8.8.3 Energy and emissions in the pulp and paper industry*

Currently the sources of energy used in the pulp and paper industry are electricity form PLN, industrial diesel oil (IDO), bark, rejected woodchips and black liquor. Bark, chip and black liquor are burnt to produce high pressure steam used for turbine generators that produce electricity. Mills often also have diesel generators. There is an expectation that the industry will shift to coal with government encouragement of the coal industry. PT Indah Kiat, the first pulp mill to begin operations in Indonesia, expects that in future only 25 per cent of its energy requirements will derive from bark, chip and black liquor while 75 per cent will come from coal (Indah Kiat, 1991). Overall, energy consumption is expected to decline by 15-20 per cent per tonne of output.

Pulp and paper mills produce gaseous, liquid and solid wastes. The most serious environmental problems are caused by water discharges from the bleaching and pulping of chemical pulp. However, environmental damage can be greatly reduced by recycling and reusing most of the waste water and many of the chemicals back into successive processing (World Bank 1984, p378). [4]

The principal atmospheric emissions from the kraft process are sulphur dioxide, particulate matter and total reduced sulphur compounds (TRS), the last of which are characterised by their unpleasant smell.

Chemical pulping requires large volumes of water at several stages of the process. The parameters best suited to describing the degree of contamination of waste water are BOD-5 (five-day biological oxygen demand), COD (chemical oxygen demand), total suspended solids (TSS), colour and ammonia nitrogen. The volume of water discharged from pulp mills exceeds the water intake because of suspended solids in the waste water.

According to the World Bank (1984, Table 1, p379), a typical kraft pulp mill producing market grade pulp discharges 177 m3 of water per tonne of pulp produced with a BOD-5 content of 41 kg/tonne and a TSS level of 70 kg/tonne of pulp. With the use of best practicable control technology widely available 10 years ago these could be reduced to 7.1 kg/tonne for BOD-5 and 10.3 kg/tonne for TSS (World Bank 1984, Table 4). Indonesian kraft pulp mills typically use the former technology , and it is still common for Indonesian firms to import second-hand pulp and paper machinery embodying older technology.

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4 The discussion of emissions is based in part on World Bank, 1984.

Note that no figures are reported here for chlorine emissions. Even though dioxins are said to be some of the most dangerous emissions from the bleaching process in pulp mills, the State Ministry of Population and Environment (KLH) has not yet developed a standard for chlorine emissions. Most of the new technologies we will discuss are designed in part to eliminate or reduce elemental chlorine in the bleaching process.

Table 8.12 reports water use and some measures of water pollution from two pulp mills operated by PT Indah Kiat in Riau Province. Pulp mill 1 uses conventional kraft pulping technology common in the 1970s and early 1980s. Pulp mill 2, which represents the direction of the rest of the industry, uses the advanced kraft process. Use of the advanced kraft process by Indah Kiat involves:

- extended delignification in the cooking process;
- use of oxygen delignification after cooking (reducing the amount of chlorine used in bleaching by around 20 per cent); and
- oxygen bleaching instead of chlorine dioxide bleaching.

The process can be represented as CD-Eo-D, i.e. bleaching with elemental chlorine and chlorine dioxide; extraction using sodium hydroxide plus oxygen delignification; and bleaching with chlorine dioxide.

The advanced kraft process does not represent a markedly different pulping technology compared to conventional technology but it does significantly reduce levels of chemical use per tonne of pulp output. Both elemental chlorine and chlorine dioxide are reduced per unit output (by 29 and 37 per cent, respectively) and the use of hypochlorite falls by 75 per cent. The shift to oxygen bleaching sees per unit oxygen use decline by only 6 per cent (Indah Kiat 1991, Table 2.2 p II-11).

The BOD level from Indah Kiat's older pulp mill is 142 kg per tonne of output (compared to the World Bank's estimate that the level could be reduced to 7.1 kg/tonne using 1984 technology). Water discharge from the newer pulp mill has a BOD level of 17 kg/tonne.

**Table 8.12 Pulp and paper: Water input, water output and water quality for Indah Kiat pulp mills, 1991**

| Parameter | Unit | Pulp mill 1 | Pulp mill 2 | KLH standard |
|---|---|---|---|---|
| Water input | $m^3/t$ | 165 | 52 | |
| Water output | $m^3/t$ | 188 | 59 | |
| BOD-5 | $kg/m^3$ | 0.754 | 0.296 | 0.125 |
| COD | $kg/m^3$ | 2.500 | 1.152 | 0.250 |
| Suspended solids | $kg/m^3$ | 0.873 | 0.092 | 0.100 |
| Zinc | $kg/m^3$ | 0.043 | 0.000 | 0.002 |
| Ammonia | $kg/m^3$ | 0.011 | 0.008 | 0.000 |
| Sulphate | $kg/m^3$ | 0.893 | 0.149 | 0.000 |

*Source*: Indah Kiat 1990, pIII-38

It is apparent from the tables above that water emissions from the Indah Kiat mills were well over the standards set by KLH. Even with the newer processes of pulp mill 2, emissions will continue to exceed standards. Water emissions from the pulp mills also contain many times the allowable emissions of some heavy metals.

## 8.9 Pulp and Paper: Changes in Technological Coefficients to 2020

*Process*

Several new technologies for improving the efficiency and minimising the environmental effects of pulp production have recently begun commercial operation overseas or are likely to be introduced in the next decade (Brunner and Pulliam 1992). Some of the alternatives include:

- extended delignification cooking;
- oxygen delignification;
- high chlorine dioxide substitution; and
- ozone, oxygen and peroxide bleaching.

A likely configuration for pulp making in Indonesia in 2020 will involve extended delignification and ozone bleaching. The first stage of bleaching will be free of chlorine compounds and some of the pre-bleaching effluent will be recycled back to recovery. The ozone bleaching process uses ozone instead of elemental chlorine in the pulping process. As a result, it reduces the volume of water used in the pulping process, lowers the BOD level and reduces chlorinated organic materials such as dioxin (Bettis 1992). The replacement of chlorine compounds with ozone has been extensively tested in laboratories but is as yet commercially unproven. The first scheduled installation using the technology described above was due to begin operation in the USA in 1992.

In more detail, the projected technological scenario for 2020 can be described in the following stages (Brunner and Pulliam, 1992, Case 5).

*Cooking*: continuous digester with extended delignification.

*Bleaching*: Four stages (represented by A-Z-Eo-D):

A - acid prewash;

Z - ozone bleaching;

Eo - oxidative extraction; and

D - final chlorine dioxide bleaching stage.

*Inputs*

The economics of the process described above (extended plus oxygen delignification and ozone bleaching) are analysed by Brunner and Pulliam (1992). Total capital costs of the new technology are around 20 per cent higher. The pulp yield from wood will decline due to extended delignification cooking and a less selective bleaching sequence meaning that wood input per unit pulp output will rise by about 5 per cent. In fact, wood inputs per unit of output have already been rising since 1985 as wood is substituted for non-wood fibres. On the other hand, greater efficiencies in the use of raw materials and increased recycling of paper are likely to reduce the wood inputs per unit of output. On balance we expect no change in the 1985 intermediate inputs from the forest products sector per unit of pulp and paper output.

The inputs of bleaching chemicals will decline by around 30 per cent compared to a conventional mill. However, around 30 per cent more electricity must be consumed to

generate ozone. In addition, coal is expected to replace diesel oil as the principal heating fuel in Indonesian mills.

In the Brunner and Pulliam analysis labour inputs per unit of output are unchanged. This is for efficient conventional pulp mills in industrialised countries, however. Interviews with plant managers in Indonesia indicate that substantial labour savings are anticipated through increased efficiencies and adoption of the newer technologies, amounting to 40 per cent labour savings per unit of output.

*Emissions*

Table 8.12 presented water use and water pollution figures for Indah Kiat's conventional kraft mill and its newer advanced kraft mill. The new ozone-bleaching technology described above is a substantial advance on the advanced kraft process. We would therefore expect the water use and water pollution figures of Table 8.12 for pulp mill 2 to provide upper limits to water use and emissions in 2020.

However, according to Brunner and Pulliam (1992, p283), the ozone-bleaching process described above will result in no decrease in water discharge compared to conventional kraft mills (in the West) because the reduction in effluent flow from the bleaching plant is offset by an increase in effluent flow from sewered process condensates. However, BOD levels for the new pulp mills will fall by 45 per cent. Given that the base case of Brunner and Pulliam is a conventional kraft mill operating efficiently in an industrialised country, there are probably improvements that can be made in water use and water pollution in Indonesia even without a significant shift away from the conventional process. Hence, savings in water use and reductions in BOD and other measures of pollution are likely to be substantially higher than the figures reported by Brunner and Pulliam.

In the absence of better data, we rely on the figures for Indah Kiat's more advanced mill (Table 8.12) to provide upper limits on water use and water emissions for 2020. However, the new technologies could result in the elimination or at least severe reduction of chlorine-based compounds and other pollutants in effluent.

Further, combining the data derived from discussions with industry experts in Indonesia with the figures of Brunner and Pulliam yields the estimates reported in Table 8.13. Changes in values of environmental parameters (and absolute levels for environmental parameters) are also presented in Table 8.13. Changes in 2020 are represented as

percentage changes over the 1985 values.

**Table 8.13 Pulp and paper: Changes in technological coefficients, 1985-2020**

| Input/impact | | Change between 1985 and 2020 (%) |
|---|---|---|
| *Intermediate inputs*[a] | | |
| 5 | Forest products | 0 |
| 7 | Coal | (.0107)[b] |
| 15 | Chemicals | -30 |
| 18 | Petroleum refining | -90 |
| 20 | Electricity | +30 |
| *Labour inputs* | | |
| Total employment | | -40 |
| *Capital inputs* | | |
| Total new capital requirements | | +20 |
| 17 | Other manufacturing | +20 |
| 23 | Construction | +20 |

*Natural resource impacts*

| | Unit | 1985 level | S1 |
|---|---|---|---|
| Water input/output | $m^3/t$ | 165 | -68 |
| Water output/output | $m^3/t$ | 188 | -69 |
| BOD | $g/m^3$ | 754 | -61 |
| COD | $g/m^3$ | 2500 | -54 |
| Suspended solids | $g/m^3$ | 873 | -89 |
| Free chlorine | $g/m^3$ | <0.02 | -100 |

Notes: a. NRMP-IEA 30-sector classification.
b. Represents absolute value of coal input coefficient (Rp/Rp) as inputs were 0 in 1985.
*Sources*: see text

# CHAPTER 9

# ELECTRICITY AND INDUSTRIAL AND HOUSEHOLD ENERGY USE*

## 9.1 Energy Consumption in Indonesia

This chapter describes the development of three sets of data relating to energy consumption and production technology:

- projections of household energy consumption used in the macroeconomic projections of private consumption;
- projections of changes in industrial energy consumption per unit of output for those sectors not covered by case studies; and
- the case study of the electricity sector (Sector 20) projecting changes in the technology and fuel shares used in power generation.

Currently, the principal sources of energy in Indonesia are oil-fired power plants, diesel generators and hydroelectricity as well as petroleum products for transport and industrial use. The economy has been very heavily dependent on oil but since the mid-1980s the government has had a policy of diversification of energy sources in order to diminish dependence on oil.

The principal forms of non-electric energy are refined petroleum, biomass, coal and natural gas. In estimating demands for various types of energy we will distinguish between electric and non-electric energy. The former include electricity from oil, coal and gas-fired power plants, hydroelectric power and geothermal power. Very large changes in the energy mix will occur in Indonesia over the next 10-20 years. There are two key trends:

- the electrification of households and industry, replacing diesel generation and non-electric forms of energy; and
- massive substitution of coal and gas and to a lesser extent geothermal energy for oil in electricity generation. [2]

Demand for energy will derive from various types of energy consumers: households, manufacturing industry, commercial and service sectors, transportation and government

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* This chapter draws heavily on *NRMP-IEA Input-Output Working Paper* Number 15 (Hamilton, 1993b) and Number 1 (Duchin and Lange, 1992b).

2 The development of nuclear power is not considered as an option because there remain serious doubts about the economic and environmental viability of a nuclear power program.

and community services. In this study we have focused on households, manufacturing industry and transportation.

Household demand for energy will depend on household income and the share of household expenditure on each type of energy, in particular electricity, refined petroleum, coal, natural gas and biomass. These in turn will be influenced by the fuel efficiency of the appliances that use energy. Since biomass is mostly a non-commercial form of energy it does not appear explicitly in the national accounts and has not been included in the current version of the input-output model.

Industrial demand for each type of energy will depend on the per unit input of each type of energy and the output of each industry. The former will depend on the technologies used, which will determine the types of fuel used, as well as measures taken to achieve fuel efficiencies. Energy demand from the transportation sector depends on the size of the fleet, the types of engines used (petroleum, diesel or natural gas) and the fuel efficiency of the fleet.

It should be pointed out that the 'electricity' sector of the BPS (1989) input-output tables shows electricity generated by the state-owned electricity utility (PLN) only. In 1985 more than half of the electricity supply in Indonesia was generated by private industry and businesses, mostly using diesel generators. This autogeneration, or captive generation, is reflected in the input-output tables by purchases from the 'petroleum refining' sector (in the case of diesel generators) by auto-generating industries. [3] Thus to the extent that electricity produced by PLN or privately owned utilities substitutes for captive generation, we need to reduce per unit purchases by industry from the petroleum refining sector and increase their per unit purchases from the electricity sector. [4]

## 9.2 Household Energy Use

Projections of household energy consumption have been incorporated into the macroeconomic projections of final demand reported in Chapter 5. In particular, private consumption from the coal, petroleum refining, liquified natural gas, electricity and gas utilities sectors (Sectors 7, 18, 19, 20 and 21) are developed there.

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3 It is reflected in the capital stock tables as purchases of generators from the 'other manufacturing' sector.
4 Some of these coefficient changes are captured by the projected energy coefficients in the industry case studies reported in other chapters of this report. Note that atmospheric emission coefficients are discussed in Chapter 14.

Households accounted for around 20 per cent of national fuel consumption in 1990 if non-commercial fuels are not taken into account (Newjec 1993, Task 3, Table 3.5-4). In rural households the principal commercial fuel is kerosene which is used to supplement fuelwood and agricultural waste. As family incomes rise, households tend to switch from non-commercial fuels to commercial fuels, but the switch has been hastened in some areas by declining availability of fuelwood (Newjec 1993, Task 1). In future, it is expected that extensive electrification and the promotion of LPG and city gas in both urban and rural areas will decrease the shares of both kerosene and biomass in household consumption. At present LPG is popular only among wealthier households because of the significant costs of investing in stoves and gas bottles that must precede its use. In addition, LPG is not available outside larger towns.

Newjec (1993, Task 3) makes projections for household energy demand for the period 1990-2019 by regressing demands for electric and non-electric energy on GDP per capita using annual data for the period 1970-1990 (see Table 9.1). In the Newjec analysis non-electric energy excludes non-commercial fuels (biomass). Newjec obtains income elasticities of demand of 2.11 for electricity and 0.85 for other forms of energy probably reflecting substitution of electricity for other forms of energy as incomes rise. Their projections, however, do not take into account the impact of energy conservation measures and the energy efficiency of new appliances.

Newjec uses a separate procedure to estimate that in 2019 non-commercial energy, used mainly by households, will be less than one percent (0.65 per cent) of total energy used, down from 36.92 per cent in 1990 (Newjec 1993, Task 3 Table 3.5-19). However, even industrialised countries continue to rely to some extent on biomass, and its share is unlikely to fall as far as Newjec anticipates.

*Electricity projections*

The rate of urban electrification has increased rapidly over the last two decades yet only about one third of villages have been supplied with electricity. According to PLN data residential sales accounted for 32 per cent of total electricity sales in 1990-91 (PLN 1991, Table 54). Per capita electricity consumption is low by regional standards and only about 33 per cent of households -- 66 per cent in urban areas and 20 per cent in rural areas -- have been connected to electricity supplies (Sudja 1992, p2).

**Table 9.1 Household energy demand as projected by Newjec (base case), 1990-2019**

| | 1980 | 1990 | 2000 | 2010 | 2019 |
|---|---|---|---|---|---|
| *Type of energy* | | | | | |
| Electric | | | | | |
| . in $10^6$ boe | 1.82 | 5.64 | 17.49 | 52.10 | 122.53 |
| . in GWh | 2,910 | 9,004 | 28,178 | 83,938 | 197,408 |
| Non-electric | | | | | |
| . in $10^6$ boe | 47.83 | 52.53 | 92.54 | 155.63 | 229.93 |

| Growth rates (% pa) | 1980-1990 | 1990-2000 | 2000-2010 | 2010-2019 |
|---|---|---|---|---|
| Electric | 11.94 | 11.98 | 11.53 | 9.97 |
| Non-electric | 0.94 | 5.83 | 5.34 | 4.43 |

Notes: Figures for 1980 and 1990 are actual. The projections extrapolate from Newjec's 'base case' which lies between the NRMP-IEA high and moderate growth paths.
*Source*: Newjec (1993) Task No. 3, Tables 3.5-2, 3.5-4 and 3.5-5. The 1985 figure for electricity consumption is from *PLN Statistics* 1990/91, Table 36.

A USAID report on demand side management of electricity supply in Indonesia considers energy savings in two end uses, refrigeration and lighting, which together are reported to account for around two-thirds of household electricity consumption (and three-quarters of peak household demand) (USAID, 1992, pIV.17). Simple changes in construction of refrigerators built in Indonesia would improve their efficiency adding only a small amount to the cost of the appliance but decreasing electricity consumption by refrigerators by 20 per cent.

Use of compact fluorescent lamps instead of standard incandescent bulbs can save up to 75 per cent of the energy that would otherwise be used. Additional savings in energy could also be made by the use of more efficient air conditioners and television sets (USAID, 1992 pp IV.18-IV.19). Perhaps the greatest energy savings could come simply from proper maintenance of electrical appliances, including electrical water pumps.

Putting together these figures, we estimate that increased efficiency could reduce household electricity consumption by up to 25 per cent by the year 2020. This estimate, however, is a best case one; a more realistic estimate would see energy savings of only 10 per cent. Consequently, we adopt levels of household electricity savings of 10 per cent in

Scenario 1 and 25 per cent in Scenario 2 (built into the macroeconomic projections of both moderate and high growth paths).

The projections of Table 9.1 for electricity represent Newjec's 'base case'. Newjec's high and low growth cases correspond closely to the NRMP-IEA model's high and moderate growth paths (see Chapter 5). Projections of household electricity demand on the high and moderate growth paths including assumed levels of energy savings appear in Table 9.2.

**Table 9.2 Projected household electricity demand under two energy savings scenarios, 1990–2020 (in GWh)**

| | 1990 | 2020 |
|---|---|---|
| *Moderate growth path* | | |
| Scenario 1 | 9004 | 208,426 |
| Scenario 2 | 9004 | 149,657 |
| *High growth path* | | |
| Scenario 1 | 9004 | 291,796 |
| Scenario 2 | 9004 | 243,278 |

*Source*: Table 9.1 and NRMP-IEA estimates.

### *Fossil-fuel projections*

In the case of non-electric energy consumption by households, the estimates in Table 9.1 for non-electric energy demand are used as a base but are adjusted to reflect energy savings. It is very likely over the next ten years that the growth of coal briquettes and gas (LNG and town gas) will substitute for a large proportion of biomass and kerosene in households for cooking.

To incorporate household energy savings, two scenarios are defined for fossil fuel consumption. S1 assumes the growth rates put forward by Newjec while S2 assumes 50 per cent savings in petroleum consumption due to more efficient vehicles and 25 per cent greater efficiencies in the burning of coal (see Duchin and Lange 1992b) . We can use these estimates to derive projections of increases in fossil fuel consumption by households. These are shown in Table 9.3.

**Table 9.3 Fossil fuel consumption by households, 2020 (times increase over 1985)**

| | Moderate | High |
|---|---|---|
| Scenario 1 | 4.3 | 5.4 |
| Scenario 2 | 2.8 | 3.6 |

*Sources:* Newjec 1993, Duchin and Lange 1992b and NRMP-IEA estimates

We adopt the projected shares of fossil fuels -- petroleum, coal and natural gas -- in total fossil fuel consumption by households developed by Duchin and Lange (1992b) with an adjustment to account for greater energy savings under S2. These estimates of shares of fossil fuels are shown in Table 9.4.

**Table 9.4 Shares of fossil fuels in total fossil fuel energy consumption by households (per cent)**

| Sector | | 1985 | 2020 S1 | 2020 S2 |
|---|---|---|---|---|
| 7 | Coal | 0 | 17 | 19 |
| 18 | Petroleum products | 98 | 62 | 47 |
| 19 | LNG | 2 | 11 | 16 |
| 21 | Gas utilities | 4 | 11 | 17 |

Notes: The shares are shares in total energy content in joules. It has been assumed that the consumption of gas is divided more or less equally between bottled gas (LNG) and piped gas (Gas utilities).
*Source*: Duchin and Lange (1992b, Table 4)

## 9.3 Industrial Energy Use

For the sectors covered by case studies (Sectors 1, 2, 3, 4, 5. 11, 13, 15, 16, 17 and 20), projected levels of energy use per unit of output in 2020 have been included in expected coefficient changes. For all other sectors estimates have been made of future changes in energy inputs from energy-providing sectors (Sectors 7, 18, 19, 20 and 21) as described below. Table 9.5 presents the energy assumptions for the 30 sectors of the model.

**Table 9.5 Changes in energy coefficients, Scenario 1, 1985-2020 (per cent)**

| Sector | | 7 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|
| 1 | Paddy | - | 0 | 0 | - | - |
| 2 | Other food crops | - | 0 | 0 | - | |
| 3 | Estate crops | - | 0 | 0 | 0 | 0 |
| 4 | Livestock & poultry | - | +30 | - | +30 | - |
| 5 | Forest products | - | 0 | 0 | 0 | 0 |
| 6 | Fisheries | - | -20 | -20 | -20 | -20 |
| 7 | Coal[a] | -20 | -20 | -20 | -20 | -20 |
| 8 | Crude oil | -20 | -20 | -20 | -20 | -20 |
| 9 | Natural gas | -20 | -20 | -20 | -20 | -20 |
| 10 | Other mining | -20 | -20 | -20 | -20 | -20 |
| 11 | Food & beverages | - | -25 | - | -25 | - |
| 12 | Wood products | - | -20 | -20 | -20 | -20 |
| 13 | Pulp & paper | - | -90 | - | +30 | - |
| 14 | Fertiliser & pesticides | - | -20 | -20 | -20 | -20 |
| 15 | Chemicals | - | -40 | - | -40 | - |
| 16 | Cement & limestone | a | -90 | -100 | -8 | - |
| 17 | Other manufacturing | +10 | -19 | +30 | -25 | - |
| 18 | Petroleum refining | -20 | -20 | -20 | -20 | -20 |
| 19 | Liquified natural gas | -20 | -20 | -20 | -20 | -20 |
| 20 | Electricity[b] | +438 | -95 | +167 | -2 | - |
| 21 | Gas utilities | -20 | -20 | -20 | -20 | -20 |
| 22 | Water utilities | -20 | -20 | -20 | -20 | -20 |
| 23 | Construction | - | -20 | -20 | -20 | -20 |
| 24 | W'sale & retail trade | - | -20 | -20 | -20 | -20 |
| 25 | Restaurants & hotels | - | -20 | -20 | -20 | -20 |
| 26 | Transport & communication | - | -25 | - | - | - |
| 27 | Real estate, finance & business services | - | -20 | -20 | -20 | -20 |
| 28 | Public admin. & defence | - | - | - | - | - |
| 29 | Social & other services | - | -20 | -20 | -20 | -20 |
| 30 | Unspecified | - | -20 | -20 | -20 | -20 |

Notes: A dash indicates that there was no input of this energy source in 1985 while a zero indicates no change in a positive input.
a. The coal input coefficient cannot be represented as a percentage change because consumption was zero in 1985. The coefficient in 2020 is projected to be 0.0716 Rp/Rp of output.
b. Includes an increase in unit consumption of natural gas (Sector 9) of +167
*Source*: NRMP-IEA case studies and sources cited in text.

### *Industrial energy conservation*

Conservation holds significant potential for energy savings in virtually all industrial sectors. Energy conservation includes measures such as housekeeping (e.g., regular tune-ups and calibration of instruments), waste heat recovery, improvements to combustion and steam systems and electric systems, process modification and cogeneration. Specific measures for each sector and the energy savings associated with these measures are discussed in detail in

Duchin and Lange (in press) based on Gamba, Caplin and Mulckhuyse (1986). We have assumed a 20 per cent reduction in energy input coefficients.

While some of these energy savings are virtually costless, others can require significant expenditures although all the measures identified are estimated to have a payback period of no more than a few years. The costs are approximated by an increase in capital requirements per unit of output of 0.5 per cent between 1985 and 2020 in the sectors affected.

*Transportation energy use*

In all countries transportation is a major source of energy demand and associated air pollution. Based on technical projections made for newly industrialising Asia in Duchin and Lange (in press) and projections for Indonesia specifically in Sathaye and Goldman (1991), the fuel efficiency of motor vehicles in Sector 26 is expected to increase by 25 per cent under Scenario S1 and 50 per cent under Scenario S2 (for both high and moderate growth paths). The fuel efficiency gains are made possible by an average 20 per cent and 30 per cent increase in the capital costs of producing an new vehicle under Scenarios S1 and S2, respectively. No assumptions have been made about the use of natural gas or biomass for transportation.

*Service and government sectors*

Trade, finance, government administration, and other services comprise a large share of Indonesia's economic activity, but they account for a very small share of total energy use -- about 1 per cent of energy use in 1985, most of which is electricity (Sathaye and Goldman 1991). Duchin and Lange (in press) projected that these sectors in newly-industrialising Asia will decrease their energy use per unit of output by 20 per cent between 1990 and 2020. A similar reduction in energy inputs will be assumed for Indonesia under both scenarios.

## 9.4 Electricity Generation

The discussion so far has focussed on total demands for energy from the household sector (private consumption) and demands for energy per unit of output from the industrial sectors. Next we make projections for one of the largest fossil fuel using sectors, electricity. We derive projections for fuel consumption and technological change in the electricity generation sector, i.e. we focus on the column of input coefficients in Sector 20.

*Current supply*

The installed capacity of the state-owned electricity utility PLN has grown from around 2.7 gigawatts (GW) in 1981-82 to around 9.3 GW in 1991-92. However, PLN's capacity has failed to keep up with booming demand. Captive power generation capacity by industry (mostly diesel generators) grew from approximately 2.0 GW in 1981-82 to around 8.6 GW in 1991-92 (Sudja 1992, p2).[5]

Since 1986 the Indonesian Government has followed a policy of diversification of energy sources in order to reduce dependence on oil. PLN has shifted away from oil towards coal, natural gas and geothermal energy. The share of oil in PLN power generation fell from 81 per cent in 1981-82 to around 46 per cent in 1991-92. Note that another source (USAID 1992, Exhibit 2-2) puts the share of oil in 1990-91 at 40 per cent, of which 10 per cent was diesel oil. Table 9.6 demonstrates that most electricity generated by PLN in the early 1990s was from coal and oil-fired power plants. These are conventional power plants located mostly on Java.

It is estimated that in 1985 captive generation accounted for 57.4 per cent of total electricity generation of 29,216 GWh. By 1990, this had fallen to 42.6 per cent (Newjec 1993, Task 1, Table A1.1-3).

In 1988-89, captive power generation by private industry was 62 per cent dependent on diesel generators. Natural gas was used by a few industries that depend on natural gas as a feedstock, notably fertilisers, and comprised 7 per cent of captive generation capacity. Hydroelectric power accounted for 11 per cent and wood for 5 per cent (USAID 1992 Exhibit 2-10). There are also many thousands of small diesel generators at the village level.

5 Note that, based on PLN data, a USAID report (1992, Exhibit 2-10) estimates captive generation at only 6.9 GW in 1990-91.

**Table 9.6 PLN's electricity production by type of power plant (TWh)**

| | 1981-82 | 1983-84 | 1985-86 | 1987-88 | 1989-90 | 1991-92 |
|---|---|---|---|---|---|---|
| Steam - oil | 4.6 | 7.4 | 7.7 | 7.0 | 7.2 | 12.2 |
| Steam - coal | - | - | 2.1 | 6.3 | 9.3 | 11.6 |
| Hydro | 1.6 | 1.8 | 3.0 | 4.5 | 6.6 | 6.6 |
| Diesel | 1.4 | 1.7 | 2.0 | 2.8 | 3.2 | 3.8 |
| Gas turbine | 1.0 | 1.1 | 0.9 | 1.4 | 1.5 | 2.6 |
| Geothermal | - | 0.2 | 0.2 | 0.7 | 1.0 | 1.1 |
| Total | 8.6 | 12.2 | 15.9 | 22.7 | 28.8 | 37.9 |

*Source*: Sudja 1992, Figure 5.

For the purposes of this analysis we require estimates of the shares of various fuels in total electricity generation, PLN and captive. Using 57.4 per cent as the estimate of the share of captive generation in total generation in 1985, we can derive estimates of fuel use for total electricity generation, as in Table 9.7.

Before estimating the shares of various fuels for electricity generation in the future we first need an estimate of the changing share of captive generation in total generation. Sudja and Pambudi (1992, Tables 4 and 5) forecast that the share of PLN and private utilities in industrial electricity consumption throughout Indonesia in 2003 will reach 90 per cent under their high scenario and 62 per cent under their low scenario, an average of 76 per cent. This is likely to be substantially higher by the year 2020. However, outside of Java and Bali there will probably be some continuing reliance on autogeneration for many years because of the costs of taking electricity to remote parts of the archipelago. In addition, the increased availability of efficient and cheap photovoltaics may result in the greater substitution of captive electric energy for non-electric energy. We estimate that in 2020 autogeneration will account for 15 per cent of total electricity generation and that it will be divided equally between diesel, hydro and solar power.

**Table 9.7 Electricity generation by type of fuel used, 1985 (TWh)**

| | PLN | Captive | Total | Share of total (%) |
|---|---|---|---|---|
| Oil | 7.7 | 0.4 | 8.1 | 21.7 |
| Coal | 2.1 | 0.0 | 2.1 | 5.6 |
| Gas | 0.9 | 1.5 | 2.4 | 6.4 |
| Diesel | 2.0 | 13.3 | 15.3 | 41.0 |
| Hydro | 3.0 | 2.4 | 5.4 | 14.5 |
| Geothermal | 0.2 | 2.8 | 3.0 | 8.0 |
| Total | 15.9 | 21.4 | 37.3 | 100.0 |

Note: In the table, 'oil' refers to residual fuel oil.
*Sources:* Column 1: PLN production for 1985-86 from Sudja (1992) Figure 5. Column 2: Captive generation = 57.4 per cent of PLN plus captive, from Newjec (1993), Task 1, Table A1.1-3; shares (for 1988-89) by fuel used in captive generation from USAID (1992), Volume II, Exhibit 2-10.

Projected shares of PLN and private utility electricity, on the one hand, and captive electricity, on the other, are shown in Table 9.8. This table assumes that the government's private power program succeeds in increasing the share of private utilities in total power generation.

**Table 9.8 Shares of utilities and captive generation in total electricity generation, 1985-2020 (per cent)**

| | Utilities | Captive |
|---|---|---|
| 1985 | 42.6 | 57.4 |
| 1990 | 57.4 | 42.6 |
| 2003 | 76.0 | 24.0 |
| 2020 | 85.0 | 15.0 |

Note: 'Utilities' includes PLN and private power utilities.
*Sources:* 1985 and 1990 - Newjec (1993, Task 1, Table A1.1-3); 2003 - Sudja and Pambudi (1992, Table 4); 2020 - NRMP-IEA estimates.

We are now in a position to develop estimates of fuel shares for electricity generation in 2020. Shares of fuels used to generate electricity will depend on the availability of fuels, costs of fuels, the capital and operating costs of plants that use various fuels, environmental considerations and the emergence of new technologies. There are two key variables that

can be influenced by government. Firstly, there are regulatory, institutional and pricing obstacles to the development of geothermal energy and the discovery and exploitation of natural gas fields, especially smaller fields that under current policies are considered uneconomic to explore or develop (World Bank, 1992). These influence the availability and cost of fuels.

Secondly, there are measures to promote cleaner technologies such as the new clean-coal technologies. It is difficult to predict which technologies will be in operation in Indonesia in 30 years time, but it is reasonable to expect that the new clean-coal technologies, such as coal gasification, will have reached a sufficiently advanced stage of development and commercial operation. However, the very large-scale investment in conventional coal-fired power stations in the 1990s and early years of the next century, and the 30-50 year life-span of these plants, will see conventional power stations continue to generate a substantial share of total electricity in 2020 and beyond. On this basis we define three scenarios for the generation of electricity, each expressed in terms of different shares of fuels and technologies in 2020.

The three scenarios are:

*Scenario 1* (PLN Scenario) This scenario takes PLN forecasts for fuel use to the year 2003 and projects them through to 2020 using a range of information. It includes our estimate that captive generation will contribute 15 per cent of total electricity, equally divided between diesel, hydroelectric and solar power.

*Scenario 2* (Natural Gas Development Scenario) Under this scenario we assume a smaller share of coal and larger shares of gas and geothermal energy. This comes about through appropriate pricing policies developed by the Ministry of Mining and Energy. There is considerable scope for the development of small natural gas fields that under the current pricing policies are uneconomic for development. There are also large reservoirs of geothermal energy which are currently not being used because of the pricing and access policies of Pertamina.

*Scenario 3* (Clean Coal Scenario) Under this scenario we assume that in addition to the greater shares of gas and geothermal energy of Scenario 2, some coal is burned using coal gasification methods in combined cycle power plants and all gas is burned in combined cycle power plants.

Building on the information of Tables 9.7 and 9.8, Table 9.9 shows projected shares of fuels and technologies used in 2020 under the three scenarios.

**Table 9.9 Shares of fuels and technologies under different scenarios (per cent)**

| | 1985 | 2020 S1 | 2020 S2 | 2020 S3 |
|---|---|---|---|---|
| *Coal* | | | | |
| Coal-fired steam | 5.6 | 45.0 | 25.5 | 15.5 |
| Coal - gasified, CC | - | - | - | 10.0 |
| *Oil* | | | | |
| Oil-fired steam | 21.7 | - | - | - |
| Diesel turbine | 41.0 | 5.0 | 5.0 | 5.0 |
| *Gas* | | | | |
| Gas steam | 6.4 | - | - | - |
| Gas CC | - | 12.8 | 20.0 | 40.0 |
| Gas turbine | - | 12.7 | 20.0 | - |
| Hydro | 14.5 | 17.8 | 17.8 | 17.8 |
| Geothermal | 8.0 | 1.7 | 6.7 | 6.7 |
| Solar | - | 5.0 | 5.0 | 5.0 |
| TOTAL | 100.0 | 100.0 | 100.0 | 100.0 |

Note: 'CC' means combined cycle. A dash means zero value.
*Source:* see text

The capital costs associated with each scenario depend on the capital costs of each type of power generating system and the share of each system in total power generation, as indicated in Table 9.9. A complete and consistent set of capital cost figures is not available. We have used as our basic source the estimates contained in Prijono (1991, Table II) and supplemented for other technologies by Newjec (1993, Task 5, Appendix 5.3) and our own estimates. Estimates of per unit capital costs for each type of technology appear in Table 9.10. The estimates of Table 9.10 are combined with the changes in shares in Table 9.9 to calculate the changes in the unit capital costs associated with the combinations of fuels and technologies that define the future scenarios. These are reported in Table 9.11 below. It is assumed that there are no changes in the labour requirements per unit of electricity generated under the three scenarios.

**Table 9.10 Capital costs per unit of energy output and thermal conversion efficiencies for various technologies**

| | Capital cost (cents/kWh) | Feasible thermal conversion efficiency (per cent) |
|---|---|---|
| *Coal* | | |
| Coal-fired steam | 2.20 | 37 |
| Coal - gasified, CC | 2.00 | 45 |
| *Oil* | | |
| Oil-fired steam | 2.26 | 37 |
| Diesel turbine | 1.20 | 37 |
| *Gas* | | |
| Gas steam | 2.26 | 37 |
| Gas CC | 1.43 | 45 |
| Gas turbine | 1.30 | 37 |
| Hydro | 1.30 | - |
| Geothermal | 2.76 | - |
| Solar | 2.00 | - |

*Sources:* Capital cost estimates for coal-steam, oil-steam, gas-steam, gas CC and geothermal are from Prijono (1991, Table II); estimates for diesel, gas turbine and hydro are derived from figures on capital costs per kW of capacity in Newjec (1993, Task 5, Appendix 5.3); estimates for gasified coal CC and solar are NRMP-IEA approximations only.

Next we need to take account of changes in thermal conversion efficiency (TCE). According to UN estimates, thermal conversion efficiency in Indonesia in 1985 was 28 per cent (United Nations 1988). In future, we expect this figure to rise significantly due to both improved operating efficiency of power plants and to the switch to combined cycle generation, both natural gas and gasified coal (see Table 9.10). Whereas coal-fired steam power plants are typically estimated to have a TCE of 37 per cent, gas combined cycle plants are estimated to have a TCE of from 42 to 50 per cent (Sudja 1992, Table 7, p15).

Duchin and Lange (1992b, p27) estimate that to obtain similar improvements in thermal conversion efficiency as well as reductions in transmission and distribution losses, an additional 20 per cent of capital inputs per unit increase in capacity will be required. We assume that this capital outlay improves average TCE from 28 to 37 per cent and that changes in the composition of generating technology account for the rest of the improvement in TCE. Estimates of average thermal conversion efficiency under the three scenarios appear in Table 9.11.

Losses in transmission and distribution by PLN fell from 20.2 per cent of energy production in 1985 to 15.6 per cent in 1990-91 (PLN, 1991, Table 31, p33). Newjec (1993, Task 5, p3)

expects these losses to fall to 9.9 per cent by 2004 and to stabilise at that level thereafter. Own use of electricity by PLN declined from 4.9 per cent of total electricity generated by PLN in 1985 to 4.8 per cent in 1990/91. Newjec (1993, Task 5, p3) expects no change in this figure in the future. These changes are also reported in Table 9.11 below. In addition, the table indicates the assumption that no change is expected in labour inputs per unit of output. The 1985 unit price is also reported in the bottom panel, which contains all of the changes in technological coefficients used in the model.

The first row of the middle panel of Table 9.11 shows the savings in fossil fuels per unit of electricity delivered that will occur as a result of increases in thermal conversion efficiency and reduced losses in transmission and distribution.

In the input-output framework, the principal inputs into electricity generation are coal, oil and gas, electricity (own use) and capital equipment and construction. The changes in input coefficients expected under each scenario are shown in the lower panel of Table 9.11.

**Table 9.11 Parameters governing thermal conversion efficiency, losses in transmission and distribution and changing input requirements under various scenarios**

| | 1985 | 2020 S1 | 2020 S2 | 2020 S3 |
|---|---|---|---|---|
| Average thermal conversion efficiency (%) | 28 | 37 | 39 | 43 |
| Losses in transmission and distribution (%) | 20 | 9.9 | 9.9 | 9.9 |
| Own-use of electricity (% of total) | 4.9 | 4.8 | 4.8 | 4.8 |
| Percentage changes in input requirements due to projected increases in thermal conversion efficiency (TCE) and reduced losses in transmission and distribution (T&D) * | | | | |
| *Inputs* | | | | |
| Fossil fuels | | -33 | -36 | -42 |
| Own-use of electricity | | -2 | -2 | -2 |
| Capital requirements | | | | |
| . to improve TCE & reduce T&D losses | | +20 | +20 | +20 |
| . due to shifts in technology | | +7 | +1 | 0 |
| Total capital requirements | | +27 | +21 | +20 |
| Total changes to input coefficients for electricity production compared to 1985 ** | | | | |
| Coal (Sector 7) | | +438 | +191 | +164 |
| Oil (Sector 18) | | -95 | -95 | -95 |
| Gas (Sector 9) | | +167 | +300 | +263 |
| Electricity (own-use) (Sector 20) | | -2 | -2 | -2 |
| Capital requirements | | +27 | +21 | +20 |
| Labour requirements | | 0 | 0 | 0 |
| 1985 unit price (Rp/kWh) | | 97.39 | | |

* Calculated as follows for S1. In 1985 1 tonne of fossil fuels on average *delivered* 22.4 per cent of maximum potential energy (= 28 x 0.8). Under S1 this increases to 33.3 per cent in 2020 (37 x 0.901). This represents a 33 per cent reduction in the amount of fossil fuels required to deliver each unit of electricity.

** Percentage changes in coal, oil and gas coefficients are calculated using the percentage changes for fossil fuels in the middle panel of this table combined with the changes in shares of fossil fuels reported in Table 9.9. Thus the change in the coal coefficient under S1 is given by [(45.0 x 0.67) - 5.6]/5.6 = 438%.

# CHAPTER 10

# FOOD, BEVERAGES AND TOBACCO*

## 10.1 Introduction

This chapter describes current and future technologies in the Indonesian food, beverages and tobacco (FB&T) sector (Sector 11 in the NRMP-IEA 30-sector classification system). It relies on case studies from the palm cooking oil and the flour milling industries to describe the technological changes expected in the period 1985-2020.

The sector has a complex mixture of industries, with processing and production occurring in establishments that vary widely in level of technology and scale of operations. Wheat flour milling, for instance, is effectively a monopoly that uses modern, capital-intensive technology; the oil and fat industry has numerous small- and medium-scale processors (including multi-national corporations) using widely differing production technologies; the tobacco industry is split between labour-intensive hand-rolled clove cigarette manufacturing and highly automated production using quite modern technology; and the sugar refining industry (which is largely state-owned) relies on antiquated equipment and processes dating from the colonial era.

The sector is composed of the Sectors 27-34 in the BPS 66-sector classification. The outputs and shares of output in 1985 are shown in Table 10.1.

**Table 10.1 FB&T: Outputs by BPS 66-sector classification, 1985**

| Sector | | Output (Rp $10^6$) | Share of total (%) |
|---|---|---|---|
| 29 | Cereal mill products | 7,934,399 | 47.53 |
| 34 | Cigarettes & tobacco products | 3,413,506 | 20.39 |
| 32 | Other food products | 1,714,324 | 10.63 |
| 28 | Oil & fat | 1,003,460 | 6.06 |
| 31 | Sugar | 815,461 | 4.90 |
| 30 | Flour (all kinds) | 783,338 | 4.78 |
| 27 | Food processing & preserving | 591,101 | 4.13 |
| 33 | Beverages | 258,759 | 1.59 |

*Source:* BPS 1989

* This chapter is based on *NRMP-IEA Input-Output Working Paper* Number 13 (Foley, Umaya and Suharno, 1993)

In 1985 the sub-sector cereal mill products accounted for over 50 per cent of total sectoral output (by value), with cigarette and tobacco products and other food products accounting for about 20 per cent and 11 per cent of output respectively (Table 1). The picture is somewhat confounded by the dominance of output by volume by the cereal mill subsector, as most of this output is in fact milled rice that is processed by thousands of rice mills throughout the rice producing areas of Indonesia. Because little change is expected in the simple technology and wide geographical dispersion of the cereal milling industry, it was not considered to be a priority for a case study despite its dominance of sectoral output.

It was decided to focus efforts on the oil and fat subsector, as this sector is expanding rapidly (due to income-induced changes in composition of diet) and because the production processes are known to have potentially severe environmental impacts in terms of production wastes.

The flour milling subsector is a special case because it relies wholly on imported raw materials and uses modern, highly-automated production processes. Its output is the basic input to much of the processed food industry (e.g. bread and noodles), a rapidly growing industry. While its environmental impact is low to moderate (minor dust and water pollution) it illustrates the likely trend towards highly-automated, capital-intensive food processing industries.

Overall, the largest intermediate input into FB&T is from Sector 1 (Paddy), which in 1985 accounted for over 50 per cent of total intermediate inputs and is explained by the dominance of the cereal mill products sub-sector. Inputs from agricultural sectors (estate crops and other food crops plus paddy) accounted for about 75 per cent of total intermediate inputs. The major intermediate inputs to this sector are listed in Table 10.2.

**Table 10.2 FB&T: Principal intermediate inputs, 1985**

| Sector | | Coefficient (Rp/Rp) |
|---|---|---|
| 1 | Paddy | 0.40422 |
| 3 | Estate crops | 0.13171 |
| 11 | FB&T | 0.06868 |
| 2 | Other food crops | 0.05150 |
| 17 | Other manufacturing | 0.00935 |

*Source:* BPS (1989)

## 10.2 Palm Cooking Oil: Current Technology

The oil and fat sub-sector consists of industries processing vegetable and animal oils. There are three types of primary vegetable oil produced in Indonesia: palm oil, coconut oil and soybean oil. By far the most import of these are palm and coconut oil, with palm oil accounting for 80 per cent of total crude vegetable oil production in 1990 (Table 10.3).

**Table 10.3 FB&T: Major types of crude vegetable cooking oil, 1990**

| | Quantity (tonnes) | Share of total (%) |
|---|---|---|
| Palm oil | 2,254,543 | 80.4 |
| Coconut oil | 505,555 | 18.0 |
| Oil from other vegetables | 44,795 | 1.6 |
| Total | 2,804,893 | 100.0 |

*Source:* BPS (1990)

Within this subsector it was decided to focus on the processing of palm oil, as production of this source of cooking and manufacturing oil is expanding rapidly, averaging 20.7 per cent p.a. over 1986-90. In addition to meeting rapidly rising domestic demand for cooking oil (11.3 per cent p.a. over 1986-90), the palm oil industry is also rapidly increasing exports of processed oil. The industry also supplies basic inputs for the production of non-food products (e.g. soap, wax, resins and surfactants).

In 1990 there were 45 registered palm cooking oil processors, compared with 37 in 1985, with a combined registered capacity of some 2.33 million tonnes per annum. However, a report by PT Data Consult (1991) notes that actual installed capacity of most plants typically exceeds their registered capacity by 2-4 times; the company selected for this case study is no exception.

The information about current technology came from a January 1993 Environmental Impact Analysis (AMDAL) of PT Sawit Malinda Edible Oil Industries (PT SME), a cooking oil producer located in Medan, North Sumatera. Their main products are olein (91 t/day or 27,300 t/annum), and stearin (24 t/day or 7,200 t/annum); their registered capacity is 14,000 t/annum. The primary raw materials are crude palm oil (CPO) and crude palm kernel oil (CPKO). PT SME is a relatively small producer, responsible for only about one percent of national production of palm cooking oil in 1990, but its production

techniques are typical of the industry. This information has been augmented by visits to other oil palm processing plants.

*Material and energy requirements*

The current technology used by PT SME involves the use of a series of cooling, degumming, bleaching and deodorising steps prior to separating (fractionating) the olein and stearin components of the CPO and CPKO. The products of fractionation are then heated, centrifuged and filtered. Raw materials and chemicals used are listed in Table 10.4.

Water consumption is 648 m3/day, or 5.6 m3 per tonne of output, and water output 4.4 m3 per tonne of output. The main source of energy is electricity bought from PLN; the company also owns a generator with a capacity of 1,810 KVA for backup. Total electrical energy used is 48,000 KWh/day, or 417.4 KWh/t of production. Total labour force at the company is 84 persons.

**Table 10.4 FB&T: Inputs used in producing palm cooking oil, 1992**

| Input/impact | Amount per unit of time | Amount per tonne of output |
|---|---|---|
| *Raw material* | *t/day* | *t/t* |
| Crude palm oil | 120 | 1.043 |
| Crude palm kernel oil | 10 | 0.087 |
| *Chemicals* | *t/year* | *t/t* |
| Sodium aluminium sulphate | 15.6 | 0.00045 |
| Magnesium sulphate | 45.6 | 0.00132 |
| Bleaching earth | 438 | 0.01269 |
| Phosphate acid | 26 | 0.00075 |
| *Energy* | | *KWh/t* |
| Electricity | | 417.4 |
| *Output* | *t/day* | *t/t* |
| Refined oil output | 115 | 1.130 |
| *Water* | | *$m^3$/t* |
| Water input | | 5.6 |
| Water output | | 4.4 |

Notes: t/t = tonnes of input per tonne of output
*Source:* Sawit Malinda Edible Oil Industries 1993

*Waste and pollutant generation*

There are two types of waste generated from refining palm oil based cooking oil (see Table 10.5 for details):

- Solid waste: bleaching earth of 438 tonnes/annum; and
- Liquid wastes: BOD, COD, TSS, dissolved solids, and oil and greases.

The solid wastes are sold to the construction industry as solid fill, and apparently have no direct adverse environmental impacts. In our estimate, in 1985 the liquid wastes were discharged unprocessed into local water courses, except for some oil being skimmed-off for use in soap production. There has been some improvement since then, but visits to production facilities in Jakarta revealed that in many palm oil plants waste water is still only partially processed, at best, before discharge. Thus, we have assumed that water pollution in 1985 is equivalent to the discharge of untreated waste water, data for which was given in the AMDAL (see Table 10.5.6).

**Table 10.5 FB&T: Water pollution in cooking oil production, 1991**

| Parameter | Unit | Level | KLH standard |
|---|---|---|---|
| Dissolved solids | $g/m^3$ | 450 | 2000 |
| Suspended solids | $g/m^3$ | 608 | 200 |
| COD | $g/m^3$ | 360 | 100 |
| BOD | $g/m^3$ | 248 | 50 |
| Oil and grease | $g/m^3$ | 20 | 5 |

Note: Pollutant measured prior to treatment, based on water output per tonne of production.
*Source:* Sawit Malinda Edible Oil Industries 1993

## 10.3 Palm Cooking Oil: Future Technology

It is expected that in the medium-term (5-10 years) there will be significant changes in cooking oil processing technology. Although this new technology is already in use in Malaysia, its widespread adoption to Indonesia will be delayed, on the whole, until the value of recent investments in processing facilities is amortised. The new technology is called Super Critical Fluid Extraction (SCFE), and is a single-step process. By eliminating most steps required by the older technology, it will markedly reduce electricity, water and

labour requirements. The range of chemicals previously used will be totally replaced by carbon dioxide (CO2).

As the new technology is a single-step process use of chemicals will be reduced to approximately half of present use per tonne of production. Similarly, the elimination of cooling and heating steps in the process will reduce the demand for process energy by an estimated 50 per cent over 1985 levels (Table 10.6). Because water is no longer used in the new process, water will only be used for domestic and cleansing purposes, and water requirements will decline by approximately 75 per cent per unit of production.

The simplification of the production process, which will be more fully automated, will also markedly reduce labour requirements while at the same time increasing the proportion of skilled labour required to operate the process. It is estimated that labour requirements will decline by about 70 per cent per tonne of production. On the other hand, the capital required per unit of output will be double that required with the present technology, substituting capital for chemical, energy and labour inputs.

**Table 10.6 FB&T: Changes in inputs per unit of output in the palm cooking oil industry, 1985-2020**

| Input | Change 1985-2020 (%) |
|---|---|
| Chemical | -50 |
| Electricity | -75 |
| Labour | -70 |
| Water | -75 |
| Capital | +100 |

*Source:* Dr Manulung, food technology expert, Bogor Agricultural University (IPB), personal communication, 1993

Changes in the production process, in particular the elimination of degumming, bleaching and deodorising chemicals, and the reduction in the use of water, will result in significant reductions in environmental impacts from waste water. Table 10.7 shows reduced levels of important pollutants due to a marked reduction in the amount of semi-processed oil discarded in waste water.

**Table 10.7 FB&T: Change in levels of water pollution in the palm cooking oil industry, 1985-2020**

| Input | Change 1985-2020 (%) |
|---|---|
| Water input/output | -75 |
| Water output/output | -75 |
| BOD | -73 |
| COD | -75 |
| Dissolved Solids | -80 |
| Suspended Solids | -86 |

*Source:* Dr Manulung, food technology expert, Bogor Agricultural University (IPB), personal communication, 1993

## 10.4 Flour Milling: Current Technology

To represent the sub-sector, wheat flour milling was chosen for the case study. Milling imported wheat accounted for some 98 per cent of total production from the sub-sector in 1990. The production of wheat and other types of flour in 1990 is given in Table 10.8. Because most rice flour is produced for own-consumption by households, the official statistics seriously underestimate actual production.

**Table 10.8 FB&T: Production of flour by type, 1990**

| Type | Quantity (t) | Value (Rp $10^3$) |
|---|---|---|
| Wheat flour | 1,744,307 | 387,304,090 |
| Rice flour | 8,058 | 5,282,280 |
| Other flours | 21,516 | 10,588,970 |
| Total | 1,773,881 | 403,175,340 |

*Source:* BPS (1991a)

There is only one producer milling wheat flour in Indonesia, PT Bogasari Flour Mills. PT Bogasari has two factories, located in Jakarta and Surabaya. Bogasari's Jakarta production capacity is 4,000 tonnes of milled flour per day. The information used here comes from PT Bogasari production staff, company literature and BPS industrial statistics (BPS 1990a). The two major flour using sectors are bread and bakery products and noodles, macaroni and the like, which consume 30 per cent and 27 per cent of the total production, respectively.

The raw material for wheat flour milling is imported wheat grain. In the first step of the milling process wheat grains are separated from other grains or foreign materials and cleaned. Sometimes wheat with different characteristics is blended after the cleaning process to obtain the required qualities for milling and various types of flour.

Moisture is added before the milling process begins. Corrugated rollers break the grains into coarse particles, and successive rollers then reduce these particles to flour. The crushed wheat is sifted through successively finer screens; air currents and sieves separate bran and classify particles.

PT Bogasari produces wheat flour (74 per cent of grain) and pollard and bran (26 per cent). Based on this milling ratio the quantity of wheat required to produce a tonne of flour is 1.35 tonnes.

Water is used for moistening the grain prior to milling and also for domestic and cleaning purposes. Total water consumption in 1985 was 114,060 m3 (367.5 m3/day). The main source of energy in 1985 was industrial diesel oil (IDO), used for own-generation of electricity. In 1985, IDO consumption was 23,400 m3 (75 m3/day or 63.8 t/day), or 0.05 m3/t of milled flour. Raw material, water and fuel inputs required for producing one tonne of flour are listed in Table 10.9.

**Table 10.9 FB&T: Materials used in producing wheat flour, 1993**

| | Units | Inputs per tonne of flour |
|---|---|---|
| Wheat Grain | t/t | 1.35 |
| Water | $m^3/t$ | 0.224 |
| IDO | $m^3/t$ | 0.05 |

*Source:* Bogasari Flour Mills, personal communication, 1993

*Labour requirements*

In 1985, the total labour at the company's Jakarta plant was 996 persons, with a slight decline in numbers to 980 by 1993 representing a 40 per cent decline over 1985 in the amount of labour required per tonne of production.

*Pollution*

The main sources of pollution from wheat milling are flour dust and waste water from domestic uses. As flour dust is in fact the main product and is valuable and relatively easy to collect, effective dust control equipment has been installed. Hence, air pollution generated by milling is minimal, this was confirmed from a visual inspection of the plant and surroundings, which are in fact quite free of dust. In the case of waste water, there is no water treatment unit to ensure that waste water is within the environmental standards and there is no information on water quality available from the company.

## 10.5 Flour Milling: Future Technology

Technological development in the next 25 years is expected to increase the efficiency of milling and refining machinery from 74 per cent to 82 per cent. The improved milling yield will result from improvements in both roller technology and in the control systems used to separate milling products (flour and bran). This will reduce the amount of grain required for one tonne of flour from 1.35 tonnes (74 per cent milling efficiency) to 1.22 tonnes (82 per cent efficiency). As a result, the production of bran and pollard milling by-products will be reduced to 18 per cent of output by weight.

Water consumption per tonne of flour production will decline in line with increased milling efficiency, from 0.224 m3/t to 0.193 m3/t, a decline of 14 per cent. Consumption of diesel fuel will decline at an identical rate, from 0.05 m3/t to 0.037 m3/t, a 14 per cent reduction per unit of flour produced.

Automation will reduce labour required from 2.0 person-years/1000 tonne in 1985 to 0.79 person-years/1000 tonne in 2020, a 60 per cent reduction in labour requirements per tonne of production. Table 10.10 summarises the expected changes in technological coefficients for inputs to flour milling in the year 2020.

**Table 10.10 FB&T: Changes in inputs per unit of output in the flour milling industry, 1985-2020**

| Input | Change 1985-2020 (%) |
|---|---|
| Wheat | -10 |
| IDO | -14 |
| Labour | -60 |
| Capital | +10 |
| Water | -14 |

*Source:* NRMP calculations

## 10.6 Food, Beverages and Tobacco: Changes in Technological Coefficients to 2020

The sector is dominated by rice milling, the technology for which is not expected to change significantly by the year 2020 since most production is by small-scale, low capital household operations. Moreover, the relative importance of rice milling is expected to decline due to rapid growth in the rest of the sector. Rapid changes in technology are anticipated in other types of food and beverage processing. These changes are likely to be similar to those occurring in the cooking oil industry, with major effects on capital intensity, energy and labour requirements and environmental impacts. In industries such as flour milling, improvements in computer-based process control will result in continuing reductions in energy and labour requirements and moderate increases in capital requirements per unit of production. Labour-intensive industries, such as cigarette manufacturing, are also expected to become much more highly mechanised and automated, with consequent declines in labour requirements and increases in energy and capital requirements per unit of output.

To estimate the impact of technological change in the FB&T sector as a whole we take account of both the changing relative weights of the sub-sectors and the expected technological changes in the palm cooking oil, flour milling and similarly affected sub-sectors. Changes in technological coefficients for the food, beverages and tobacco sector are presented below in Table 10.11.

**Table 10.11 Food, beverages and tobacco: Changes in technological coefficients, 1985-2020**

| | | Change between 1985 and 2020 (%) |
|---|---|---|
| *Intermediate inputs*[a] | | |
| 13 | Pulp and paper | +6 |
| 15 | Chemicals | -25 |
| 17 | Other manufacturing | -3 |
| 18 | Petroleum refining | -25 |
| 20 | Electricity | -35 |
| *Labour inputs* | | |
| Total employment per unit output | | -50 |
| *Capital inputs* | | |
| Total new capital requirements | | +75 |
| 17 | Other manufacturing | +75 |
| 23 | Construction | +75 |

*Natural resource impacts*

| | Unit | 1985 level | |
|---|---|---|---|
| Water input/output | $m^3/t$ | 5.6 | -75 |
| Water output/output | $m^3/t$ | 4.4 | -75 |
| BOD | $g/m^3$ | 248 | -73 |
| COD | $g/m^3$ | 360 | -75 |
| Dissolved solids | $g/m^3$ | 450 | -80 |
| Suspended solids | $g/m^3$ | 608 | -86 |

Note: a. NRMP-IEA 30-sector classification.
*Sources*: see text

# CHAPTER 11

# CEMENT AND CONSTRUCTION*

## 11.1 Cement: The Industry

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. PC type II, PC type V, white cement, and oil-well cement, which have special uses and limited demand are also produced (Data Consult 1992). Average utilisation of the industry's capacity in 1990 was 90 per cent. There were a total of 10 companies in 1990, with production dominated by PT Indocement Tunggal Prakasa (ITP), with a 46 per cent share of total production. The second largest company is PT Semen Cibinong (SC), with a 17 per cent share of total production capacity.

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.

The construction industry is the major user of cement, consuming nearly 90 per cent of total production by value in 1985. The remaining 10 per cent is used by other manufacturing sectors, including manufacture of nonmetallic mineral products and other products.

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 installed 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 million tonnes per annum by 2000.

The case study focused 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

* This chapter draws on *NRMP-IEA Input-Output Working Paper* Number 11 (Foley and Umaya, 1993).

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 next few years.

## 11.2 Cement: Current Technology

There are two types of production processes 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:

- the technology for raw materials mixing, preparation and control is simpler;
- labour requirements are lower; and
- there is less pollution of the environment by dust.

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

*Raw Materials*

The main inputs to cement manufacturing are limestone (80 per cent of total), clay (5-10 per cent) and gypsum (2-5 per cent). Additives such as silica sand, iron oreor pyrite cinder are used in differing 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 per cent 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. According to ITP and SC, the proportions of limestone and clay used for clinker production has remained unchanged over 1985-90.

Table 11.1 lists the main intermediate inputs to cement production in 1985 by value. Inputs from these nine sectors account for over 90 per cent of total intermediate inputs. From this table it is clear that energy inputs from petroleum refining (oil and natural gas) and from other mining (limestone and clay) were the most important. It is important to note that coal, a minor input in 1985, had by 1990 become the major energy source for cement production, substituting for oil and natural gas.

**Table 11.1 Cement: Principal intermediate inputs, 1985**

| Sector | | Coefficient (Rp/Rp) |
|---|---|---|
| 18 | Petroleum refining | 0.1461 |
| 10 | Other mining | 0.1103 |
| 13 | Pulp and paper | 0.0763 |
| 26 | Transport and communication | 0.0498 |
| 20 | Electricity | 0.0390 |
| 15 | Chemicals | 0.0294 |
| 27 | Real estate & finance | 0.0243 |
| 7 | Coal | 0.0143 |
| 23 | Construction | 0.0102 |

*Source:* BPS (1989)

*Labour requirements*

Data from different official sources on the 1985 workforce in the cement sector (including limestone quarrying) conflict. The input-output tables (BPS 1989) report a workforce of 102,340 persons (including the workforce engaged in limestone quarrying) while the national inter-censal survey (SUPAS) gives a figure of 17,406 persons. No data are available directly from cement industry sources for 1985, but at the beginning of 1990 total labor in the cement industry was 16,354 persons according to the industry (FBCII 1991).

Company and survey data indicate that in 1990 ITP's production technology was approximately half as labour intensive as the industry as a whole -- 0.542 person-years per thousand tonnes of output for ITP as opposed to 1.036 for the industry as a whole (see Foley and Umaya, 1993). Unskilled and semi-skilled workers make up the bulk of the workforce in the industry (including ITP and SC), with highly-trained technical staff a minority.

*Energy consumption*

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

A comparison of thermal energy consumption (excluding electricity) of the cement plants in Indonesia in 1990 shows substantial variation around the industry average of 3.391 GJ/t. Among the bigger plants, Semen Tonasa had a consumption of 3.099 GJ/t while Semen Gresik had 5.065, SC had 4.052 and ITP had 3.288. 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.

The energy diversification program for the cement industry in Indonesia has led to a substitution of coal for oil and natural gas. In 1985 coal supplied 26 per cent of the industry's total energy, fuel oil 26 per cent, IDO 20 per cent and natural gas 28 per cent. By 1989 coal was supplying 78 per cent of the industry's total energy, fuel oil less than 4 per cent, IDO less than 2 per cent, but natural gas use had increased four times to 17 per cent. Part of coal requirements are currently met by importing coal from Australia and China.

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 there is little 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 11.2.

**Table 11.2 Cement: Sources of air pollution**

| Source | Emission |
|---|---|
| Raw materials grinding and handling | particulates (dust) |
| Kiln operations and clinker cooling | particulates (dust)<br>CO, SOx, NOx,<br>hydrocarbons<br>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. Both ITP and SC use a range of dust control equipment (e.g. multi-cyclones and bag filters) plus newly installed electrostatic precipitators to reduce dust emissions and recycle dust. The electrostatic precipitators at both ITP and SC are rated at 99.99 per cent efficient. In practice, the efficiency of this equipment depends greatly on the temperature of the dust particles and the amount of water in the particles (Marlin 1987).

It should be noted that dust generation represents a significant fraction of clinker production throughput, about 12 per cent according to IC Consult data (1991). There are thus obvious economic incentives to recycle clinker dust, which has already consumed substantial amounts of raw materials, energy and labour in processing to a semi-finished state. According to SC's staff, using an electrostatic precipitator (and other dust control equipment), 99.99 per cent of dust is recycled to produce clinker. The investment required for their first two electrostatic precipitator 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 claims 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.

On the basis of direct observation it appears highly unlikely that only 0.012 kg/t of dust is released into the air. If, for instance, only 99 per cent of dust is captured by the dust control equipment this would result in the release of some 1.2 kg/t, one hundred times the 'official' figure.

For 1985, before the installation of electrostatic precipitators by any of the cement producers, we assume that only 95 per cent of dust from kiln operations was recycled. IC Consult (1991) estimate uncontrolled dust emissions to be 122 kg/t. These give an estimate of 6.1 kg/t of output in 1985 for technically advanced producers such as ITP and SC.

## 11.3 Cement: Changes in Technological Coefficients to 2020

Most technological development in the cement industry focuses on energy savings due to 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 per cent 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 continue to produce 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 now 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 operate it either properly or on a full-time basis.

*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 petroleum was 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 both for firing clinker kilns and on-site generation of electricity. This shift in fuel sources is estimated to have resulted in a 90 per cent reduction in the use of products from the petroleum refining sector and a 100 per cent reduction in LPG use. The savings in energy use possible from improvements in process efficiency are described below.

Compared to the wet process, the dry process (with a suspended preheater kiln system) results in a significant reduction of energy consumption (40-50 per cent) and has already resulted in widespread 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 processing. Thus, energy savings in the future will be incremental rather than sudden. However, the scale of potential energy savings is still significant.

According to industry sources, further potential reductions in energy consumption could come from calcination of clinker in a fluidised bed kiln, changing the mineralogy of cement by using a mineraliser, adoption of low temperature technology for clinker processing using calcium chloride, 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. According to UNIDO (1985), these technologies carry a potential for energy savings of 58-87 per cent in the case of fuels and 25-40 per cent in the case of electricity.

A comparison of the wide range of energy consumption rates for 1985 and 1990 referred to in the previous section shows major energy savings are readily achievable and have already been achieved by some producers despite lower thermal efficiencies caused by the switch to coal. If we assume that the average plant by 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 reduction of 7.9 per cent 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.

Additional energy savings are possible if the new technologies listed above were put into place by 2020. With some combination of these technologies further improvements in thermal efficiency of at least 25 per cent (less than half the possible improvement according to UNIDO) should be achievable by 2020. A further 25 per cent improvement

over 2000 in efficiency by 2020 would reduce thermal energy required to about 2.32 GJ/t, a saving of 31.5 per cent compared to 1985.

*Labour requirements*

ITP and SC's combined labour requirements in 1992/93 were about 0.560 person-years/1000 t. Assuming production in their existing plants reaches 90 per cent of design capacity 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 represents a net decline in labour inputs of about 57 per cent or a reduction in labour requirements of 36 per cent per unit of production. This level of labour requirements is probably close to the maximum 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 technologically advanced as ITP and SC are now.

*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 anecdotal evidence of turning off dust control equipment already installed is 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 to substantially increase the number of trained personnel available for equipment operation and maintenance since increases in the efficiency of most types of emission controls depends crucially on operational and maintenance standards.

According to both ITP and SC, equipment capable of controlling dust emissions from kiln operations to well below the GOI environmental standard of 400 mg/m$^3$ has already been installed. However, the GOI standard is eight times the World Bank standard of 50 mg/m3. This is a measure of dust concentration in the atmosphere whereas the measures developed below are emissions of dust per unit of cement output.

For 1985, we estimate a level of 6.1 kg of dust emissions per tonne of cement output, based on dust control equipment being 95 per cent effective. If efficiency improves to 99 per cent dust emissions would fall to 1.22 kg/t of output. Reductions below this level will be harder to achieve, requiring markedly higher investments in purchase and maintenance of dust control equipment. Compared to 1985, 1.22 kg/t represents an 80 per cent reduction in dust emission per unit output in 2020.

It is estimated that by 2020 thermal fuel consumption will have declined to 2.32 GJ/t, a reduction in requirements of 31.5 per cent 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.

Changes in technological coefficients for the cement sector are summarised in Table 11.3.

**Table 11.3 Cement: Changes in technological coefficients, 1985-2020**

| | | | Change between 1985 and 2020 (%) |
|---|---|---|---|
| *Intermediate inputs*[a] | | | |
| 7 | Coal | | (.0716)[b] |
| 18 | Petroleum refining | | -90 |
| 19 | LNG | | -100 |
| 20 | Electricity | | -8 |
| *Labour inputs* | | | |
| Total employment per unit output | | | -57 |
| *Capital inputs* | | | |
| 17 | Other manufacturing | | +17 |
| 23 | Construction | | |
| *Natural resource impacts* | | | |
| | Unit | 1985 level | |
| Dust | kg/tonne | 6.1 | -80 |

Notes: a. NRMP-IEA 30-sector classification.
b. The coefficient for coal is the absolute level of coal inputs per unit output in Rp/Rp.

## 11.4 Construction: Changes in Technological Coefficients to 2020

The construction sector is a major direct user of energy as well as a major user of energy-intensive materials like steel, cement, and aluminum. As the economy continues to grow, it can be expected that maintenance and repair will constitute an increasing share of

construction activities. This assumption is significant because replacement and maintenance activities are considerably less material-intensive than new construction although they require increased inputs of labour and chemicals, mainly paints.

Within new construction, there will be a significant expansion in the construction of buildings due to income growth and urbanisation and relatively slower growth of infrastructure and engineering construction. The former uses more cement, concrete, and wood, while the latter is more metal-intensive. Aluminum, produced in Indonesia in increasing quantities, will substitute for many other materials in construction.

The combined effect of these assumptions about construction is a reduction in the physical quantity of raw materials required for an average structure. Estimates of the average annual percent change of input coefficients to construction for Indonesia, based on the assumptions of Duchin and Lange (in press) for newly industrialising Asia, are shown in Table 11.4. These changes contribute toward a substantial, although indirect, savings of energy per unit of output of the construction sector.

**Table 11.4 Construction: Changes in input coefficients, 1985-2020**

| | | 2020 relative to 1985 (%) |
|---|---|---|
| 15 | Chemicals | +42 |
| 16 | Cement & limestone | -16 |
| 17 | Other manufacturing | -12 |

*Source:* Duchin and Lange (in press)

# CHAPTER 12

# TEXTILES, LEATHER AND WEARING APPAREL*

## 12.1 Textiles, Leather and Wearing Apparel: The Industry

The textiles, leather and wearing apparel industry is classified as Sector 17.2 in the NRMP-IEA 30-sector classification (part of Sector 17, Other Manufacturing). It is Sector 36 in the BPS 66-sector classification. It covers several industries including weaving, wearing apparel, knitting, tanned and finished leather, footwear and leather products, and carpets and rugs. Using the detailed BPS 169-sector classification, the shares of each sub-sector in value of output in 1985 are shown in Table 12.1.

**Table 12.1 Textiles, leather & wearing apparel: Shares of output, 1985**

| BPS 169-sector classification | | Share of 1985 value of output |
|---|---|---|
| 76 | Weaving | 49.7 |
| 79 | Wearing apparel | 25.1 |
| 83 | Footwear and leather products | 7.5 |
| 78 | Knitting | 5.6 |
| 80 | Carpets, rugs, rope and the like | |
| 77 | Made-up textile goods (except (wearing apparel) | 3.8 |
| 82 | Tanned and finished leather | 2.2 |
| 81 | Other textiles | 0.9 |

*Source*: BPS 1989

It is apparent from Table 12.1 that weaving and wearing apparel accounted for a very large share of total output in 1985. In 1990, the weaving subsector still contributed the biggest share in the sector but wearing apparel had grown more rapidly. According to the BPS Industry Survey (BPS, 1990), the share of weaving had fallen to 45.3 per cent in 1990, wearing apparel had risen to 29.4 per cent, footwear and leather products to 9.5 per cent, and knitting to 8.5 per cent.

* This chapter draws on *NRMP-IEA Input-Output Working Paper* Number 14 (Hamilton and Iskandar, 1993b)

The major intermediate inputs for the sector are provided by yarn spinning, textiles, leather and wearing apparel, chemicals and petroleum refining. The principal intermediate inputs for Sector 17.2 are listed in Table 12.2.

**Table 12.2 Textiles, leather & wearing apparel: Principal intermediate inputs, 1985**

| Sector | | Coefficient (Rp/Rp) |
|---|---|---|
| 17.2 | Textile, leather & wearing apparel | 0.449 |
| 15 | Chemicals | 0.051 |
| 18 | Petroleum refining | 0.013 |

*Source*: BPS 1989

In this case study of the textile, leather and wearing apparel sector, we focus on two subsectors, weaving and the tanned and finished leather industry. These two subsectors accounted for 51.9 per cent of the value of output in the sector in 1985. Selection was based on their shares in the total value of output and their environmental impacts.

## 12.2 Weaving: Current Technology

The description of current technology is derived from data gathered from PT Argo Pantes, an integrated textile plant, PT Century Textile and PT Sandratex. Argo Pantes produces printed and non-printed fabrics while Century Textile and Sandratex produce only non-printed fabrics.

According to Capricorn Indo Consult (1991), Argo Pantes and Sandratex are two of the biggest textile plants in Indonesia, each with a capacity of 0.6 per cent of total Indonesian capacity. Century Textile contributes 0.4 per cent of total capacity. Argo Pantes uses the most advanced technology in textile making in Indonesia. According to the plant manager from this company, the technology used in Argo Pantes is almost 10 years ahead of the average textile plant in Indonesia.

The production process in these companies includes weaving, desizing, bleaching, mercerizing, dyeing and finishing. For printed fabrics, before the finishing process, fabrics undergo the printing process.

The difference in technology used in more advanced plants occurs in the machines used in the weaving process and in the chemical recycling process. According to Argo Pantes, currently there are only 10 factories (out of a total of around 1,083 in Indonesia in 1991) which use a chemical recycling process. More advanced plants use air-jet machines as well as shuttles (conventional weaving machines). Of approximately one million weaving machines in Indonesia, only 10,000 are air-jet machines. Most textile plants in Indonesia therefore do not use air-jet machines and do not recycle chemicals.

In the weaving subsector, there are two industries to focus on for describing the technology, manufacture of weaving except gunny and manufacture of printed textiles.

*12.2.1 Manufacture of weaving except gunny*

The principal raw materials used in the weaving process are yarn and starch for sizing. Usually there are four types of starch used -- natural starch, PVA (polyvinyl alcohol), acrylic and wax. This process requires only a small amount of water to dissolve the starch.

Fabrics produced from the weaving process are further processed in the dyeing finishing department. This process includes desizing, bleaching, mercerizing, drying, dyeing and finishing.

The technology used in the three selected companies is more advanced than the average textile factory in Indonesia. To describe the technology used in the majority of textile factories we need to exclude the chemical recycling process and the use of air-jet machines from the technology used by the selected companies.

Labour requirements for the three plants indicate that the mean number of person-years per tonne of output is 3.70. The three companies use air-jet machines as well as shuttles and this reduces the number of workers required. According to Argo Pantes, one operator can operate 30 shuttle machines compared to only 16 air-jet machines. However, each air-jet machine can produce approximately 8,000 yards of unfinished cloth per month compared to 2,700 yards for each shuttle, giving a ratio of 1:1.6 tonnes per person year in favour of air-jet machines. The use of air-jet machines will reduce the amount of labour required in weaving substantially, from 5.92 tonnes/person year to 3.70.

Sources of energy for the production process are PLN, generators and boilers. Boilers are used to produce steam for the steaming process, and water heaters are used in the washing process. According to Century Textile, the weaving process uses 60-70 per cent of total electricity and 10 per cent of total steam and the dyeing process uses 10-12 per cent of total electricity and 80 per cent of total steam.

Natural gas is used in the singeing, drying and curing processes. In future, it is expected that Argo Pantes will use natural gas for its boiler, because gas produces cleaner air and higher heat efficiency. By using IDO and natural gas, the factory can economise and obtain heat efficiency of up to 92 per cent compared to around 80 per cent heat efficiency for fuel oil alone. However, air-jet machines consume more energy than shuttle machines.

### *12.2.2 Manufacture of printed textiles*

The major stages in production of printed textiles are similar to those for weaving other than in the printing process. The stages of production (after the weaving process) are desizing, bleaching, mercerising, dyeing, printing and finishing. The raw materials used in manufacturing printed textiles are similar to those in weaving.

#### *Environmental impacts*

The environmental impacts of the weaving industry (including the manufacture of weaving and printed textiles) take the form of air pollution and water effluent. The major environmental problem of the weaving industry is waste water, produced from several stages of production, including desizing (starch and soda ash), boiling and mercerizing (caustic soda, hydrochloric acid and suspended solids), bleaching (chlorine and sodium hypochlorite), dyeing (dye stuff), printing (synthetic starch, detergents and sodium hydrosulphide) and finishing (silicon, dissolved solids, and detergents). Estimates of water pollutants for PT Argo Pantes are presented in Table 12.3. According to the World Bank (1984), air-borne wastes (mainly particulates) do not present a major problem in the production of textiles.

Waste water quality for an average textile factory are estimated in column 3 of Table 12.3. According to Argo Pantes, almost 80 per cent of textile factories in Indonesia have waste water treatment facilities. However, a wealth of informal evidence suggest that the great majority of textile factories in Indonesia do not treat their waste water, and that even if they do have waste water treatment facilities they do not always use them effectively. Therefore it is estimated that in 1985 the average levels of water pollutants can be represented by a weighted mean of the before and after treatment figures in Table 12.3, with the weights being 30 per cent of 'after treatment' (column 1) and 70 per cent of 'before treatment' (column 2).

**Table 12.3 Weaving: Waste water quality, 1993 (g/m3)**

| Parameter | 1 | 2 | 3 | Standard |
|---|---|---|---|---|
| BOD | 8.73 | 407.50 | 287.87 | 85 |
| COD | 21.05 | 1052.58 | 743.12 | 250 |
| Dissolved solids | 1052 | 32700 | 23205.6 | 1500 |
| Suspended solids | 229 | 15 | 79.2 | 60 |
| Ammonia | 0.75 | 2.03 | 1.65 | 0.02 |
| Fluoride | 0.73 | 2.57 | 2.02 | 1.50 |

Note: 1 = waste water after treatment; 2 = waste water before treatment; 3 = 30 per cent of Column 1 plus 70 per cent of Column 2; Standard = KLH standards
*Source*: Sucofindo Analytical Laboratories, 1993

## 12.3 Weaving: Changes in Technological Coefficients to 2020

According to industry sources, the future of the weaving industry will be characterised by more recycling of chemicals and the use of more advanced machinery, especially air-jet machines. The technological changes in the future are likely to include:

- an increase in recycling of caustic soda from 20 to 70 per cent;
- recycling of up to 80 per cent of PVA. It is also expected that factories will switch to use of PVA alone without mixing it with natural or other starches. This process will require additional investment in recycling equipment;
- use of more advanced machinery in the finishing process, reducing the amount of chemicals used in the finishing process by 10-30 per cent; and
- use of narrower basins in the dyeing process, saving 5-10 per cent of dye stuff used.

It is expected that by 2020 textile mills will not use shuttle machines but only air-jet machines. In addition to working three times faster than shuttle machines, air-jet machines produce higher quality grey. However, air-jet machines cannot use yarn with knots, so splicers must be used to produce yarn without knots.

It is also expected that automated machinery will be used more widely including computerisation of colour mixing and design. With these changes the industry will require more highly skilled workers.

The use of heat recovery boilers will be widespread in the industry by 2020. With heat recovery, Argo Pantes expects to reduce IDO consumption substantially. It is also expected that weaving plants will use exhaust gases for cogeneration, increasing the efficiency of generators to 75 per cent, an increase of 25 per cent. The industry also expects to use more natural gas. Coal will not be used because of storage constraints and because dust from coal affects the quality of the product produced. Sandratex will install two waste gas boilers and four heat exchanger, involving capital outlay of Rp 200 million for each waste gas boiler and Rp 7 million for each heat exchanger.

According to industry sources, it is expected that by 2020 all textile factories in Indonesia will have waste water treatment facilities, as the government will be much stricter about industrial effluent. The projected waste water quality from textile factories in year 2020 are reported in Table 12.4 which is derived from Table 12.3. Although it is expected that in the year 2020 all factories will operate waste water treatment facilities, it is likely that not all of the water treatment will be as efficient as the figures reported for Argo Pantes suggest.

**Table 12.4 Weaving: Waste water quality, 2020 (g/m3)**

| Parameter | 1985 | 2020 | Standard |
|---|---|---|---|
| BOD | 288 | 128 | 85 |
| COD | 743 | 330 | 250 |
| Dissolved. solids | 23206 | 10546 | 1500 |
| Suspended solids | 79.2 | 165 | 60 |
| Ammonia | 1.65 | 1 | 0.02 |
| Fluoride | 2.02 | 1 | 1.50 |

Note: Standard = KLH standards
*Source*: Table 12.3. Expected water quality is taken to be 70 per cent of the 'after treatment' levels of Column 1 in Table 12.3 and 30 per cent of the 'before treatment' levels of Column 2.

Each of these technological changes will require additional investment, including investment in machinery for recycling PVA, air-jet machines, heat recovery and exhaust gas systems, waste gas boilers and heat exchangers and computerisation. According to industry sources, additional investment will be approximately 35 per cent of the value of fixed assets, 0.5 per cent for recycling PVA machines, 3.5 per cent for heat recovery and cogeneration, 27.5 per cent for air-jet machines and 3.5 per cent for computerisation.

Table 12.5 summarises the expected changes in technological and pollution coefficients in the weaving industry.

**Table 12.5 Weaving: Changes in technological coefficients, 1985-2020**

| | | Change between 1985 and 2020 (%) |
|---|---|---|
| *Intermediate inputs*[a] | | |
| 15 Chemicals | | -70 |
| 18 Petroleum refining | | -24 |
| 19 LNG | | +600 |
| 20 Electricity | | -23 |
| *Labour inputs* | | |
| Total employment | | -20 |
| *Capital inputs* | | |
| 17 Other manufacturing | | +35 |
| *Environmental impacts* | 1985 level | |
| Water input/output ($m^3/t$) | 46.38 | -22 |
| Water output/output ($m^3/t$) | 38.70 | -22 |
| BOD ($g/m^3$) | 288 | -69 |
| COD ($g/m^3$) | 743 | -69 |
| Dissolved solids ($g/m^3$) | 23206 | -68 |
| Suspended solids ($g/m^3$) | 79 | +135 |

*Note*: a. NRMP-IEA 30-sector classification.
*Source*: see text

## 12.4 Leather: Current Technology

The stages of production in leather tanning are:

- *Liming* Leathers are soaked in solution to remove body furs and to make them thick, so that they can more easily absorb chemicals. This process uses lime, sodium chloride and sodium nitrate;

- *Flashing* In this process fats are removed from leather by grazing them over a rotating blade and washing them with water;

- *Pickling*: The purpose of this process is to further cook producing white leathers. Chemicals used are lime, hydrochloric acid, acetic acid, sodium bicarbonate and hyposulfide;

- *Bleaching*: This process consists of the wet blue process and the formalin process. Wet blue is used to obtain dark coloured leather, while formalin is used to obtain bright coloured leather. Both processes use HCl, acetate, sodium bicarbonate and hyposulfide;

- *Retanning*: This is the finishing process of leather tanneries in which leathers are soaked in a solution of dyestuff, fat liquor, acetic acid, sodium and alum.

After these steps, leathers are dried and stretched then folded and pressed.

Information on current technologies and likely future changes has been obtained from the firms Tjakung Leather and Pan Vici. They are representative of the industry overall and use processes that have not changed in recent years and are unlikely to change in the next few years.

The tanneries of these firms draw their energy from the state-owned electricity utility, PLN.

According to UNIDO (1990), there are two major sources of waste from leather tanning activities:

- constituents of raw hides or skins which are removed or modified during the tanning process, including the hair or wool (whole, pulped or completely broken down and dissolved), various collagenous and non-collagenous proteins, natural fats, trimmings, splits and shavings; and

- surplus and residual chemicals from the tanning process. These wastes can be present in the form of liquid, solid or gaseous discharges.

Furthermore, UNIDO (1990) notes that the quantity and quality of liquid discharges generated from the tanning process depend directly on its water consumption. There are several substances contained in waste water from leather tanneries:

- protein and other organic chemicals, such as synthetic tanning materials, oil and greases and organic chemicals. These chemicals increase the level of BOD and

COD in water effluent. Nevertheless these organic substances are biologically degradable, so in practice the waste problem is not severe; and

inorganic substances, such as chromium, sulphides, chlorides, sulphates and solids (lime).

Tjakung Leather currently uses ground water. Their system of waste water treatment uses three basins, the first for neutralisation using limestone, the second for screening and the third as water reservoir before discharging into the river.

The first column of Table 12.6 contains estimates of current levels of waste water quality from leather tanning factories in Indonesia.

**Table 12.6 Leather: Waste water quality, 1993 and 2020 (g/m3)**

| Parameter | Current | 2020 | Standard |
|---|---|---|---|
| BOD | 1300 | 650 | 150 |
| COD | 3500 | 1750 | 175 |
| Suspended solids | 3300 | 1650 | 150 |
| Sulphide | 160 | 80 | 1 |
| Total nitrogen | 220 | 110 | - |
| Ammonia nitrogen | 65 | 32.5 | 0.02 |
| Chrome | 100 | 3 | 2 |
| Chloride | 3500 | 1750 | - |
| Sulphate | 900 | 450 | - |

Note: Standard = KLH standards
*Source*: UNIDO (1990)

## 12.5 Leather: Changes in Technological Coefficients to 2020

According to industry sources, there will not be major changes in the technology of tanning processes in the leather tanning industry in the foreseeable future. The major changes are likely to be designed to reduce environmental impacts. One of the expected changes is a reduction in amounts of chrome used in the tanning process to only five per cent of the current consumption. Chrome will be replaced by Bascal-S which is much less hazardous to the environment. Consumption of chemicals per unit of production is not expected to change significantly in the foreseeable future.

With computerisation, the industry is expected to reduce unskilled labour by 50 per cent and increase senior high school educated labour by 20 per cent. It is also expected that factories will reduce labour in toggling and related activities by 40 per cent and that the industry will reduce energy consumption (electricity) by 30 per cent in future by increasing machine efficiency. Computerisation will require additional investment. It is expected that installation of computerised systems will add 1 per cent to current total fixed capital.

It is also likely that chemical effluents will decrease as more factories operate waste water treatment and the efficiency of waste water treatment increases. The chemical compounds in waste water are expected to decrease by around 50 per cent by the year 2020, except for chrome which will fall by 97 per cent. Although chemical effluents will fall by 50 per cent, they will still exceed KLH standards. Expected waste water quality measures for the year 2020 are shown in the second column of Table 12.6.

Table 12.7 summarises the expected changes in technological and pollution coefficients in the leather tanning industry.

## 12.6 Textile, Leather & Wearing Apparel: Changes in Technological Coefficients to 2020

Within Sector 17.2 (Textiles, leather and wearing apparel), the other major subsectors not yet covered in this chapter are (with shares of 1985 total value shown in parentheses) wearing apparel (25 per cent) and knitting (6 per cent). Currently, wearing apparel is the fastest growing subsector. By the year 2020, the share of wearing apparel is expected to rise to 45 per cent of the sector's total output value and weaving will take up 20 per cent of the sector, a decrease of 15 per cent from its 1985 share. In other words, wearing apparel is expected to continue to grow faster than weaving. Wearing apparel also has a higher unit value.

To assess technological change in the sector as a whole we need at least some approximate assessment of expected changes in the wearing apparel subsector. After informal discussions with industry experts in the wearing apparel industry, it is expected that there will be some technological changes associated with energy saving, labour saving and automation.

**Table 12.7 Leather: Changes in technological coefficients, 1985-2020**

| | | Change between 1985 and 2020 (%) |
|---|---|---|
| *Intermediate inputs*[a] | | |
| 15 Chemicals | | 0 |
| 20 Electricity | | -30 |
| *Labour inputs* | | |
| Total employment | | -20 |
| *Capital inputs* | | |
| 17 Other manufacturing | | +1 |
| *Environmental impacts* | 1985 level | |
| Water input/output ($m^3/t$) | 21.83 | 0 |
| Water output/output ($m^3/t$) | 21.83 | 0 |
| BOD ($g/m^3$) | 1300 | -50 |
| COD ($g/m^3$) | 3500 | -50 |
| Dissolved solids ($g/m^3$) | - | - |
| Suspended solids ($g/m^3$) | 3300 | -50 |
| Chrome ($g/m^3$) | 100 | -97 |

Note: a. NRMP-IEA 30-sector classification.
*Source*: see text

Wearing apparel is a labour-intensive industry. In absolute terms, it employs five times more labour than the weaving industry despite the fact that the weaving industry occupies a larger share of the value of output. With automation, it is expected that the amount of labour used per unit of output in the wearing apparel industry will decline by 20 per cent by 2020.

Electricity is the main form of energy used in the wearing apparel industry. It is expected that energy consumption for lighting will fall by 5 per cent due to improved efficiency. Lighting contributes around 30 per cent of total electric energy consumption, so that energy saving in this subsector will be around 2 per cent.

Technology in the knitting industry is very much like in weaving industry and changes in technology will be similar.

Using the shares of the weaving subsector and the wearing apparel subsector in 1985, we estimate the input changes for the whole of Sector 17.2. In 1985, the share of weaving was 45 per cent and wearing apparel 35 per cent of the total value of output.

Energy savings are expected to reduce electricity consumption by 23 per cent in the weaving industry, 30 per cent in the leather industry and 2 per cent in the wearing apparel industry. With predicted shares of output in 2020, including a share of tanned and finished leather of 2 per cent, the reduction of electricity consumption for the whole sector is estimated to be 16 per cent. In the year 2020, the predicted chemical input coefficient for the whole sector is expected to fall by around 28 per cent.

Expected reductions in labour inputs per unit output for 2020 for the weaving, tanned and finished leather, and wearing apparel sectors are 20 per cent. For the whole sector, it is thus expected that the labour input coefficient will decline by 20 per cent.

The additional capital requirements per unit output due to changes in technology will vary among subsectors. The weaving subsector will require 35 per cent additional capital per unit output, tanned and finished leather 1 per cent and wearing apparel 15 per cent. The weighted average for the whole sector is 19.2 per cent.

Table 13 summarises the expected changes in technological and pollution coefficients for the textiles, leather and wearing apparel sector as a whole (Sector 17.2).

**Table 12.8 Textiles, leather & wearing apparel: Changes in technological coefficients, 1985-2020**

| | | Change between 1985 and 2020 (%) |
|---|---|---|
| *Intermediate inputs*[a] | | |
| 15 Chemicals | | -28 |
| 18 Petroleum refining | | -9 |
| 19 LNG | | +210 |
| 20 Electricity | | -16 |
| *Labour inputs* | | |
| Total employment | | -20 |
| *Capital inputs* | | |
| 17 Other manufacturing | | +19 |
| *Environmental impacts* | 1985 level | |
| Water input/output ($m^3/t$) | 46.38 | -22 |
| Water output/output ($m^3/t$) | 38.70 | -22 |
| BOD ($g/m^3$) | 288 | -69 |
| COD ($g/m^3$) | 743 | -69 |
| Dissolved solids ($g/m^3$) | 23206 | -68 |
| Suspended solids ($g/m^3$) | 79 | +135 |

Note: a. NRMP-IEA 30-sector classification.
*Source*: see text

# CHAPTER 13

# OTHER MANUFACTURING SECTORS

## 13.1 Introduction

Two subsectors of the 'Other manufacturing' sector (Sector 17 in the NRMP-IEA 30-sector classification) were the subject of case studies, the iron and steel sector (Sector 17.5) and the textiles, leather and wearing apparel sector (Sector 17.2). The previous chapter (Chapter 12) reported the case study of the textiles, leather and wearing apparel sector. This chapter presents summaries of the case studies of the iron and steel sector (Sector 17.5) and the chemicals sector (Sector 15). The reason for presenting these case studies together is that the case studies are based on outlines only of the technologies used in the industries. The case studies should therefore be regarded as first approximations rather than fully developed analyses of technological change.

This chapter also provides an assessment of technological change for Sector 17 as a whole by combining the data from Sectors 17.2 (textiles, leather and wearing apparel) and 17.5 (iron and steel) with information on the remaining subsectors of 'Other manufacturing'.

## 13.2 Chemicals: Current Technology*

In the period 1986-93 the Indonesian chemicals industry underwent rapid growth; 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 the inorganic chemicals industry (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 principal intermediate inputs into chemicals production in 1985 are reported in Table 13.1.

The assessment of technological change in the chemicals sector relies on two case studies, one of a large polyvinyl chloride plant and one of a company manufacturing formaldehyde resins.

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* The discussion of the chemicals sector is drawn from *NRMP-IEA Input-Output Working Paper* Number 12 (Foley and Siswondo, 1993).

**Table 13.1 Chemicals: Principal intermediate inputs, 1985**

| Sector | | Coefficient (Rp/Rp) |
|---|---|---|
| 15 | Chemicals | 0.57203 |
| 24 | Wholesale & retail trade | 0.11705 |
| 17 | Other manufacturing | 0.05517 |
| 26 | Transportation & communication | 0.04986 |

*Source:* BPS (1989)

### *13.2.1 Case study of polyvinyl chloride (PVC)*

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

PT ASC relies on electricity from PLN for most of its energy requirements. It also has its own back-up generating plant and process heat for the VCM plant is supplied by oil-fired boilers.

Total water use per annum in 1992 was 1.1 million cubic metres (Table 13.2), and water output about one million cubic metres, the difference being used up in production and lost through evaporation. Given 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.

The composition of waste water has been estimated from a study conducted by PT VCM in 1992 (Table 13.3). On this basis, water pollution by PT ASC in 1992 was well below government standards for every measure.

**Table 13.2 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

**Table 13.3 PT ASC water pollution coefficients, 1992**

| Parameter ($g/m^3$) | Quality | Std |
|---|---|---|
| Suspended solids | 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

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.

### *13.2.2 Case study of formaldehyde resins*

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

The production of the resins begins with the oxidation of methanol combined with sodium hydroxide and 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. The output is separated and unreacted methanol is 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 Dover Chemicals 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.

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 Dover Chemicals at 28,800 cubic metres. This is equivalent to 0.8421 tonnes per tonne of production.

## 13.3 Chemicals: Changes in Technological Coefficients to 2020

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

There is no substitute for the basic raw materials (raw salt and ethylene) and the 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.

PT ASC has made a feasibility study for recycling waste water output but concluded that the process is too expensive. In the future, however, PT ASC plans to obtain their water from the adjacent Krakatau Steel'siron and steel plant and possibly in 5-10 years to begin

to recycle waste water. In the near term it is aiming to reduce water consumption by about 5 per cent through improved maintenance and process control.

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.

The changes in technological coefficients presented in Table 13.4 are based in part on the material presented above and partly on more general information from industry experts.

**Table 13.4 Chemicals: Changes in technological coefficients, 1985-2020**

| | | Change between 1985 and 2020 (%) |
|---|---|---|
| *Intermediate inputs*[a] | | |
| 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 | g/m3 | 8.25 | |
| COD | g/m3 | 13.48 | |
| Suspended solids | g/m3 | 3.45 | |

Note: a. NRMP-IEA 30-sector classification.
*Sources*: see text

These estimates of change should be treated with caution. In addition to doubts about the reliability of the estimates, the chemicals sector is undergoing rapid change both in terms of scale and composition of production.

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 is 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 around 40 per cent and to increase capital costs by 5 per cent (plus by a 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.

## 13.4 Iron and Steel: Current Technology*

### *13.4.1 The industry*

The state-owned PT Krakatau Steel is Indonesia's only fully integrated producer of iron and steel and the sole producer of steel slab. All other domestic steel producers use crude steel (slab and billet) and scrap steel (both domestic and imported) to produce steel billets and hot and cold rolled products (e.g. steel plate and reinforcing rods). These smaller producers, of which there were some 13 in 1991, are commonly called 'mini-mills' (capacity ranging from 12,000 to 500,000 tonnes p.a. with total capacity of about two million tonnes p.a.). The mini-mills concentrate on producing a small range of products for the domestic market (commonly steel reinforcing rods for road and building construction). It is expected that the proportion of domestic steel demand met by mini-mills will markedly increase during the next decade.

Despite the rapid increase in domestic production since the mid-1980s (16 per cent p.a. over 1985-90), Indonesia still imported nearly two million tonnes of crude steel and steel products in 1990. In addition, imports of scrap steel have continued to increase as scrap is the main raw material input for the growing number of mini-mills and domestic supply is inadequate both in quantity and quality. However, the most modern of these mini-mills use combinations of technology that were common in Europe, America or Japan in the late-1970s and early-1980s.

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* The discussion of the iron and steel sector is drawn from *NRMP-IEA Input-Output Working Paper* Number 16 (Foley 1993e).

Two case studies were undertaken to determine details of production technology, labour and natural resource requirements and environmental impacts. The first case study examined the production processes of PT Krakatau Steel, located in the rapidly expanding industrial complex at Ciligon, West Java. The second study examined the production processes of a medium-sized mini-mill, PT Budidharma, located in north Jakarta, whose sole products are a range of steel reinforcing bars and rods for use in the construction industry.

### *13.4.2 Case study of Krakatau Steel*

Krakatau Steel's sponge iron production process uses direct reduction technology whereby iron ore pellets are reacted directly with carbon monoxide and hydrogen at high temperatures. The process uses natural gas (mainly CH4) as both the heat source and the source of carbon and hydrogen. The speed and yield of the reaction is enhanced by using a nickel catalyst. The current production process has two direct reduction units with a combined annual capacity of 1.5 million tonnes of sponge iron.

The sponge iron from this process is combined, in a separate process using an electric arc furnace, with steel scrap (30 per cent) and limestone (used as a flux) to produce crude steel. During this smelting process alloys are added to the melt to obtain the required qualities. The molten steel is then cast into billets or steel slabs using a continuous casting process. PT Krakatau currently has eight electric arc furnaces and six continuous casting units with a combined annual capacity in 1992 of 0.550 million tonnes of steel billet and 1.2 million tonnes of steel slab.

Steel billets and slabs are reheated to about 1,200 degrees Centigrade prior to further processing. The billets are rolled into a range of bar and rod products, while slabs are used for producing steel sheet. Annual production from crude steel billets in 1992 was 0.150 million tonnes of plain and deformed (patterned) reinforcing bars, 0.200 million tonnes of reinforcing rods, 0.045 million tonnes of steel sections and angles, and 0.018 million tonnes of zinc coated wire and nails. Annual capacity in 1992 for sheet steel was 1.2 million tonnes of hot rolled steel coils and 0.850 million tonnes of cold rolled coils and black steel sheet.

In the next few years, the company plans to approximately halve the size of the workforce as part of its plans for increasing automation and use of computer-based control systems, and replace most unskilled and semi-skilled workers with technical high school and college graduates. If this goes ahead it will result in at least a 50 per cent reduction in labour inputs per unit of production. Labour saving technology is discussed in more detail below.

There is only fragmentary information from the company on water pollution and no useful standardised information available on the air pollution impacts of this large iron and steel complex. More recent data collected and analysed for evaluating the environmental impacts of the iron and steel complex have yet to be made public.

Water requirements for iron and steel production have been estimated at 5,600 litres per tonne. According to company staff, little or no water remains to be discharged from the plant as a result of rapid evaporation during production and rolling operations. Despite this assertion, the data on discharge water quality reported in Table 13.5 were provided by the company. We were unable to gain access to recent or complete environmental impact assessment documents, and this evaluation is based on fragmentary information provided by PT Krakatau and a partial environmental impact assessment conducted by Padjadjaran University in 1982. In addition to the water pollutants of Table 13.5, the waste water also contains heavy metal compounds.

**Table 13.5 Iron and steel: Water quality of PT Krakatau Steel (g/m3)**

| Parameter | Pollutant |
|---|---|
| BOD | 32 |
| COD | 68 |
| $CO_2$ | 28 |
| $HCO_3$ | 231 |

*Source:* Padjadjaran 1983

### *13.4.3 Case study of Budidharma*

This mini-mill at Cilincing, in the north-east of the Jakarta metropolitan area, has been in operation since 1972 and current annual production is about 130,000 tonnes of steel reinforcing rod. The plant uses an electric arc furnace, a continuous casting unit and a semi-automated rolling mill. The bulk of its raw material input is scrap steel (of which two-thirds is imported from Holland) supplemented by pig iron. In general, European and Japanese technology of 1970s vintage is employed for electric arc furnaces, steel rolling and process control.

Pig iron, steel scrap and alloys are smelted in an electric arc furnace. Oxygen is also added during smelting to reduce the carbon content of the melt and provide additional reaction energy for heating. The molten steel from the furnace is transferred by ladle directly to the

four-strand continuous casting unit for casting billets. Billets are either taken directly into the rolling mill (after cooling) or stored for later processing (after reheating). The roughing and rolling mill can manufacture plain or deformed reinforcing bar in sizes from 12mm to 32mm.

Company technical staff anticipate that electric energy consumption by the electric arc furnace could be reduced to about 400 kWh/t from 575 kWh/t by increasing the amount of oxygen injected during smelting. Reducing energy consumption requires major investments in upgrading the smelting gas injection control system, investments the company has not been willing to make. According to company officials, a major replacement program (amounting to almost a complete replacement of smelting and rolling equipment) would be required if the company aimed to achieve production efficiencies comparable to those current in the US, Europe or Japan. At present it is unclear whether the company plans to make an investment of this scale at the present plant site.

Company technical staff claim that the company discharges no waste water as all water evaporates during the production process or from settling ponds. The solid waste from the settling ponds, which are located within the factory boundary, is sold to the construction industry as solid fill. The main source of air pollution, according to the company, is dust and combustion gases from the electric arc furnace. These are controlled by use of dust collecting equipment and observation suggests that current dust control equipment is quite effective.

## 13.5 Iron and Steel: Changes in Technological Coefficients to 2020

The main technological changes expected in this sector are improvements in energy efficiency, reductions in labour requirements and a reduction in demand for water. As part of the government's overall energy strategy there will be a shift from natural gas to coal as the main energy source for sponge iron production. Electricity from coal-fired generating plants (from PLN and own-generated) will remain the main source of energy for steel smelting at both PT Krakatau and mini-mills. The fragmentary data on water and air pollution provides no basis for making reliable estimates of reductions in environmental impacts.

Improvements in production technology will have interacting impacts on energy, labour and raw materials requirements as follows:

- *Energy efficiency*: The adoption of the more efficient Correx direct reduction process by PT Krakatau for production of sponge iron. This will lead to major reductions in natural gas consumption per unit of production; and substitution of coal for natural gas.

- *Energy and labour requirements*: Reductions of electricity use in electric arc furnaces due to adoption of direct current smelting technology, and reductions in energy and labour use due to improvements in process control (smelting and rolling) from the adoption of computer-based control systems.

- *Raw materials and energy*: Increasing proportion of steel produced by mini-mills from recycled scrap steel (domestic and imported). This change will proportionately reduce the amount of imported iron ore required to meet total steel demand and reduce the amount of energy required per unit of production (as recycling eliminates the energy-intensive iron-making step of production).

Reductions in labour requirements will result from a gradual improvement in the education level and skills of the workforce coupled with the more widespread adoption of computer-based automation of production processes and control systems. The increasing proportion of steel produced by the more labour-efficient mini-mills will also result in a reduction in labour requirements.

Reductions in water use per unit of production will stem from the same sources: improved control of production processes and increasing importance of steel production coming from the more water-efficient mini-mills.

Expected changes in technological coefficients for this sector between 1985 and 2020 are presented in Table 13.6

**Table 13.6 Iron and steel: Changes in technological coefficients, 1985-2020**

| | | | Change between 1985 and 2020 (%) |
|---|---|---|---|
| *Intermediate inputs*[a] | | | |
| 7 | Coal | | +50 |
| 19 | LNG | | -75 |
| 20 | Electricity | | -30 |
| *Labour inputs* | | | |
| Employment | | | -50 |
| *Capital inputs* | | | |
| New capital requirements | | | 0 |
| *Natural resource impacts* | Unit | 1985 level | |
| Water input/output | m3/t | 0.560 | -50 |
| Water output/output | m3/t | 0.190 | -50 |
| BOD | g/m3 | 32.0 | |
| COD | g/m3 | 69.0 | |

Note: a. NRMP-IEA 30-sector classification.
*Sources*: see text

## 13.6 Other Manufacturing: Changes in Technological Coefficients to 2020

The 'Other manufacturing' sector (Sector 17) has the composition indicated in Table 13.7 (using the BPS 66-sector classification). Sector 17.2 (Textiles, leather and wearing apparel) in the NRMP-IEA classification includes sectors 35 and 36 of the BPS 66-sector classification, accounting for 25 per cent of total sector output and 50 per cent of employment. Sector 17.5 (Iron and steel) corresponds to sector 45 of the BPS 66-sector classification, accounting for 6 per cent of total output of NRMP-IEA Sector 17 and less than 1 per cent of employment. Thus our case study sectors account for 31 per cent of 1985 output and 51 per cent of 1985 employment of Sector 17.

**Table 13.7 Composition of other manufacturing (Sector 17) using the BPS 66-sector classification, 1985**

| Sector (66-sector classification) | | Share of 1985 value of output (%) | Share of 1985 employment (%) |
|---|---|---|---|
| 35 | Yarn spinning | 7 | 6 |
| 36 | Textiles, leather & apparel | 18 | 44 |
| 42 | Rubber & plastic products | 15 | 6 |
| 43 | Non-metallic mineral products | 6 | 13 |
| 45 | Basic iron and steel | 6 | 1 |
| 46 | Non-ferrous metal products | 6 | 3 |
| 47 | Fabricated metal products | 9 | 8 |
| 48 | Machinery, incl electrical | 17 | 5 |
| 49 | Transport equipment | 15 | 11 |
| 50 | Other manufacturing | 2 | 3 |

*Source:* BPS (1989)

The data from the case studies of 17.2 and 17.5 plus information from *NRMP-IEA Input-Output Working Paper* Number 1 (Duchin and Lange, 1992b) combined with the information reported above allow us to make some rough estimates of coefficient change for Sector 17 as a whole. These are shown in Table 13.8. The reasoning for each of the reported changes in input coefficients appears below.

The coal input coefficient (Sector 7) is expected to increase between 1985 and 2020 by around 10 per cent due to increased coal consumption in the iron and steel industry. The chemicals input coefficient (Sector 15) is expected to fall by around 10 per cent due principally to savings in the textile industry. The petroleum input coefficient (Sector 18) is expected to fall by around 19 per cent due to industrial energy conservation (Duchin and Lange 1992b). The LNG input coefficient (Sector 19) is expected to increase by around 30 per cent due to the switch from oil to gas in the weaving industry. The electricity input coefficient is expected to fall by around 25 per cent due to industrial energy conservation and increased purchases from PLN in place of captive generation.

**Table 13.8 Other manufacturing (Sector 17): Changes in technological coefficients, 1985-2020**

| | | | Change between 1985 and 2020 (%) |
|---|---|---|---|
| *Intermediate inputs*[a] | | | |
| 7 | Coal | | +10 |
| 15 | Chemicals | | -10 |
| 18 | Petroleum refining | | -19 |
| 19 | LNG | | +30 |
| 20 | Electricity | | -25 |
| *Labour inputs* | | | |
| Employment | | | -35 |
| *Capital inputs* | | | |
| New capital requirements | | | 0 |
| *Natural resource impacts* | Unit | 1985 level | |
| Water input/output | m3/Rp $10^6$ | 31 | 0 |
| Water output/output | m3/Rp $10^6$ | 31 | 0 |

Note: a. NRMP-IEA 30-sector classification.
*Sources*: see text

Labour inputs per unit of output from Other manufacturing are expected to fall between 1985 and 2020 by around 35 per cent. This is because employment in Sector 17 is dominated by textiles and apparel, and while little labour saving is expected, in apparel its share of output and employment will diminish. In addition, large labour savings are expected in most other sectors. While most sectors will become much more capital intensive, some capital equipment is more productive reducing unit capital costs. The net result is expected to be no change in capital requirements per unit of output.

Water use per Rp 1 million of output has been derived from data on a range of manufacturing industries in West Java (Delft Hydraulics 1989, Table 4.3) from which water use per employee has been converted to water use per Rp 1 million of output using output and employment data from the input-output tables (BPS 1989).

# CHAPTER 14

# LAND, LABOUR AND CAPITAL: CONCEPTS AND DATA

## 14.1 Land Coefficients and Land Availability

In this section we report our estimates of land use and land availability for expansion of agriculture and forestry. Table 14.1 shows the land coefficients employed in the model and the projected changes in these coefficients under different scenarios. The coefficients show the area of land required in 1985 to produce one tonne of agricultural output (Sectors 1, 2 and 3) and to produce one cubic metre of forest products (Sector 5). Detailed explanations of the projected changes in these coefficients due to changes in technology in the relevant sectors are contained in Chapters 6 and 7 (for the agricultural sectors) and Chapter 8 (for forestry).

**Table 14.1 Land coefficients and changes in land coefficients, 1985-2020**

| Sector | | 1985 coefficient (ha/unit output) | 2020 relative to 1985 S1 | S2 |
|---|---|---|---|---|
| 1 | Paddy (t) | 0.2367 | 0.65 | 0.44 |
| 2 | Other food crops (t) | 0.2227 | 0.71 | 0.76 |
| 3 | Estate crops (t) | 1.4180 | 0.56 | 0.56 |
| 5 | Forest products ($m^3$) | 0.0265 | 0.65 | 0.40 |

*Sources*: Case studies

*Agricultural land availability*

The best estimates of total agricultural land use and land availability are contained in RePPProT (1990). RePPProT was a very extensive study of land resources undertaken for the Ministry of Transmigration by a team funded by the British Overseas Development Administration. The study assessed only larger land areas suitable for development and divided 'recommended development areas' into five land types: wetland arable, dryland arable, tree crops, mixed tree crops and dryland arable, and land suitable for livestock and agroforestry. 'Wetland arable' corresponds to land used in this study's paddy sector (Sector 1); 'dryland arable' corresponds closely to land used for other food crops (Sector 2), and 'tree crops' corresponds to estate crops in our classification (Sector 3). The estimate of land for livestock is more difficult because most livestock (predominantly chickens) is

extensively produced on mixed farms so that no distinct land area is identifiable. In addition, extensive livestock production, which is expected to expand very rapidly in future, uses little land. RePPProT does not identify the total land used for livestock in 1990.

The RePPProT study cautions that the maximum estimated area will be substantially reduced in practice. Based on past experience, only 35 per cent of the area initially identified as suitable for arable wetland and dryland development is actually developed. The equivalent figure for tree crops is 70 per cent (RePPProT 1990, p190). RePPProT estimates of land available for development and land already in various uses in 1990 are reported in Table 14.2. Note that land classified as suitable for 'mixed treecrops and dryland arable' has been allocated to the dryland arable category because it seems likely that in future the land constraint will affect other food crops (Sector 2) rather than estate crops (Sector 3).

**Table 14.2 Land use and land available for development, 1990**

| Land suitability | Land use ($10^3$ ha) | Land available ($10^3$ ha) | Gross additional area (%) | Net additional area (%) |
|---|---|---|---|---|
| Paddy | 7666 | 956 | 12.5 | 0 |
| Other food crops | 5322 | 1602 | 30.0 | 30.0 |
| Estate crops | 7687 | 5345 | 70.0 | 70.0 |
| Livestock | -- | 287 | -- | -- |

Notes: Areas suitable for development are outside of Java and Bali. It has been assumed that 70 per cent of the area initially identified for livestock and agroforestry proves to be suitable in practice. For definition of net and gross see text.
*Sources*: RePPProT (1990), Table 4.3 and Annex 3.6.1, and Foley (1993a)

In Table 14.2 we have calculated the gross increase in area available for development as the proportion of the area available over the area actually farmed in 1990. In the case of Paddy we have calculated a net availability of paddy land by subtracting the loss of paddy land on Java and Bali due to urban and industrial expansion. Foley (1993a) estimates that the rate of urban encroachment on paddy fields is occurring at about the same rate as the development of new paddy fields outside of Java and Bali so that the net area of land available for new paddy is zero.

It is most important to note that a very large share of new land available for paddy (62 per cent) and other food crops (36 per cent) is located in Irian Jaya. RePPProT warns (1990,

p191) that most of the identified land is in the remote border region of the southeast corner of Irian Jaya, a region that presents 'unusual difficulties' for development, including poor soils, unfavourable weather and sensitive sociopolitical issues.

There are two other important assumptions concerning agricultural land that have been built into the data base. Firstly, since all paddy is treated as an intermediate input into Sector 11 (food, beverages and tobacco) where it is milled, growth in Sector 11 will induce similar growth of output and land requirements in Sector 1 (paddy) unless we adjust the input coefficient of Sector 1 into Sector 11. In practice, demand for rice will grow more slowly than demand for food in general. We have therefore adjusted the parameters governing the composition of agricultural inputs into Sector 11 to ensure that demand for rice (and thus demand for paddy land) does not exceed our independently estimated growth rate.

The second assumption concerns land requirements in Sector 2 (other food crops). Initial results showed that on the high growth path, demand for land in Sector 2 would very quickly exceed the area of land available for these crops. For the period 2000 to 2020 (the period in which the land constraint makes itself felt), we have therefore increased imports of other food crops under the high growth scenarios in order to limit domestic production and thus demand for land for these crops.

*Forest land availability*

The total area of production forest in Indonesia is approximately 61 million hectares (FAO-MoFr 1990, Vol. 2, Table 2.2).

It was reported in Chapter 8 that there are around 5.2 million ha of dry grassland and 14.6 million ha of scrubland suitable for establishment of forest plantations, a total of 19.8 million ha. These compare with the RePPProT total estimates of 10.3 million ha of grassland and 18.9 million ha of scrubland, a total of 29.2 million ha (RePPProT, 1990 Table 3.6.1). Using these estimates around two-thirds of grassland and scrubland is suitable for plantation establishment.

## 14.2 Labour Coefficients

The labour input coefficients for 1985 are taken directly from the BPS input output tables which contain both total value of output and employment for each sector (BPS, 1989). It should be remembered that in Chapter 3 we adjusted the level of employment in the four agricultural sectors to take account of disguised unemployment. Projected changes in

labour input coefficients under both scenarios (S1 and S2) are derived from the case studies for those sectors subject to case studies (Sectors 1, 2, 3, 4, 5, 11, 13, 15, 16, 17 and 20). For the other sectors we have made the following assumptions. For the mining sectors, fisheries, petroleum refining, LNG and construction (Sectors 6, 7, 8, 9, 10, 18, 19 and 23) we have assumed an annual rate of increase in labour productivity of 1.5 per cent (which translates into a decline of 40 per cent in labour inputs per unit of output over the period 1985 to 2020). For manufacturing industries (Sectors 12 and 14) we have assumed an annual rate of increase in labour productivity of 2.5 per cent (a 60 per cent decline in labour inputs per unit output between 1985 and 2020). For the service sectors (Sectors 21, 22, 24-30) we have assumed an annual rate of increase in labour productivity of 2.0 per cent (a 49 per cent decline in labour inputs per unit output between 1985 and 2020). The labour coefficients in 1985 and projected changes in labour coefficients between 1985 and 2020 are reported in Table 14.3.

## 14.3 Capital Coefficients

For the base year 1985, unpublished data on capital stocks by sector in purchasers' prices were provided by BPS. These were converted to producers' prices and then put into a matrix of of capital expansion coefficients for 1985 using methods described in Duchin and Lange (1992a). The columns of the B matrix (the matrix of new capital requirements per unit of output) consist of inputs from three sectors producing capital goods (livestock, other manufacturing and construction, Sectors 4, 17 and 23, respectively) and three sectors represented as delivering 'margins' (trade, transportation and financial and business services, Sectors 24, 26 and 27, respectively). The totals of capital inputs to each sector are shown in Table 14.3.

Projections of B coefficients through to 2020 were made for each sector subject to a case study as part of the case study. Other sectors were treated in one of two ways. Sectors considered to be currently using reasonably modern technology are not expected to increase in capital intensity significantly. These include all mining sectors (Sectors 7-10), fertiliser and pesticides, petroleum refining and LNG (Sectors 14, 18 and 19 respectively). The remaining sectors, mainly service sectors, are expected to experience varying levels of increase in capital intensity in part related to projected gains in labour productivity. Table 14.4 shows projected changes in total capital requirements per unit of output in each sector between 1985 and 2020 under Scenarios 1 and 2.

**Table 14.3 Labour coefficients and changes in labour coefficients, 1985-2020 (person years per Rp million of output)**

| Sector | | Coefficient 1985 | 2020 relative to 1985 S1 | S2 |
|---|---|---|---|---|
| 1 | Paddy | 1.5551 | 0.74 | 0.55 |
| 2 | Other food crops | 2.6064 | 0.72 | 0.86 |
| 3 | Estate crops | 0.7066 | 0.65 | 0.65 |
| 4 | Livestock & poultry | 0.3096 | 0.34 | 0.34 |
| 5 | Forest products | 0.2412 | 3.11 | 3.89 |
| 6 | Fisheries | 0.4845 | 0.60 | 0.60 |
| 7 | Coal | 0.1545 | 0.60 | 0.60 |
| 8 | Crude oil | 0.0049 | 0.60 | 0.60 |
| 9 | Natural gas | 0.0049 | 0.60 | 0.60 |
| 10 | Other mining | 0.3508 | 0.60 | 0.60 |
| 11 | Food & beverages | 0.0897 | 0.50 | 0.50 |
| 12 | Wood products | 0.5083 | 0.40 | 0.40 |
| 13 | Pulp & paper | 0.1558 | 0.60 | 0.60 |
| 14 | Fertiliser & pesticides | 0.0202 | 0.40 | 0.40 |
| 15 | Chemicals | 0.0770 | 0.40 | 0.40 |
| 16 | Cement & limestone | 0.1507 | 0.83 | 0.83 |
| 17 | Other manufacturing | 0.1626 | 0.65 | 0.65 |
| 18 | Petroleum refining | 0.0024 | 0.60 | 0.60 |
| 19 | Liquified natural gas | 0.0024 | 0.60 | 0.60 |
| 20 | Electricity | 0.0548 | 1.00 | 1.00 |
| 21 | Gas utilities | 0.0548 | 0.51 | 0.51 |
| 22 | Water utilities | 0.0548 | 0.51 | 0.51 |
| 23 | Construction | 0.1230 | 0.60 | 0.60 |
| 24 | W'sale & retail trade | 0.6509 | 0.51 | 0.51 |
| 25 | Restaurants & hotels | 0.0612 | 0.51 | 0.51 |
| 26 | Transport & communication | 0.2057 | 0.51 | 0.51 |
| 27 | Real estate, finance & business services | 0.0198 | 0.51 | 0.51 |
| 28 | Public admin. & defence | 0.3793 | 0.51 | 0.51 |
| 29 | Social & other services | 0.7559 | 0.51 | 0.51 |
| 30 | Unspecified | 0.0000 | | |

*Sources*: All 1985 coefficients are from BPS (1989) with total input values from Volume 1, Table 2 and sectoral employment from Volume 2, Table 8. Projections of changes for sectors 1, 2, 3, 4, 5, 11, 13, 15, 16, 17 and 20 are from the case studies. Projections for other sectors -- see text.

**Table 14.4 Total capital coefficients and changes in capital coefficients, 1985-2020 (Rp per Rp of output)**

| Sector | | Coefficient 1985 | 2020 relative to 1985 S1 | S2 |
|---|---|---|---|---|
| 1 | Paddy | 1.0204 | 1.0000 | 1.0000 |
| 2 | Other food crops | 0.0423 | 1.0000 | 1.0000 |
| 3 | Estate crops | 1.4100 | 1.0000 | 1.0000 |
| 4 | Livestock & poultry | 0.3087 | 2.0500 | 2.0500 |
| 5 | Forest products | 1.7841 | 1.0004 | 1.0006 |
| 6 | Fisheries | 0.6943 | 1.6299 | 1.6299 |
| 7 | Coal | 1.7511 | 1.0000 | 1.0000 |
| 8 | Crude oil | 1.7511 | 1.0000 | 1.0000 |
| 9 | Natural gas | 1.7511 | 1.0000 | 1.0000 |
| 10 | Other mining | 1.7511 | 1.0000 | 1.0000 |
| 11 | Food & beverages | 0.2667 | 1.7500 | 1.7500 |
| 12 | Wood products | 0.4303 | 1.9181 | 1.9181 |
| 13 | Pulp & paper | 0.3596 | 1.0217 | 1.0217 |
| 14 | Fertiliser & pesticides | 0.3409 | 1.0000 | 1.0000 |
| 15 | Chemicals | 0.3419 | 1.0600 | 1.0600 |
| 16 | Cement & limestone | 0.3467 | 1.0284 | 1.0284 |
| 17 | Other manufacturing | 0.3409 | 1.0000 | 1.0000 |
| 18 | Petroleum refining | 0.3720 | 1.0000 | 1.0000 |
| 19 | Liquified natural gas | 0.3720 | 1.0000 | 1.0000 |
| 20 | Electricity | 1.6608 | 1.3584 | 1.3074 |
| 21 | Gas utilities | 1.6313 | 1.2898 | 1.2898 |
| 22 | Water utilities | 1.6313 | 1.2898 | 1.2898 |
| 23 | Construction | 0.2691 | 1.7853 | 1.7853 |
| 24 | W'sale & retail trade | 0.5756 | 1.6796 | 1.6796 |
| 25 | Restaurants & hotels | 0.9448 | 1.6796 | 1.6796 |
| 26 | Transport & communication | 2.1321 | 1.3773 | 1.3773 |
| 27 | Real estate, finance & business services | 1.4150 | 1.1893 | 1.1893 |
| 28 | Public admin. & defence | 1.3467 | 1.1141 | 1.1141 |
| 29 | Social & other services | 0.7417 | 1.4890 | 1.4890 |
| 30 | Unspecified | 0 | | |

*Source*: see text

# CHAPTER 15

# ATMOSPHERIC EMISSIONS, WATER USE AND WATER POLLUTION

## 15.1 Atmospheric Emissions Coefficients

The air pollutants examined in this study are carbon dioxide and oxides of sulphur and nitrogen. The first is important mainly because of its potential contribution to global climate change. Indonesia would be one of the nations affected most adversely by global warming and sea-level rise. Sulphur and nitrogen, partly in the form of acid rain, are responsible for local damage to health and property. The emissions of all three gases in the course of human activities are associated mainly with the combustion of the fossil fuels -- petroleum products, coal and gas. This combustion takes place throughout the economy: during the generation of electricity, in the delivery of transportation, in the course of production both in manufacturing and in agriculture, and by private households.

The inputs and outputs associated with economic activities are specific to each economy, especially in non-manufacturing sectors like agriculture and forestry. That is why to the extent possible the data base has been built using data collected in Indonesia. However, in the case of the amounts of gases generated in the process of combustion, there are only a small number of parameters that need to be taken into account. For this reason, it has been possible to rely on the significant body of work that has been done by Duchin and Lange (in press), for all parts of the world economy, associating emissions of carbon dioxide and oxides of sulphur and nitrogen with the combustion of different fuels in different sectors of the economy.

The physical determinants of emissions are independent of the economy in which combustion takes place. Emissions of carbon are directly related to the carbon content of the fuel which varies within a narrow range for a given fuel provided that combustion is relatively complete. The carbon emissions per unit of fuel used in this study are shown in Table 15.1.

**Table 15.1 Carbon emissions coefficients (tonnes of carbon per tce)**

| Fuel | Emissions |
|---|---|
| Oil | 0.576 |
| Natural gas | 0.399 |
| Coal | 0.697 |

*Source:* Duchin and Lange (1992b and in press)

The quantity of sulphur emissions depends upon the following factors: the average sulphur content in the particular mineral deposit, the quality of the fuel (i.e. its energy content), whether or not the fuel is cleaned prior to combustion, and whether the sulphur is removed from the flue gas. Estimates of emission parameters for Indonesia are shown in Table 15.2. The sulphur and energy content of Indonesian coal and oil is based on Foell and Green (1990), and it is assumed that no pollution control practices are in force to remove sulphur either before or after combustion.

**Table 15.2 Sulphur emissions coefficients (tonnes of SO2 per tce)**

| Fuel | Sulphur content of fuel | Tonnes of fuel per tce | Conversion of fuel sulphur to SO2 | Emissions of SO2 (t/tce) |
|---|---|---|---|---|
| Coal (all sectors) | 0.6 | 1.8 | 1.95 | 2.11 |
| Natural gas | na | na | na | na |
| Oil | | | | |
| Agriculture | 0.50 | 0.737 | 1.90 | 0.70 |
| Mining | 1.13 | 0.724 | 1.90 | 1.55 |
| Industry | 1.13 | 0.724 | 1.90 | 1.55 |
| Transportation | 0.27 | 0.737 | 1.90 | 0.38 |
| Electric power | 1.75 | 0.737 | 1.90 | 2.41 |
| Commercial | 0.58 | 0.737 | 1.90 | 0.81 |
| Households | 0.04 | 0.737 | 1.90 | 0.06 |

Note: The last column of numbers (emissions of SO2 per tce of fuel) is given by the product of the first three.
na – not applicable
*Source:* Duchin and Lange (1992b and in press)

The nitrogen in nitrogen oxide emissions comes not from the fuel but from the air. The volume of emissions per unit of fuel depends upon the temperature at which combustion takes place which in turn is directly related to the boiler technology. The parameters shown in Table 15.3 reflect the assumptions made in Duchin and Lange (in press) for the region of newly-developing Asia.

**Table 15.3 Nitrogen emissions coefficients (tonnes of NO2 per tce)**

| Sector | Oil | Natural gas | Coal |
|---|---|---|---|
| Agriculture | 33.71 | 2.74 | 4.41 |
| Mining | 2.07 | 3.84 | 5.26 |
| Industry | 2.07 | 3.84 | 5.26 |
| Transportation | 36.64 | na | 6.01 |
| Electric power | 6.71 | 7.52 | 9.99 |
| Commercial | 2.07 | 2.74 | 4.41 |
| Households | 11.80 | 2.74 | 1.67 |

*Source:* Duchin and Lange (1992b and in press)

## 15.2 Water Use and Water Emissions

While most water withdrawals in Indonesia are for agriculture, especially for paddy irrigation, water demand for industrial and household use will increase steeply in future. Part of this new demand can be satisfied by improving the efficiency of irrigation, and there will be increasing pressure to do so.

Most industrial use of water is required for electricity generation and the production of pulp and paper, chemicals and petrochemicals, food and beverages, and other manufacturing, notably iron and steel and other metal processing. Most industrial water is used to convey heat (i.e. for cooling), for cleaning and to transport solids. Industrial establishments in Indonesia withdraw most of their water directly from rivers, with the remainder coming mainly from groundwater. However, the food processing sector (Sector 11) may get as much as 30 per cent of its water from utilities and about 20 per cent of the water used in petroleum refineries is seawater.

Water uptake and discharge per unit of output (measured in 1985 Rupiah) are shown for some agricultural and industrial sectors in Table 15.4. Only about 25 per cent of the uptake shown for paddy in 1985 is actually used because of water losses due to leakages. This fraction is expected to rise to 50 per cent by 2020 due to investment in better maintenance of irrigation systems. Improvement in efficiency is one reason for the sharp drop in water uptake. Improvements in efficiency of water use is also expected in some industrial sectors due mainly to good housekeeping measures and increased re-use and recycling of water before discharge. This is indicated in Table 15.5 which shows data for water use and pollution in two types of pulp and paper mills in Indonesia.

**Table 15.4 Water uptake and discharge coefficients for some major water-using sectors, 1985 and 2020 (cubic metres per thousand Rupiah of output)**

| | | Water in | | | Water out | |
|---|---|---|---|---|---|---|
| Sector | | 1985 | S1 | S2 | 1985 | S1 & S2 |
| 1 | Paddy | 51.6000 | 0.19 | 0.14 | | |
| 4 | Livestock | 0.0007 | 1.14 | 1.14 | | |
| 11 | Food, beverages | 0.0076 | 0.25 | 0.25 | 0.0060 | 0.25 |
| 13 | Pulp & paper | 0.1758 | 0.32 | 0.32 | 0.0608 | 0.56 |
| 15 | Chemicals | 0.0007 | 1.00 | 1.00 | 0.0007 | 1.00 |
| 17 | Other manufacturing | 0.0199 | 1.00 | 1.00 | 0.0199 | 1.00 |
| Households ($10^6$ $m^3$) | | 8,757 | 2.11 | 2.11 | | |

Note: Figures for 2020 represent levels of coefficients in 2020 relative to those in 1985 so that 1.00 means that the coefficient is unchanged. The figure for households measures the absolute level of water consumption in 1985 in million cubic metres.
*Source:* NRMP-IEA estimates

**Table 15.5 Water use and pollution associated with different pulp and paper mills in Indonesia, 1993**

| Variable | Pulp mill 1 | Pulp mill 2 | Paper mill 1 | Paper mill 2 |
|---|---|---|---|---|
| Water input ($m^3/t$) | 110.00 | 34.50 | 18.00 | 0.00 |
| Water output ($m^3/t$) | 157.00 | 49.00 | 18.00 | 0.31 |
| BOD (g/m3) | 170.00 | 170.00 | 80.00 | 80.00 |
| COD (g/m3) | 690.00 | 690.00 | 370.00 | 370.00 |
| Dissolved solids ($g/m^3$) | - | - | - | - |
| Suspended solids ($g/m^3$) | 547.00 | 547.00 | 289.00 | 289.00 |
| Heavy metals ($g/m^3$) | - | - | - | - |

Notes: Pulp mill 1 represents an older technology while Pulp mill 2 represents a new technology.
*Source:* Indah Kiat (1991)

While it has not been possible to cover all large water-using sectors in Table 15.4, the small size of the coefficients for industrial sectors relative to agriculture indicates that these omissions, mainly of electricity generation and petrochemicals, will not affect the total water use greatly. Note that household use has been projected as a level rather than in terms of parameters; this level is based on per capita use in 1985 and the projected rate of growth of per capita water use.

The major industrial pollutants of water are organic products responsible for depleting oxygen in the receiving body of water, measured as BOD (biological oxygen demand). Chemical oxygen demand (COD) and various suspended and dissolved solids are also serious pollutants. Pollutant discharge coefficients for the principal water-polluting sectors are shown in Table 15.6. It can be seen that in most of the sectors shown dramatic improvements are anticipated on a per unit of output basis. This is because in this area the constraints of environmental protection legislation are likely to coincide with favorable economics of product recovery from the waste stream.

Different water pollution problems are associated with households and agriculture. No attempt has been made in the present study to track the generation of sewage, but the framework for the integrated analysis of the load on water utilities and sewage treatment plants has been developed in Duchin (1992). Assessing the destination of nitrates and other water-borne agricultural chemicals has not been attempted at this stage of the work.

**Table 15.6 Water pollutant discharge coefficients for some major polluting sectors, 1985 and 2020 (grammes per cubic metre of water)**

| Sector | | BOD | | COD | | TSS | |
|---|---|---|---|---|---|---|---|
| | | 1985 | 2020 | 1985 | 2020 | 1985 | 2020 |
| 11 | Food & beverages | 248.0 | 2.70 | 360.0 | 0.25 | 608.0 | 0.14 |
| 13 | Pulp & paper | 754.0 | 0.39 | 2502.6 | 0.46 | 671.5 | 0.11 |
| 15 | Chemicals | 8.3 | 1.00 | 13.5 | 1.00 | 34.5 | 1.00 |
| 17 | Other manufacturing | 200.0 | 0.40 | 800.0 | 0.40 | 1000.0 | 0.25 |

Note: Figures for 2020 represent levels of coefficients in 2020 relative to those in 1985 so that 1.00 means that the coefficient is unchanged.
*Source:* NRMP-IEA estimates

# APPENDIX A

# THE DYNAMIC INPUT-OUTPUT MODEL WITH NATURAL RESOURCES

The dynamic input-output model consists of three inter-related submodels. The physical model relates the stocks and flows of goods and services and resources and pollutants. The "dual" price model describes the relationship between the costs and prices of these stocks and flows. Finally, the income model integrates the physical and price models and represents the division of total national income among labor and the owners of capital and resources. The 3-part model, involving only the economic but not yet the environmental relationships, was described for the first time in (Duchin, 1988), where they are discussed in more detail, and has been implemented for the US economy. An implementation of the first model for Indonesia (Duchin and Lange, 1992) was the basis of the model used in this work.

Model (1) shown below is extended to include the use of resources and the generation of pollutants in physical terms The price equation (2), which is not yet implemented, goes on to show how rents on resources and possible taxes on pollutants are easily taken into account in the calculation of cost-based prices. Finally, these are included along with all other factor costs in the income equation (3).

For each of the three models, the description below includes the definition of variables and parameters, the initial conditions, and the equations of the model, followed by a short discussion.

## A.1 Physical Model

*Definition of Variables and Parameters*

| | |
|---|---|
| $c(t)$ | capacity at beginning of period t |
| $c^*(t+\tau)$ | capacity planned in period t for $t+\tau$ where $\tau$ is the maximum number of periods lag between delivery of a capital good and its use in production, in its current application, 2 years |
| $o(t+\tau)$ | increase in capacity, if any, planned in period t for $t+\tau$ |



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| | |
|---|---|
| R | matrix of requirements for replacement of existing capacity |
| $\delta_i$ | maximum admissable annual rate of expansion of capacity for sector i |
| A, x, y | defined as usual (A is the matrix of current account requirements per unit of output, x is the vector of outputs, and y is the vector of deliveries to final users) |
| $B^{\theta}(t)$ | matrix of those capital requirements per unit increase in output that need to be produced in period t for first use in period $t+\theta$ |
| L | matrix of labor requirements per unit of output by educational category and by sector |
| e | vector of labor requirements by educational category |
| N | matrix of natural resource inputs or outputs per unit of sectoral output (see text for exceptions) |
| m | vector of natural resource inputs and outputs |

*Initial Conditions*

$c(t_0)$

$c^*(t),\ t = t_0+1, \ldots, t_0+\tau-1$

$x(t),\ t = t_0-\tau, \ldots, t_0-1$

The initial conditions are completed by computing o and then c, according to the equations below for $t = t_0+1, \ldots, t_0+\tau-1$.

*Model*

For $t = t_0, \ldots, t_T$

$$c^*(t+\tau) = \min \left[ 1+\delta_i, \frac{x_i(t-1)+x_i(t-2)}{x_i(t-2)+x_i(t-3)} \right]^{\tau+1} \cdot x_i(t-1)$$

$$o(t+\tau) = \max\,[0,\ c^*(t+\tau) - c(t+\tau-1)]$$

$$c(t+\tau) = c(t+\tau-1) + o(t+\tau)$$

$$[I-A(t)-R+(t)]x(t) = \sum_{\theta=1}^{\tau} B^{\theta}(t)o(t+\theta) + y(t) \quad (1)$$

$$L(t)\,x(t) = e(t) \quad (1.a)$$



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$N(t)\ x\ (t) = m(t)$ (1.b)

*Discussion*

Model (1) is the version of the model that relates the stocks and flows of economic goods and services. Given the technical coefficients and the deliveries to final consumers, the model calculates levels of production. Investment is endogenous, and is spread over several time periods, as governed by the capital coefficients (B). Expansion of capacity takes place only if there is unused capacity.

For some sectors, the variable representing the increase in capacity (o) needed to be defined differently than is indicated in the equation in model (1). Instead of allowing it to take on the value 0, it was constrained to be at least half its magnitude in the preceding period. This adjustment does not affect the total amount of investment over the time horizon under study but does smooth out a sector's investment flow. As the B matrix is progressively improved, this adjustment should not be needed.

Equation (1a) shows the calculation of labor requirements by educational category of workers while (1b) represents the calculation of resource use, such as land, and pollutants generated, such as carbon dioxide emissions. In the case of the environmental variables, (1b) is only schematic as not all calculations were made on a per-unit-of-output basis. In particular, air pollutants are calculated by applying the emission coefficients (in N) to the amount of fossil fuel combustion in a sector) while erosion is estimated relative to total land use in a sector.

## A.2 Price Model

*Definition of Variables, Parameters*

A, R, B, L as in (1)

r diagonal matrix of rates of return on capital by sector

W matrix of employment compensation rates by occupation and by sector

p vector of prices

$\pi$ vector of resource rents or pollution taxes

w vector of employment compensation rates by sector where the entries of w are

defined as the diagonal elements of the matrix W'L.

*Initial Conditions*

$p(t_0-1)$, $p(t_0-2)$, $p(t_0-3)$

*Model*

$$(I - A(t) - R(t))' \, p(t) = w(t) + \pi(t)' \, N(t)$$

$$(I + r(t)) \sum_{\theta=1}^{\tau} B^{\theta}(t-\theta)' p(t-\theta) \sum_{\theta=1}^{\tau} B^{\theta}(t+1-\theta)' \, p(t+1-\theta) \qquad (2)$$

*Discussion*

In this model replacement costs are $R(t)' \, p(t)$, the return on capital is $r(t) \sum_{\theta=1}^{\tau} B^{\theta}(t-\theta)$ and the revaluation of the capital stock is

$$\sum_{\theta=1}^{\tau} [B^{\theta}(t-\theta)' \, p(t-\theta) - B^{\theta}(t+1-\theta)' \, p(t+1-\theta)].$$

While the cost of replacement and the value of capital (on which a return is computed) are always positive, not only the magnitude but also the sign of the revaluation term depends upon changing capital requirements per unit increase in output and changes in relative prices: typically, it turns out to be negative because of the appreciation of the capital stock.

The dynamic price model describes sectoral prices as the sums of the costs of corresponding inputs including intermediate goods and services, labor, capital, resource rents, and any taxes on the generation of pollutants. Computed prices depend upon both the technical coefficients and the factor prices -- wage rates, rates of return on capital, rents, and pollutant tax rates.

## A.3 Income Model

*Definition of Variables, Parameters, and Initial Conditions*

All variables, parameters, and initial conditions are defined as in (1) and (2), the physical and price models.

*Model*

$$p(t)'\, y(t) + \sum_{\theta=1}^{\tau} p(t)'\, B^{\theta}(t)\, o(t+\theta) = \pi'(t)\, N(t)\, x(t) +$$

$$v(t)'\, x(t) + r(t) \sum p(t-\theta)'\theta B^{\theta}(t-\theta)\, x(t)$$

$$-\sum_{\theta=1}^{\tau} [p(t+1-\theta)'\, B^{\theta}(t+1-\theta) - p(t-\theta)'B^{\theta}(t-\theta)]\, x(t) \qquad (3)$$

*Discussion*

In equation (3), factor earnings are represented by the four terms on the righthand side: rents (or taxes) on resources (or pollution), employment compensation, a return on the replacement value of utilized capital (that is, what it would cost to replace that capacity at the technology and prices of period t), net of any appreciation of the stock over the current period. Factor outlays, on the lefthand side, cover consumption and the actual cost of investment for expansion.

## APPENDIX B

## DATA SOURCES AND COEFFICIENT CHANGES

The vectors of variables and matrixes of parameters figuring in the dynamic input-output model were described in Appendix A. The database consists of the values for A, B, L, N, and y for 1985 and for all subsequent years through 2020. In the case of most of the technical parameters, projections were made only for 2020 and values for the intervening years were interpolated. The sources of data are described below.

*For 1985*

The A matrix and y vector are from BPS (1989).

The B matrix was developed by BPS specifically for this study. On the basis of preliminary computations, adjustments needed to be made to this matrix. The principal change was that a portion of the construction activities attributed to certain sectors (Sectors 20-22 and 26-28) was removed from the B matrix and treated instead as exogenous government demand. This change made the model more stable and is also a more realistic representation because the construction activity in question is related more closely to public works than to the mechanism that drives the dynamic model, that is, anticipated changes in demand.

The L matrix was developed as follows. Total employment in all sectors (i.e., column totals) are from BPS (1989, Volume 2, Table 8). The composition of employment in each sector by five educational levels was provided especially for this study by BPS based on survey data.

For the N matrix, all coefficients were provided by the case studies which are described in Chapters 6-13 with additional data on atmospheric emissions and water use and water pollution in Chapter 15, and data on land in Chapter 14.

*For 2020*

Projections of technical coefficients were developed in the case studies, the approach to which is described in Chapter 2. Technological changes are described as percentage

changes from the 1985 coefficients except for the composition of each sector's employment which, as a first approximation, has been left unchanged.

Values for y are provided by the macroeconomic projections which are described in Chapter 5. Tables B1-B5 show the macroeconomic projections on the moderate growth path for the components of final demand (private consumption, government consumption, exports and imports) and total final demand (excluding investment).

Tables B6 and B7 show schematically those intermediate, capital labour and natural resources coefficients for which estimates of future change have been made.

Table B.1 Private consumption by sector on the moderate growth path, 1985–2020 (Rp million, constant 1985 prices)

| | Sector | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | Other food crops | 6,381,115 | 7,382,289 | 8,416,945 | 9,479,348 | 10,496,927 | 11,481,862 | 12,620,625 | 13,382,714 |
| 3 | Estate crops | 988,538 | 1,195,807 | 1,425,651 | 1,684,307 | 1,943,637 | 2,207,703 | 2,524,989 | 2,791,741 |
| 4 | Livestock, poultry & products | 2,655,218 | 3,638,404 | 4,914,115 | 6,631,330 | 8,593,214 | 10,859,883 | 13,892,626 | 17,273,887 |
| 5 | Forest products | 258,775 | 335,795 | 429,470 | 546,906 | 673,608 | 812,313 | 989,355 | 1,168,506 |
| 6 | Fisheries | 1,566,661 | 2,051,960 | 2,585,608 | 3,246,140 | 3,986,191 | 4,830,372 | 6,029,855 | 7,367,037 |
| 7 | Coal | 0 | 0 | 93,610 | 215,089 | 353,981 | 646,445 | 967,854 | 1,395,987 |
| 8 | Crude oil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Other mining | 212 | 256 | 306 | 361 | 417 | 473 | 542 | 599 |
| 11 | Food, beverages & tobacco | 13,882,991 | 16,793,868 | 20,021,784 | 23,654,342 | 27,296,363 | 32,961,070 | 37,920,839 | 45,248,100 |
| 12 | Wood products | 329,199 | 514,499 | 792,631 | 1,229,308 | 1,802,151 | 2,553,936 | 3,682,259 | 5,186,669 |
| 13 | Pulp, paper & products | 161,069 | 226,046 | 312,689 | 432,793 | 573,501 | 739,907 | 967,219 | 1,230,105 |
| 14 | Fertilizer & pesticides | 53,163 | 71,792 | 95,556 | 126,961 | 162,293 | 202,533 | 255,695 | 313,569 |
| 15 | Chemicals | 759,001 | 1,024,961 | 1,364,242 | 1,812,604 | 2,317,038 | 2,891,534 | 3,650,524 | 4,476,781 |
| 16 | Cement & limestone | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Other manufacturing | 3,300,824 | 5,058,499 | 7,641,456 | 11,608,391 | 16,706,170 | 23,271,033 | 30,495,380 | 39,519,716 |
| 18 | Petroleum refining | 1,354,863 | 1,765,897 | 2,000,905 | 2,294,282 | 2,654,857 | 3,243,980 | 4,058,744 | 5,091,247 |
| 19 | Liquified natural gas | 27,650 | 73,579 | 117,012 | 172,071 | 247,787 | 387,867 | 593,201 | 903,286 |
| 20 | Electricity | 402,079 | 529,779 | 893,513 | 1,506,978 | 1,929,711 | 3,571,127 | 6,608,735 | 12,263,410 |
| 21 | Gas utilities | 54,113 | 70,219 | 128,713 | 186,410 | 283,185 | 423,128 | 624,422 | 903,286 |
| 22 | Water utilities | 66,047 | 97,002 | 147,928 | 208,376 | 275,048 | 378,113 | 513,911 | 667,035 |
| 23 | Construction | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | Wholesale & retail trade | 5,334,211 | 7,087,584 | 9,281,982 | 12,121,785 | 15,583,973 | 19,815,674 | 25,505,303 | 35,061,204 |
| 25 | Restaurants and hotels | 4,544,430 | 6,038,199 | 7,907,696 | 10,327,039 | 13,002,969 | 16,002,219 | 19,909,486 | 24,045,195 |
| 26 | Transport & communications | 5,541,377 | 7,776,835 | 10,757,685 | 14,889,712 | 19,730,587 | 25,455,560 | 33,275,971 | 42,320,231 |
| 27 | Real estate, financial & business | 4,162,367 | 5,885,260 | 8,202,078 | 11,442,668 | 15,269,088 | 19,827,325 | 26,094,490 | 33,422,043 |
| 28 | Public administration & defence | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | Social & other services | 5,395,180 | 7,164,896 | 9,378,387 | 12,240,960 | 16,986,146 | 22,862,750 | 30,946,530 | 40,530,081 |
| 30 | Unspecified | (17,679) | (23,478) | (30,731) | (40,111) | (50,481) | (62,097) | (77,223) | (93,219) |
| Total private consumption | | 57,201,404 | 74,759,947 | 96,879,230 | 126,018,048 | 160,818,362 | 205,364,709 | 262,051,334 | 334,469,210 |
| | Growth (%) | | 5.5 | 5.3 | 5.4 | 5.0 | 5.0 | 5.0 | 5.0 |

Note: Figures for private consumption reflect energy consumption assumptions under S1 (see Chapter 9).

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Table B.2 Government consumption by sector on the moderate growth path, 1985–2020 (Rp million, constant 1985 prices)

| | Sector | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | Other food crops | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | Estate crops | 3,756 | 5,026 | 7,149 | 9,934 | 13,045 | 16,649 | 21,248 | 27,119 |
| 4 | Livestock, poultry & products | 31 | 41 | 59 | 82 | 108 | 137 | 175 | 224 |
| 5 | Forest products | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Fisheries | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Coal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Crude oil | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Other mining | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Food, beverages & tobacco | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | Wood products | 6,592 | 8,822 | 12,547 | 17,434 | 22,894 | 29,219 | 37,292 | 47,595 |
| 13 | Pulp, paper & products | 114,633 | 153,405 | 218,191 | 303,175 | 398,119 | 508,113 | 648,495 | 827,662 |
| 14 | Fertilizer & pesticides | 11,166 | 14,943 | 21,253 | 29,531 | 38,779 | 49,493 | 63,168 | 80,620 |
| 15 | Chemicals | 74,635 | 99,878 | 142,060 | 197,391 | 259,207 | 330,821 | 422,221 | 538,872 |
| 16 | Cement & limestone | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Other manufacturing | 356,912 | 477,629 | 679,343 | 943,942 | 1,239,553 | 1,582,018 | 2,019,100 | 2,576,941 |
| 18 | Petroleum refining | 152,836 | 204,529 | 290,907 | 404,213 | 530,798 | 677,448 | 864,614 | 1,103,491 |
| 19 | Liquified natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | Electricity | 102,432 | 137,077 | 194,968 | 270,907 | 355,746 | 454,031 | 579,472 | 739,569 |
| 21 | Gas utilities | 13,786 | 18,449 | 26,240 | 36,460 | 47,879 | 61,107 | 77,989 | 99,536 |
| 22 | Water utilities | 916 | 1,226 | 1,744 | 2,423 | 3,181 | 4,060 | 5,182 | 6,614 |
| 23 | Construction | 374,209 | 500,776 | 712,266 | 989,688 | 1,299,625 | 1,658,687 | 2,116,952 | 2,701,827 |
| 24 | Wholesale & retail trade | 140,634 | 188,200 | 267,681 | 371,941 | 488,421 | 623,362 | 795,586 | 1,015,392 |
| 25 | Restaurants and hotels | 651,757 | 872,198 | 1,240,548 | 1,723,733 | 2,263,547 | 2,888,923 | 3,687,079 | 4,705,751 |
| 26 | Transport & communications | 372,974 | 499,123 | 709,915 | 986,422 | 1,295,336 | 1,653,213 | 2,109,965 | 2,692,910 |
| 27 | Real estate, financial & business | 377,020 | 504,538 | 717,616 | 997,123 | 1,309,387 | 1,671,147 | 2,132,854 | 2,722,123 |
| 28 | Public administration & defence | 6,374,999 | 8,531,187 | 12,134,114 | 16,860,262 | 22,140,321 | 28,257,283 | 36,064,250 | 46,028,137 |
| 29 | Social & other services | 2,296,707 | 3,073,512 | 4,371,531 | 6,074,210 | 7,976,445 | 10,180,190 | 12,992,789 | 16,582,457 |
| 30 | Unspecified | (25,897) | (34,656) | (49,292) | (68,491) | (89,940) | (114,789) | (146,503) | (186,979) |
| Total government consumption | | 11,400,098 | 15,255,903 | 21,698,840 | 30,150,380 | 39,592,450 | 50,531,114 | 64,491,929 | 82,309,860 |
| | Growth (%) | | 6.0 | 7.3 | 6.8 | 5.6 | 5.0 | 5.0 | 5.0 |

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Table B.3 Exports by sector on the moderate growth path, 1985–2020 (Rp million, constant 1985 prices)

| | Sector | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 77,583 | 126,361 | 184,083 | 239,179 | 290,934 | 371,068 | 486,229 | 639,319 |
| 2 | Other food crops | 51,864 | 84,472 | 123,059 | 159,890 | 194,488 | 248,058 | 325,042 | 427,383 |
| 3 | Estate crops | 1,126,809 | 1,996,462 | 2,908,447 | 3,778,948 | 4,596,659 | 5,862,759 | 7,682,254 | 10,101,040 |
| 4 | Livestock, poultry & products | 30,161 | 179,108 | 260,925 | 339,020 | 412,379 | 525,964 | 689,196 | 906,192 |
| 5 | Forest products | 87,610 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Fisheries | 176,769 | 551,137 | 802,896 | 1,043,204 | 1,268,939 | 1,618,454 | 2,120,738 | 2,788,460 |
| 7 | Coal | 30,615 | 50,302 | 68,272 | 92,062 | 118,451 | 159,804 | 221,493 | 308,053 |
| 8 | Crude oil | 9,562,215 | 10,199,287 | 8,316,220 | 6,434,933 | 5,516,907 | 3,442,727 | 0 | 0 |
| 9 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Other mining | 189,181 | 293,860 | 377,059 | 480,687 | 584,701 | 745,750 | 977,192 | 1,284,865 |
| 11 | Food, beverages & tobacco | 160,210 | 286,500 | 744,009 | 1,122,624 | 1,500,645 | 2,103,344 | 3,028,790 | 4,376,420 |
| 12 | Wood products | 1,000,111 | 4,085,190 | 5,548,256 | 6,118,768 | 5,831,616 | 5,827,767 | 5,983,321 | 6,164,150 |
| 13 | Pulp, paper & products | 20,945 | 37,456 | 75,740 | 111,161 | 155,667 | 228,575 | 344,816 | 521,959 |
| 14 | Fertilizer & pesticides | 85,019 | 153,451 | 271,882 | 402,739 | 538,354 | 754,571 | 1,086,573 | 1,570,033 |
| 15 | Chemicals | 160,545 | 426,566 | 936,225 | 2,041,548 | 3,133,632 | 5,043,415 | 8,339,274 | 13,836,383 |
| 16 | Cement & limestone | 14,669 | 32,748 | 60,392 | 88,635 | 102,777 | 124,961 | 156,093 | 195,650 |
| 17 | Other manufacturing | 2,093,815 | 4,471,011 | 11,610,710 | 19,192,921 | 32,237,112 | 47,335,631 | 66,584,985 | 91,798,704 |
| 18 | Petroleum refining | 895,856 | 1,157,331 | 1,341,664 | 1,540,315 | 0 | 0 | 0 | 0 |
| 19 | Liquified natural gas | 3,917,190 | 6,113,715 | 8,143,010 | 10,897,184 | 18,779,699 | 27,978,918 | 38,513,851 | 47,083,701 |
| 20 | Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | Gas utilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | Water utilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | Construction | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | Wholesale & retail trade | 1,147,776 | 1,782,874 | 2,398,675 | 3,206,325 | 4,089,420 | 5,468,955 | 7,514,044 | 10,359,386 |
| 25 | Restaurants and hotels | 212,737 | 330,451 | 424,008 | 566,775 | 722,878 | 966,735 | 1,328,241 | 1,831,205 |
| 26 | Transport & communications | 920,651 | 1,430,074 | 1,924,019 | 2,571,848 | 3,280,195 | 4,386,743 | 6,027,145 | 8,309,443 |
| 27 | Real estate, financial & business | 522,705 | 811,933 | 1,092,373 | 1,460,182 | 1,862,350 | 2,490,599 | 3,421,947 | 4,717,735 |
| 28 | Public administration & defence | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | Social & other services | 2,038 | 2,903 | 3,726 | 4,314 | 4,539 | 5,009 | 5,678 | 6,458 |
| 30 | Unspecified | 35,467 | 50,529 | 64,835 | 75,076 | 79,000 | 87,165 | 98,806 | 112,386 |
| Total exports | | 22,522,541 | 34,653,721 | 47,680,486 | 61,968,337 | 85,301,343 | 115,776,973 | 154,935,706 | 207,338,925 |
| Total oil and gas exports | | 14,375,261 | 17,470,333 | 17,800,895 | 18,872,432 | 24,296,606 | 31,421,645 | 38,513,851 | 47,083,701 |
| Total non–oil exports | | 8,147,280 | 17,183,388 | 29,879,591 | 43,095,906 | 61,004,737 | 84,355,327 | 116,421,856 | 160,255,224 |
| Growth of exports (%) | | | 9.0 | 6.6 | 5.4 | 6.6 | 6.3 | 6.0 | 6.0 |
| Growth of oil and gas exports (%) | | | 4.0 | 0.4 | 1.2 | 5.2 | 5.3 | 4.2 | 4.1 |
| Growth of non–oil exports (%) | | | 16.1 | 11.7 | 7.6 | 7.2 | 6.7 | 6.7 | 6.6 |

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Table B.4 Imports by sector on the moderate growth path, 1985–2020 (Rp million, constant 1985 prices)

| | Sector | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | Other food crops | (428,888) | (618,881) | (757,878) | (906,807) | (1,076,205) | (1,288,223) | (1,503,671) | (1,750,288) |
| 3 | Estate crops | (377,792) | (545,150) | (667,588) | (798,773) | (947,990) | (1,134,749) | (1,324,529) | (1,541,766) |
| 4 | Livestock, poultry & products | (15,264) | (22,026) | (26,973) | (32,273) | (38,302) | (45,847) | (53,515) | (62,292) |
| 5 | Forest products | (3,605) | (5,202) | (6,370) | (7,622) | (9,046) | (10,828) | (12,639) | (14,712) |
| 6 | Fisheries | (1,339) | (1,932) | (2,366) | (2,831) | (3,360) | (4,022) | (4,695) | (5,464) |
| 7 | Coal | (5,859) | (10,958) | (15,549) | (21,208) | (28,363) | (37,668) | (48,307) | (61,705) |
| 8 | Crude oil | (959,495) | (1,224,586) | (1,164,569) | (1,058,060) | (911,163) | (693,585) | (542,809) | (348,863) |
| 9 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Other mining | (201,674) | (377,195) | (535,225) | (730,007) | (976,292) | (1,296,582) | (1,662,772) | (2,123,971) |
| 11 | Food, beverages & tobacco | (229,428) | (342,603) | (427,713) | (520,592) | (627,548) | (761,418) | (899,719) | (1,060,030) |
| 12 | Wood products | (4,105) | (5,923) | (7,254) | (8,679) | (10,301) | (12,330) | (14,392) | (16,752) |
| 13 | Pulp, paper & products | (301,926) | (435,676) | (533,527) | (638,368) | (757,620) | (906,875) | (1,058,545) | (1,232,157) |
| 14 | Fertilizer & pesticides | (112,895) | (173,464) | (220,069) | (271,712) | (331,628) | (407,197) | (486,112) | (578,549) |
| 15 | Chemicals | (2,193,551) | (3,229,019) | (3,998,805) | (4,832,430) | (5,787,378) | (6,982,274) | (8,208,288) | (9,621,975) |
| 16 | Cement & limestone | (5,282) | (12,275) | (12,275) | (12,275) | (12,374) | (12,859) | (13,209) | (13,553) |
| 17 | Other manufacturing | (7,957,314) | (18,212,122) | (29,047,914) | (43,972,609) | (64,686,498) | (93,353,246) | (129,095,939) | (177,654,209) |
| 18 | Petroleum refining | (484,068) | (647,792) | (846,638) | (1,080,549) | (1,336,536) | (1,668,770) | (1,940,050) | (2,260,647) |
| 19 | Liquified natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | Gas utilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | Water utilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | Construction | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | Wholesale & retail trade | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | Restaurants and hotels | (431,243) | (622,279) | (762,040) | (911,786) | (1,082,114) | (1,295,296) | (1,511,927) | (1,759,899) |
| 26 | Transport & communications | (648,433) | (935,682) | (1,145,831) | (1,370,995) | (1,627,107) | (1,947,656) | (2,273,390) | (2,646,249) |
| 27 | Real estate, financial & business | (904,935) | (1,305,812) | (1,599,090) | (1,913,323) | (2,270,746) | (2,718,094) | (3,172,679) | (3,693,031) |
| 28 | Public administration & defence | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | Social & other services | (908,754) | (1,311,322) | (1,605,839) | (1,921,397) | (2,280,329) | (2,729,565) | (3,186,069) | (3,708,617) |
| 30 | Unspecified | (58,247) | (84,050) | (102,927) | (123,153) | (146,159) | (174,953) | (204,213) | (237,705) |
| Total imports | | (16,234,097) | (30,123,949) | (43,486,441) | (61,135,449) | (84,947,259) | (117,482,037) | (157,217,467) | (210,392,436) |
| Total oil & gas imports | | (1,443,563) | (1,872,378) | (2,011,207) | (2,138,609) | (2,247,699) | (2,362,355) | (2,482,859) | (2,609,509) |
| Total non–oil & gas imports | | (14,790,534) | (28,251,571) | (41,475,233) | (58,996,840) | (82,699,560) | (115,119,683) | (154,734,609) | (207,782,927) |
| Total imports growth (%) | | | 13.2 | 7.6 | 7.1 | 6.8 | 6.7 | 6.0 | 6.0 |
| Growth of total oil & gas imports (%) | | | 5.3 | 1.4 | 1.2 | 1.0 | 1.0 | 1.0 | 1.0 |
| Growth of total non–oil & gas imports (%) | | | 13.8 | 8.0 | 7.3 | 7.0 | 6.8 | 6.1 | 6.1 |

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Table B.5 Total final demand (excluding investment) by sector on the moderate growth path, 1985–2020 (Rp million, constant 1985 prices)

| | Sector | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 77,583 | 126,361 | 184,083 | 239,179 | 290,934 | 371,068 | 486,229 | 639,319 |
| 2 | Other food crops | 6,004,091 | 6,847,880 | 7,782,125 | 8,732,431 | 9,615,210 | 10,441,697 | 11,441,997 | 12,059,809 |
| 3 | Estate crops | 1,741,311 | 2,652,145 | 3,673,659 | 4,674,415 | 5,605,350 | 6,952,362 | 8,903,962 | 11,378,133 |
| 4 | Livestock, poultry & products | 2,670,146 | 3,795,527 | 5,148,126 | 6,938,159 | 8,967,399 | 11,340,137 | 14,528,483 | 18,118,011 |
| 5 | Forest products | 342,780 | 330,593 | 423,099 | 539,284 | 664,562 | 801,484 | 976,716 | 1,153,794 |
| 6 | Fisheries | 1,742,091 | 2,601,165 | 3,386,139 | 4,286,513 | 5,251,770 | 6,444,805 | 8,145,898 | 10,150,032 |
| 7 | Coal | 24,756 | 39,344 | 146,332 | 285,943 | 444,069 | 768,581 | 1,141,041 | 1,642,334 |
| 8 | Crude oil | 8,602,720 | 8,974,701 | 7,151,651 | 5,376,873 | 4,605,743 | 2,749,142 | (542,809) | (348,863) |
| 9 | Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Other mining | (12,281) | (83,078) | (157,861) | (248,959) | (391,175) | (550,359) | (685,039) | (838,508) |
| 11 | Food, beverages & tobacco | 13,813,773 | 16,737,765 | 20,338,080 | 24,256,374 | 28,169,461 | 34,302,995 | 40,049,911 | 48,564,490 |
| 12 | Wood products | 1,331,797 | 4,602,588 | 6,346,180 | 7,356,830 | 7,646,360 | 8,398,593 | 9,688,480 | 11,381,562 |
| 13 | Pulp, paper & products | (5,279) | (18,770) | 73,094 | 208,761 | 369,667 | 569,719 | 901,985 | 1,347,569 |
| 14 | Fertilizer & pesticides | 36,453 | 66,721 | 168,623 | 287,520 | 407,598 | 599,400 | 919,323 | 1,385,672 |
| 15 | Chemicals | (1,199,370) | (1,677,614) | (1,556,277) | (780,887) | (77,502) | 1,283,496 | 4,203,731 | 9,230,061 |
| 16 | Cement & limestone | 9,387 | 20,474 | 48,117 | 76,360 | 90,403 | 112,102 | 142,884 | 182,097 |
| 17 | Other manufacturing | (2,205,763) | (8,204,984) | (9,116,405) | (12,227,355) | (14,503,663) | (21,164,564) | (29,996,474) | (43,758,848) |
| 18 | Petroleum refining | 1,919,487 | 2,479,966 | 2,786,838 | 3,158,260 | 1,849,119 | 2,252,659 | 2,983,308 | 3,934,092 |
| 19 | Liquified natural gas | 3,944,840 | 6,187,294 | 8,260,022 | 11,069,256 | 19,027,486 | 28,366,786 | 39,107,052 | 47,986,987 |
| 20 | Electricity | 504,511 | 666,856 | 1,088,481 | 1,777,884 | 2,285,457 | 4,025,158 | 7,188,207 | 13,002,979 |
| 21 | Gas utilities | 67,899 | 88,668 | 154,953 | 222,871 | 331,064 | 484,235 | 702,411 | 1,002,822 |
| 22 | Water utilities | 66,963 | 98,228 | 149,672 | 210,799 | 278,230 | 382,173 | 519,093 | 673,649 |
| 23 | Construction | 374,209 | 500,776 | 712,266 | 989,688 | 1,299,625 | 1,658,687 | 2,116,952 | 2,701,827 |
| 24 | Wholesale & retail trade | 6,622,621 | 9,058,658 | 11,948,339 | 15,700,051 | 20,161,814 | 25,907,991 | 33,814,934 | 46,435,982 |
| 25 | Restaurants and hotels | 4,977,681 | 6,618,569 | 8,810,213 | 11,705,760 | 14,907,279 | 18,562,581 | 23,412,879 | 28,822,254 |
| 26 | Transport & communications | 6,186,569 | 8,770,350 | 12,245,788 | 17,076,987 | 22,679,010 | 29,547,861 | 39,139,692 | 50,676,335 |
| 27 | Real estate, financial & business | 4,157,157 | 5,895,919 | 8,412,977 | 11,986,650 | 16,170,080 | 21,270,977 | 28,476,612 | 37,168,869 |
| 28 | Public administration & defence | 6,374,999 | 8,531,187 | 12,134,114 | 16,860,262 | 22,140,321 | 28,257,283 | 36,064,250 | 46,028,137 |
| 29 | Social & other services | 6,785,171 | 8,929,989 | 12,147,804 | 16,398,087 | 22,686,802 | 30,318,383 | 40,758,928 | 53,410,379 |
| 30 | Unspecified | (66,356) | (91,655) | (118,116) | (156,679) | (207,580) | (264,674) | (329,133) | (405,517) |
| Total final demand | | 74,889,946 | 94,545,622 | 122,772,116 | 157,001,316 | 200,764,895 | 254,190,758 | 324,261,502 | 413,725,559 |
| | Growth (%) | | 4.8 | 5.4 | 5.0 | 5.0 | 4.8 | 5.0 | 5.0 |

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Table B.6 Intermediate, labour and capital coefficients for which changes are projected

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| 4 | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| 14 | X | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | X | | X | | X | | X | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | X | | | | | | X | | | | X | | | | | | | | | | | | | | | |
| 18 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 19 | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | |
| 20 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 21 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| B | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

Note: L = labour coefficients, B = capital coefficients

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Table B.7 Natural resource coefficients that have been developed for 1985 and for which changes are projected

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land | X | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil erosion | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Deforestation | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Water in | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Water out | X | | | X | | | | | | | X | X | X | X | X | X | X | | | X | | | | | | | | | | | X |
| BOD | | | | | | | | | | | X | X | X | X | X | X | X | | | X | | | | | | | | | | | X |
| COD | | | | | | | | | | | X | X | X | X | X | X | X | | | | | | | | | | | | | | |
| Dissolved solids | | | | | | | | | | | X | X | X | X | X | X | X | | | | | | | | | | | | | | |
| Suspended solids | | | | | | | | | | | X | X | X | X | X | X | X | | | | | | | | | | | | | | |
| CO2 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| NOx | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| SOx | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

Notes: C = private consumption.

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## APPENDIX C

## NRMP–IEA 30–SECTOR CLASSIFICATION

**Table C.1 Sectoral correspondences between NRMP–IEA and BPS classifications**

| | NRMP–IEA 30–sector classification | BPS 66–sector classification |
|---|---|---|
| 1 | Paddy | 1 |
| 2 | Other food crops | 2–6 |
| 3 | Estate crops | 7–17 |
| 4 | Livestock, poultry & products | 18–20 |
| 5 | Forest products | 21–22 |
| 6 | Fisheries | 23 |
| 7 | Coal | 24 |
| 8 | Crude oil | 25 |
| 9 | Natural gas | 25 |
| 10 | Other mining | 24,26 |
| 11 | Food, beverages & tobacco | 27–34 |
| 12 | Wood products | 37 |
| 13 | Pulp, paper & products | 38 |
| 14 | Fertiliser & pesticides | 39 |
| 15 | Chemicals | 40 |
| 16 | Cement and limestone | 44 |
| 17 | Other manufacturing | 35,36,42,43,45–50 |
| 18 | Petroleum refining | 41 |
| 19 | Liquified natural gas | 41 |
| 20 | Electricity | 51 |
| 21 | Gas utilities | 51 |
| 22 | Water utilities | 51 |
| 23 | Construction | 52 |
| 24 | Wholesale & retail trade | 53 |
| 25 | Restaurants & hotels | 54 |
| 26 | Transport & communications | 55–60 |
| 27 | Real estate, finance & business services | 61,62 |
| 28 | Public administration & defence | 63 |
| 29 | Social & other services | 64,65 |
| 30 | Unspecified | 66 |

*Source:* BPS classification from BPS (1989).

# APPENDIX D

# SOME DETAILED RESULTS

Table D.1 Annual sectoral outputs under the Base Scenario (MS1), 1985–2020 (Kp billion)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 7040 | 7429 | 5380 | 4842 | 1585 | 2123 | 78 | 14477 | 852 | 1317 | 16414 | 2602 | 933 | 1093 |
| 1986 | 7166 | 7658 | 5584 | 5205 | 1720 | 2320 | 80 | 14652 | 912 | 1181 | 17141 | 3208 | 934 | 1123 |
| 1987 | 7279 | 7885 | 5720 | 5562 | 1847 | 2516 | 80 | 14780 | 969 | 1009 | 17860 | 3803 | 919 | 1148 |
| 1988 | 7389 | 8113 | 5890 | 5922 | 2038 | 2713 | 82 | 15047 | 1030 | 926 | 18589 | 4494 | 926 | 1176 |
| 1989 | 7495 | 8343 | 6097 | 6289 | 2255 | 2911 | 86 | 15386 | 1093 | 892 | 19325 | 5226 | 948 | 1205 |
| 1990 | 7603 | 8577 | 6567 | 6682 | 2485 | 3109 | 99 | 15845 | 1165 | 989 | 20092 | 5983 | 1016 | 1249 |
| 1991 | 7753 | 8839 | 6757 | 7125 | 2630 | 3295 | 125 | 15700 | 1224 | 922 | 21000 | 6392 | 1074 | 1296 |
| 1992 | 7906 | 9107 | 7206 | 7594 | 2835 | 3482 | 161 | 15757 | 1294 | 1038 | 21940 | 6892 | 1189 | 1357 |
| 1993 | 8048 | 9375 | 7685 | 8068 | 3030 | 3669 | 198 | 15806 | 1364 | 1156 | 22886 | 7380 | 1308 | 1419 |
| 1994 | 8180 | 9643 | 8172 | 8540 | 3227 | 3857 | 237 | 15850 | 1433 | 1283 | 23833 | 7874 | 1427 | 1481 |
| 1995 | 8305 | 9912 | 8697 | 9017 | 3454 | 4044 | 278 | 15956 | 1505 | 1461 | 24787 | 8414 | 1560 | 1544 |
| 1996 | 8462 | 10199 | 9301 | 9648 | 3690 | 4262 | 335 | 16258 | 1603 | 1717 | 25868 | 8870 | 1744 | 1618 |
| 1997 | 8608 | 10487 | 9905 | 10280 | 3915 | 4479 | 392 | 16535 | 1700 | 1959 | 26951 | 9310 | 1929 | 1691 |
| 1998 | 8729 | 10772 | 10431 | 10903 | 4018 | 4696 | 443 | 16554 | 1790 | 2023 | 28020 | 9569 | 2072 | 1758 |
| 1999 | 8822 | 11051 | 10832 | 11504 | 3969 | 4911 | 484 | 16238 | 1870 | 1857 | 29063 | 9603 | 2150 | 1814 |
| 2000 | 8902 | 11326 | 10929 | 12074 | 3987 | 5124 | 517 | 15926 | 1943 | 1636 | 30080 | 9732 | 2190 | 1853 |
| 2001 | 8991 | 11596 | 11174 | 12744 | 4033 | 5355 | 562 | 16005 | 2147 | 1552 | 31143 | 9810 | 2298 | 1901 |
| 2002 | 9081 | 11870 | 11543 | 13430 | 4161 | 5587 | 616 | 16268 | 2358 | 1619 | 32228 | 10013 | 2448 | 1957 |
| 2003 | 9169 | 12147 | 12036 | 14132 | 4330 | 5820 | 677 | 16640 | 2574 | 1790 | 33332 | 10281 | 2631 | 2019 |
| 2004 | 9256 | 12426 | 12642 | 14846 | 4535 | 6054 | 744 | 17102 | 2794 | 2053 | 34454 | 10604 | 2843 | 2087 |
| 2005 | 9340 | 12708 | 13381 | 15573 | 4773 | 6288 | 819 | 17659 | 3019 | 2415 | 35595 | 10982 | 3088 | 2162 |
| 2006 | 9539 | 13009 | 14053 | 16393 | 5022 | 6577 | 935 | 18245 | 3289 | 2644 | 37233 | 11427 | 3329 | 2255 |
| 2007 | 9726 | 13313 | 14987 | 17237 | 5227 | 6867 | 1060 | 18806 | 3564 | 2937 | 38895 | 11811 | 3596 | 2360 |
| 2008 | 9903 | 13613 | 15644 | 18059 | 5546 | 7156 | 1183 | 19462 | 3835 | 3246 | 40540 | 12366 | 3847 | 2450 |
| 2009 | 10045 | 13912 | 16402 | 18880 | 5576 | 7444 | 1294 | 19651 | 4098 | 3254 | 42177 | 12485 | 4047 | 2541 |
| 2010 | 10166 | 14202 | 16780 | 19659 | 5594 | 7729 | 1391 | 19676 | 4350 | 3081 | 43771 | 12581 | 4170 | 2611 |
| 2011 | 10287 | 14542 | 17244 | 20704 | 5654 | 8130 | 1516 | 19587 | 4653 | 2884 | 45379 | 12796 | 4365 | 2712 |
| 2012 | 10421 | 14888 | 17813 | 21768 | 5961 | 8533 | 1662 | 19921 | 4968 | 3030 | 47021 | 13390 | 4640 | 2822 |
| 2013 | 10564 | 15244 | 18781 | 22885 | 6381 | 8939 | 1834 | 20549 | 5298 | 3489 | 48721 | 14163 | 5018 | 2953 |
| 2014 | 10711 | 15607 | 19998 | 24027 | 6910 | 9347 | 2025 | 21405 | 5638 | 4190 | 50461 | 15110 | 5471 | 3098 |
| 2015 | 10838 | 15970 | 21339 | 25172 | 7308 | 9755 | 2215 | 22060 | 5977 | 4790 | 52207 | 15862 | 5913 | 3246 |
| 2016 | 11063 | 16290 | 22703 | 26429 | 7558 | 10233 | 2452 | 23080 | 6301 | 5089 | 54574 | 16435 | 6347 | 3427 |
| 2017 | 11284 | 16605 | 23687 | 27654 | 8003 | 10711 | 2690 | 24261 | 6620 | 5455 | 56920 | 17303 | 6762 | 3589 |
| 2018 | 11469 | 16918 | 24624 | 28871 | 8199 | 11187 | 2913 | 25031 | 6930 | 5501 | 59251 | 17793 | 7122 | 3745 |
| 2019 | 11622 | 17224 | 25416 | 30062 | 8199 | 11661 | 3120 | 25418 | 7228 | 5247 | 61553 | 17978 | 7402 | 3890 |
| 2020 | 11756 | 17523 | 25842 | 31215 | 8201 | 12134 | 3314 | 25681 | 7516 | 4833 | 63819 | 18162 | 7618 | 4015 |

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Table D.1 (cont.)

| | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 2043 | 730 | 17044 | 7075 | 3945 | 1541 | 183 | 133 | 19446 | 14323 | 5826 | 10420 | 8232 | 6375 | 9344 |
| 1986 | 1643 | 668 | 14489 | 7077 | 4393 | 1577 | 188 | 141 | 17950 | 14682 | 6163 | 10943 | 8631 | 6806 | 9875 |
| 1987 | 1058 | 595 | 10455 | 7009 | 4842 | 1591 | 190 | 149 | 16372 | 14687 | 6486 | 11325 | 8971 | 7237 | 10331 |
| 1988 | 597 | 579 | 7095 | 7149 | 5290 | 1622 | 194 | 158 | 16472 | 14984 | 6830 | 11829 | 9401 | 7669 | 10817 |
| 1989 | 251 | 590 | 4506 | 7395 | 5739 | 1669 | 200 | 167 | 17277 | 15552 | 7187 | 12441 | 9890 | 8100 | 11351 |
| 1990 | 593 | 635 | 7514 | 7820 | 6187 | 1785 | 215 | 178 | 18188 | 16634 | 7582 | 13293 | 10533 | 8531 | 11967 |
| 1991 | 243 | 642 | 3196 | 8027 | 6602 | 1889 | 230 | 192 | 19074 | 17306 | 8046 | 14098 | 11174 | 9252 | 12759 |
| 1992 | 589 | 720 | 4393 | 8534 | 7016 | 2066 | 254 | 209 | 21278 | 18660 | 8558 | 15210 | 12018 | 9972 | 13651 |
| 1993 | 1003 | 793 | 6224 | 9027 | 7431 | 2249 | 279 | 225 | 23223 | 20151 | 9073 | 16375 | 12876 | 10693 | 14578 |
| 1994 | 1433 | 869 | 8230 | 9516 | 7845 | 2432 | 305 | 242 | 25264 | 21532 | 9588 | 17503 | 13731 | 11414 | 15473 |
| 1995 | 1968 | 973 | 11019 | 10094 | 8260 | 2627 | 332 | 258 | 28086 | 23071 | 10115 | 18700 | 14638 | 12134 | 16384 |
| 1996 | 2871 | 1119 | 14912 | 10903 | 8822 | 2920 | 364 | 279 | 32113 | 25144 | 10814 | 20357 | 15911 | 13079 | 17605 |
| 1997 | 3764 | 1255 | 18805 | 11675 | 9384 | 3213 | 397 | 301 | 35846 | 27397 | 11515 | 22077 | 17186 | 14025 | 18879 |
| 1998 | 4396 | 1285 | 21107 | 12064 | 9946 | 3471 | 425 | 320 | 36390 | 29128 | 12176 | 23574 | 18288 | 14970 | 20104 |
| 1999 | 4642 | 1184 | 20883 | 11953 | 10507 | 3672 | 447 | 337 | 33026 | 29617 | 12775 | 24579 | 19118 | 15915 | 21120 |
| 2000 | 4171 | 1108 | 14063 | 11850 | 11069 | 3803 | 459 | 352 | 31779 | 29438 | 13345 | 25293 | 19836 | 16860 | 21972 |
| 2001 | 4122 | 1099 | 10562 | 11696 | 12661 | 3951 | 486 | 372 | 32160 | 30195 | 14025 | 26513 | 20905 | 17916 | 23416 |
| 2002 | 4411 | 1165 | 9627 | 11813 | 14253 | 4140 | 519 | 393 | 34641 | 31604 | 14744 | 28006 | 22139 | 18972 | 24958 |
| 2003 | 5021 | 1275 | 11342 | 12095 | 15844 | 4365 | 557 | 416 | 38138 | 33570 | 15493 | 29729 | 23500 | 20028 | 26597 |
| 2004 | 5911 | 1423 | 15441 | 12509 | 17436 | 4619 | 599 | 440 | 42489 | 35997 | 16267 | 31644 | 24968 | 21084 | 28316 |
| 2005 | 7128 | 1609 | 22382 | 13063 | 19028 | 4909 | 646 | 465 | 47653 | 38989 | 17070 | 33795 | 26559 | 22140 | 30136 |
| 2006 | 7986 | 1756 | 23922 | 13905 | 20895 | 5457 | 702 | 497 | 52536 | 41933 | 17953 | 36090 | 28291 | 23364 | 32244 |
| 2007 | 9425 | 1894 | 31161 | 14708 | 22763 | 6051 | 765 | 531 | 55997 | 44843 | 18851 | 38419 | 30083 | 24587 | 34329 |
| 2008 | 10264 | 2094 | 32323 | 15654 | 24631 | 6594 | 821 | 564 | 62893 | 47708 | 19743 | 40693 | 31861 | 25811 | 36373 |
| 2009 | 11189 | 2078 | 35919 | 15905 | 26499 | 7127 | 876 | 595 | 61755 | 49906 | 20580 | 42704 | 33380 | 27034 | 38410 |
| 2010 | 11215 | 2018 | 31310 | 15912 | 28367 | 7562 | 917 | 622 | 60705 | 50564 | 21349 | 44085 | 34625 | 28257 | 40117 |
| 2011 | 11587 | 1953 | 24938 | 16098 | 30515 | 8358 | 980 | 659 | 59782 | 51701 | 22380 | 46103 | 36406 | 29819 | 42501 |
| 2012 | 12322 | 2089 | 20568 | 16912 | 32663 | 9204 | 1049 | 699 | 65584 | 54108 | 23488 | 48635 | 38533 | 31380 | 45040 |
| 2013 | 14024 | 2348 | 24725 | 18164 | 34811 | 10158 | 1134 | 744 | 74130 | 58465 | 24689 | 51962 | 41055 | 32942 | 47945 |
| 2014 | 16335 | 2712 | 34174 | 19754 | 36959 | 11179 | 1231 | 792 | 85484 | 64162 | 25958 | 55835 | 43867 | 34503 | 51084 |
| 2015 | 18840 | 2987 | 46430 | 21044 | 39107 | 12210 | 1331 | 839 | 93153 | 69802 | 27214 | 59692 | 46609 | 36064 | 54269 |
| 2016 | 21412 | 3110 | 54090 | 21926 | 40883 | 13826 | 1452 | 888 | 96252 | 74310 | 28525 | 63220 | 49440 | 38057 | 57577 |
| 2017 | 23220 | 3344 | 53296 | 23052 | 42659 | 15375 | 1562 | 937 | 105195 | 78546 | 29830 | 66604 | 52267 | 40050 | 60751 |
| 2018 | 24794 | 3385 | 51681 | 23564 | 44435 | 16896 | 1668 | 984 | 107303 | 82558 | 31081 | 69859 | 54846 | 42043 | 64030 |
| 2019 | 25934 | 3266 | 47114 | 23508 | 46211 | 18357 | 1767 | 1027 | 104103 | 85086 | 32255 | 72524 | 57089 | 44035 | 67075 |
| 2020 | 26270 | 3114 | 34579 | 23268 | 47987 | 19737 | 1852 | 1068 | 101336 | 86501 | 33374 | 74717 | 59107 | 46028 | 69889 |

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Table D.2 Sectoral employment by five-year intervals under MS1, 1985–2020 (millions)

| | Sector | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 6,859 | 7,123 | 7,483 | 7,721 | 7,734 | 5,056 | 8,200 | 8,478 |
| 2 | Other food crops | 12,131 | 13,596 | 14,886 | 16,285 | 17,422 | 11,623 | 19,815 | 20,603 |
| 3 | Estate crops | 2,382 | 2,666 | 3,445 | 4,223 | 4,651 | 3,492 | 6,596 | 7,448 |
| 4 | Livestock, poultry & products | 939 | 1,170 | 1,418 | 1,684 | 1,878 | 2,016 | 2,120 | 2,059 |
| 5 | Forest products | 382 | 775 | 1,307 | 1,875 | 2,472 | 3,443 | 4,903 | 6,171 |
| 6 | Fisheries | 1,028 | 1,420 | 1,735 | 2,058 | 2,349 | 2,675 | 3,105 | 3,527 |
| 7 | Coal | 12 | 13 | 37 | 68 | 96 | 154 | 224 | 308 |
| 8 | Crude oil | 71 | 72 | 68 | 65 | 65 | 69 | 70 | 75 |
| 9 | Natural gas | 4 | 5 | 6 | 8 | 11 | 15 | 19 | 22 |
| 10 | Other mining | 462 | 288 | 420 | 546 | 583 | 803 | 1,079 | 1,028 |
| 11 | Food, beverages & tobacco | 1,472 | 172 | 1,904 | 2,122 | 2,277 | 2,524 | 2,674 | 2,862 |
| 12 | Wood products | 1,323 | 2,769 | 3,497 | 3,730 | 3,604 | 3,698 | 3,889 | 3,701 |
| 13 | Pulp, paper & products | 145 | 143 | 211 | 292 | 362 | 467 | 602 | 714 |
| 14 | Fertilizer & pesticides | 22 | 23 | 26 | 28 | 28 | 30 | 32 | 32 |
| 15 | Chemicals | 157 | (0) | 115 | 282 | 327 | 496 | 698 | 812 |
| 16 | Cement & limestone | 110 | 89 | 130 | 169 | 202 | 278 | 377 | 393 |
| 17 | Other manufacturing | 2,772 | 403 | 1,465 | 2,807 | 2,231 | 3,829 | 5,163 | 3,749 |
| 18 | Petroleum refining | 17 | 17 | 21 | 24 | 23 | 28 | 33 | 33 |
| 19 | Liquified natural gas | 9 | 14 | 17 | 22 | 35 | 48 | 61 | 69 |
| 20 | Electricity | 84 | 95 | 143 | 213 | 265 | 416 | 668 | 1,083 |
| 21 | Gas utilities | 10 | 11 | 16 | 20 | 25 | 33 | 42 | 52 |
| 22 | Water utilities | 7 | 9 | 12 | 15 | 18 | 22 | 27 | 30 |
| 23 | Construction | 2,391 | 2,091 | 2,850 | 3,470 | 4,219 | 5,575 | 7,377 | 7,529 |
| 24 | Wholesale & retail trade | 9,323 | 9,819 | 12,673 | 15,748 | 17,690 | 21,700 | 26,007 | 28,847 |
| 25 | Restaurants and hotels | 357 | 430 | 531 | 649 | 749 | 851 | 965 | 1,043 |
| 26 | Transport & communications | 2,144 | 2,506 | 3,277 | 4,192 | 4,930 | 5,932 | 7,081 | 7,856 |
| 27 | Real estate, financial & business | 163 | 191 | 247 | 314 | 374 | 447 | 532 | 596 |
| 28 | Public administration & defence | 2,418 | 3,009 | 3,958 | 5,051 | 6,046 | 6,966 | 10,132 | 8,903 |
| 29 | Social & other services | 7,062 | 8,369 | 10,613 | 13,240 | 16,291 | 19,770 | 23,712 | 26,972 |
| 30 | Unspecified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 54,257 | 57,286 | 72,513 | 86,925 | 96,959 | 102,456 | 136,204 | 144,992 |

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Table D.3 Land requirements by five–year intervals under MS1, 1985–2020 (million ha)

| | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Natural forest | 27.98 | 39.77 | 49.55 | 52.70 | 53.36 | 55.39 | 58.27 | 57.63 |
| Plantations | 0.22 | 0.56 | 0.97 | 1.33 | 1.78 | 2.45 | 3.30 | 4.44 |

Note: The land requirements for plantations indicate land required for *Acacia mangium* plantations as described in Chapter 8. They do not reflect the contributions of long–estabilished plantations of slow–growing timber.

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Table D.4 Atmospheric emissions under MS1, 1985, 2000, 2020 (thousands of tons)

| Sector | 1985 Carbon | 1985 Sulphur | 1985 Nitrogen | 2000 Carbon | 2000 Sulphur | 2000 Nitrogen | 2020 Carbon | 2020 Sulphur | 2020 Nitrogen |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.00 | 0.06 | 1.3 | 0.00 | 0.08 | 1.7 | 0.00 | 0.10 |
| 2 | 18.2 | 0.02 | 1.06 | 27.7 | 0.03 | 1.62 | 42.9 | 0.05 | 2.51 |
| 3 | 132.5 | 0.16 | 7.71 | 269.2 | 0.33 | 15.66 | 636.5 | 0.77 | 37.03 |
| 4 | 125.5 | 0.15 | 7.23 | 352.5 | 0.42 | 20.35 | 1047.5 | 1.26 | 60.58 |
| 5 | 134.2 | 0.16 | 7.82 | 337.6 | 0.41 | 19.69 | 694.3 | 0.84 | 40.49 |
| 6 | 273.4 | 0.33 | 15.99 | 660.0 | 0.80 | 38.59 | 1562.8 | 1.90 | 91.38 |
| 7 | 92.2 | 2.72 | 0.62 | 608.0 | 17.93 | 4.11 | 3897.7 | 114.95 | 26.37 |
| 8 | 3864.6 | 46.21 | 26.91 | 4251.3 | 50.84 | 29.60 | 6855.3 | 81.98 | 47.73 |
| 9 | 1597.2 | 0.32 | 15.30 | 3642.4 | 0.72 | 34.90 | 14091.7 | 2.80 | 135.01 |
| 10 | 266.7 | 7.22 | 0.99 | 331.3 | 8.97 | 1.23 | 978.4 | 26.49 | 3.62 |
| 11 | 352.3 | 9.36 | 1.31 | 577.9 | 15.33 | 2.15 | 1034.4 | 27.35 | 3.87 |
| 12 | 256.3 | 6.87 | 0.93 | 864.0 | 23.15 | 3.14 | 1377.3 | 36.91 | 5.01 |
| 13 | 52.6 | 1.37 | 0.20 | 178.4 | 5.02 | 1.07 | 875.5 | 25.85 | 6.48 |
| 14 | 1716.6 | 10.00 | 14.29 | 2868.2 | 15.83 | 24.07 | 6092.2 | 31.02 | 51.70 |
| 15 | 243.6 | 7.01 | 1.52 | 469.1 | 13.55 | 3.01 | 2716.6 | 78.95 | 18.11 |
| 16 | 508.5 | 13.88 | 2.28 | 813.1 | 23.07 | 4.69 | 2436.7 | 72.23 | 17.78 |
| 17 | 1032.7 | 27.09 | 3.95 | 789.5 | 20.58 | 3.06 | 1736.2 | 44.78 | 6.86 |
| 18 | 908.0 | 11.93 | 5.72 | 1500.6 | 19.97 | 9.50 | 2892.9 | 39.16 | 18.41 |
| 19 | 282.5 | 2.14 | 1.96 | 779.4 | 5.98 | 5.46 | 3301.4 | 25.88 | 23.37 |
| 20 | 3132.1 | 102.16 | 41.56 | 5940.5 | 170.06 | 83.33 | 18444.9 | 314.51 | 299.23 |
| 21 | 284.9 | 6.85 | 1.29 | 649.5 | 15.50 | 2.97 | 2266.2 | 53.45 | 10.51 |
| 22 | 39.5 | 0.25 | 0.14 | 94.3 | 0.61 | 0.34 | 244.1 | 1.57 | 0.89 |
| 23 | 6581.5 | 43.19 | 23.66 | 9695.6 | 63.62 | 34.85 | 26409.4 | 173.31 | 94.93 |
| 24 | 623.7 | 3.95 | 2.31 | 1155.6 | 7.32 | 4.29 | 2900.4 | 18.37 | 10.76 |
| 25 | 579.7 | 3.62 | 2.18 | 1197.1 | 7.48 | 4.49 | 2557.4 | 15.97 | 9.60 |
| 26 | 4772.0 | 67.45 | 302.96 | 9847.3 | 139.18 | 625.10 | 22250.5 | 314.42 | 1,412.12 |
| 27 | 101.2 | 0.61 | 0.39 | 219.8 | 1.32 | 0.85 | 559.4 | 3.36 | 2.17 |
| 28 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 |
| 29 | 363.0 | 2.11 | 1.44 | 769.4 | 4.47 | 3.05 | 2090.6 | 12.1539 | 8.29551 |
| 30 | 13.7 | 0.09 | 0.05 | 6.7 | 0.04 | 0.02 | 20.3 | 0.133284 | 0.072973 |
| 31 | 5806.9 | 5.45 | 116.16 | 21030.1 | 194.26 | 295.52 | 41327.6 | 446.013 | 534.634 |

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Table D.5 Atmospheric emissions under MS2, 1985, 2000, 2020 (thousands of tons)

| Sector | 1985 Carbon | 1985 Sulphur | 1985 Nitrogen | 2000 Carbon | 2000 Sulphur | 2000 Nitrogen | 2020 Carbon | 2020 Sulphur | 2020 Nitrogen |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.00 | 0.06 | 1.3 | 0.00 | 0.08 | 1.7 | 0.00 | 0.10 |
| 2 | 18.2 | 0.02 | 1.06 | 27.8 | 0.03 | 1.62 | 42.9 | 0.05 | 2.51 |
| 3 | 132.5 | 0.16 | 7.71 | 270.7 | 0.33 | 15.75 | 618.7 | 0.75 | 36.00 |
| 4 | 125.5 | 0.15 | 7.23 | 353.1 | 0.42 | 20.39 | 1044.7 | 1.25 | 60.42 |
| 5 | 134.2 | 0.16 | 7.82 | 352.9 | 0.43 | 20.58 | 689.1 | 0.83 | 40.19 |
| 6 | 273.4 | 0.33 | 15.99 | 660.4 | 0.80 | 38.62 | 1562.0 | 1.90 | 91.34 |
| 7 | 92.2 | 2.72 | 0.62 | 1074.3 | 31.68 | 7.27 | 2999.0 | 88.45 | 20.29 |
| 8 | 3864.6 | 46.21 | 26.91 | 4887.1 | 58.44 | 34.03 | 6075.4 | 72.65 | 42.30 |
| 9 | 1597.2 | 0.32 | 15.30 | 6641.5 | 1.32 | 63.63 | 13777.1 | 2.74 | 132.00 |
| 10 | 266.7 | 7.22 | 0.99 | 378.3 | 10.24 | 1.40 | 898.3 | 24.32 | 3.33 |
| 11 | 352.3 | 9.36 | 1.31 | 578.6 | 15.35 | 2.15 | 1032.8 | 27.30 | 3.87 |
| 12 | 256.3 | 6.87 | 0.93 | 887.8 | 23.79 | 3.23 | 1369.7 | 36.70 | 4.98 |
| 13 | 52.6 | 1.37 | 0.20 | 185.9 | 5.23 | 1.11 | 854.4 | 25.23 | 6.32 |
| 14 | 1716.6 | 10.00 | 14.29 | 2787.5 | 15.38 | 23.39 | 5739.3 | 29.22 | 48.71 |
| 15 | 243.6 | 7.01 | 1.52 | 505.2 | 14.60 | 3.24 | 2534.6 | 73.66 | 16.90 |
| 16 | 508.5 | 13.88 | 2.28 | 921.6 | 26.15 | 5.32 | 2350.0 | 69.66 | 17.15 |
| 17 | 1032.6 | 27.09 | 3.95 | 845.0 | 22.03 | 3.27 | 966.0 | 24.92 | 3.81 |
| 18 | 908.0 | 11.93 | 5.72 | 1479.2 | 19.68 | 9.36 | 2355.9 | 31.89 | 14.99 |
| 19 | 282.5 | 2.14 | 1.96 | 1605.3 | 12.32 | 11.24 | 3298.1 | 25.85 | 23.34 |
| 20 | 3132.1 | 102.16 | 41.56 | 10628.4 | 301.14 | 149.38 | 12770.2 | 183.05 | 212.23 |
| 21 | 284.9 | 6.85 | 1.29 | 1156.7 | 27.61 | 5.29 | 2425.2 | 57.20 | 11.25 |
| 22 | 39.5 | 0.25 | 0.14 | 95.1 | 0.61 | 0.35 | 242.3 | 1.56 | 0.89 |
| 23 | 6581.3 | 43.19 | 23.66 | 11155.5 | 73.21 | 40.10 | 26187.3 | 171.85 | 94.13 |
| 24 | 623.7 | 3.95 | 2.31 | 1203.9 | 7.63 | 4.46 | 2807.8 | 17.78 | 10.41 |
| 25 | 579.7 | 3.62 | 2.18 | 1207.6 | 7.54 | 4.53 | 2542.0 | 15.88 | 9.54 |
| 26 | 4772.0 | 67.45 | 302.96 | 9415.8 | 133.06 | 597.62 | 17509.0 | 247.29 | 1110.56 |
| 27 | 101.2 | 0.61 | 0.39 | 224.8 | 1.35 | 0.87 | 552.3 | 3.32 | 2.14 |
| 28 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 |
| 29 | 363.0 | 2.11 | 1.44 | 781.4 | 4.54 | 3.10 | 2072.3 | 12.05 | 8.22 |
| 30 | 13.7 | 0.09 | 0.05 | 8.2 | 0.05 | 0.03 | 3.7 | 0.02 | 0.01 |
| 31 | 5806.9 | 5.45 | 116.18 | 15239.9 | 140.85 | 207.14 | 27817.3 | 321.38 | 328.42 |

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Table D.6 Atmospheric emissions under HS1, 1985, 2000, 2020 (thousands of tons)

| Sector | 1985 Carbon | 1985 Sulphur | 1985 Nitrogen | 2000 Carbon | 2000 Sulphur | 2000 Nitrogen | 2020 Carbon | 2020 Sulphur | 2020 Nitrogen |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.00 | 0.06 | 1.2 | 0.00 | 0.07 | 1.8 | 0.00 | 0.11 |
| 2 | 18.2 | 0.02 | 1.06 | 28.0 | 0.03 | 1.64 | 43.8 | 0.05 | 2.56 |
| 3 | 132.5 | 0.16 | 7.71 | 348.0 | 0.42 | 20.28 | 1182.0 | 1.43 | 68.77 |
| 4 | 125.5 | 0.15 | 7.23 | 385.2 | 0.46 | 22.24 | 1497.8 | 1.80 | 86.62 |
| 5 | 134.1 | 0.16 | 7.82 | 437.2 | 0.53 | 25.50 | 1358.5 | 1.64 | 79.23 |
| 6 | 273.4 | 0.33 | 15.99 | 775.6 | 0.94 | 45.36 | 2393.9 | 2.91 | 139.99 |
| 7 | 92.1 | 2.72 | 0.62 | 787.1 | 23.21 | 5.32 | 6243.4 | 184.13 | 42.23 |
| 8 | 3864.4 | 46.21 | 26.91 | 5697.3 | 68.13 | 39.67 | 13123.4 | 156.93 | 91.37 |
| 9 | 1597.2 | 0.32 | 15.30 | 4766.6 | 0.95 | 45.67 | 24047.8 | 4.78 | 230.40 |
| 10 | 266.6 | 7.22 | 0.99 | 600.6 | 16.26 | 2.22 | 3500.1 | 94.77 | 12.97 |
| 11 | 352.3 | 9.36 | 1.31 | 613.1 | 16.26 | 2.28 | 1454.3 | 38.45 | 5.45 |
| 12 | 256.2 | 6.87 | 0.93 | 1145.1 | 30.68 | 4.16 | 2633.8 | 70.57 | 9.58 |
| 13 | 52.6 | 1.37 | 0.20 | 227.3 | 6.40 | 1.36 | 1682.1 | 49.67 | 12.44 |
| 14 | 1716.6 | 10.00 | 14.29 | 3292.6 | 18.17 | 27.63 | 9217.7 | 46.93 | 78.22 |
| 15 | 243.5 | 7.01 | 1.52 | 1039.6 | 30.04 | 6.67 | 7111.9 | 206.67 | 47.42 |
| 16 | 508.4 | 13.88 | 2.28 | 1203.1 | 34.14 | 6.95 | 6629.8 | 196.52 | 48.37 |
| 17 | 1032.5 | 27.09 | 3.95 | 2378.0 | 61.99 | 9.22 | 14130.1 | 364.49 | 55.80 |
| 18 | 907.9 | 11.93 | 5.72 | 1925.6 | 25.62 | 12.18 | 5854.3 | 79.26 | 37.26 |
| 19 | 282.5 | 2.14 | 1.96 | 1052.5 | 8.08 | 7.37 | 5707.6 | 44.74 | 40.39 |
| 20 | 3131.9 | 102.16 | 41.56 | 6901.9 | 197.59 | 96.81 | 28756.5 | 490.34 | 466.52 |
| 21 | 284.9 | 6.85 | 1.29 | 778.0 | 18.57 | 3.56 | 3624.1 | 85.48 | 16.80 |
| 22 | 39.5 | 0.25 | 0.14 | 98.3 | 0.63 | 0.36 | 336.7 | 2.17 | 1.23 |
| 23 | 6579.2 | 43.17 | 23.65 | 13177.8 | 86.48 | 47.37 | 63830.3 | 418.87 | 229.44 |
| 24 | 623.6 | 3.95 | 2.31 | 1447.0 | 9.16 | 5.37 | 5792.9 | 36.69 | 21.48 |
| 25 | 579.7 | 3.62 | 2.18 | 1316.1 | 8.22 | 4.94 | 4215.6 | 26.33 | 15.82 |
| 26 | 4771.7 | 67.45 | 302.95 | 11694.2 | 165.28 | 742.34 | 38910.4 | 549.83 | 2469.42 |
| 27 | 101.2 | 0.61 | 0.39 | 258.2 | 1.55 | 1.00 | 1014.2 | 6.09 | 3.93 |
| 28 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 |
| 29 | 363.0 | 2.11 | 1.44 | 843.8 | 4.91 | 3.35 | 3254.8 | 18.92 | 12.92 |
| 30 | 13.7 | 0.09 | 0.05 | 43.1 | 0.28 | 0.15 | 292.9 | 1.92 | 1.05 |
| 31 | 5806.9 | 5.45 | 116.18 | 25907.3 | 243.48 | 361.01 | 52707.9 | 560.85 | 687.46 |

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Table D.7 Atmospheric emissions under HS2, 1985, 2000, 2020 (thousands of tons)

| Sector | 1985 Carbon | 1985 Sulphur | 1985 Nitrogen | 2000 Carbon | 2000 Sulphur | 2000 Nitrogen | 2020 Carbon | 2020 Sulphur | 2020 Nitrogen |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.00 | 0.06 | 1.2 | 0.00 | 0.07 | 1.8 | 0.00 | 0.10 |
| 2 | 18.2 | 0.02 | 1.06 | 28.1 | 0.03 | 1.64 | 43.7 | 0.05 | 2.56 |
| 3 | 132.5 | 0.16 | 7.71 | 351.7 | 0.42 | 20.46 | 1129.9 | 1.36 | 65.74 |
| 4 | 125.5 | 0.15 | 7.23 | 386.5 | 0.46 | 22.31 | 1487.6 | 1.78 | 86.03 |
| 5 | 134.1 | 0.16 | 7.82 | 459.0 | 0.56 | 26.77 | 1198.2 | 1.45 | 69.88 |
| 6 | 273.4 | 0.33 | 15.99 | 776.4 | 0.94 | 45.40 | 2390.4 | 2.90 | 139.78 |
| 7 | 92.1 | 2.72 | 0.62 | 1446.6 | 42.66 | 9.79 | 4750.7 | 140.10 | 32.14 |
| 8 | 3864.4 | 46.21 | 26.91 | 7075.5 | 84.61 | 49.26 | 11240.9 | 134.42 | 78.27 |
| 9 | 1597.2 | 0.32 | 15.30 | 10546.8 | 2.10 | 101.05 | 23674.0 | 4.70 | 226.82 |
| 10 | 266.6 | 7.22 | 0.99 | 670.9 | 18.17 | 2.49 | 2844.5 | 77.02 | 10.54 |
| 11 | 352.3 | 9.36 | 1.31 | 614.3 | 16.29 | 2.29 | 1447.7 | 38.27 | 5.42 |
| 12 | 256.2 | 6.87 | 0.93 | 1179.0 | 31.59 | 4.29 | 2409.6 | 64.57 | 8.76 |
| 13 | 52.6 | 1.37 | 0.20 | 239.8 | 6.75 | 1.43 | 1579.0 | 46.63 | 11.68 |
| 14 | 1716.6 | 10.00 | 14.29 | 3224.1 | 17.79 | 27.05 | 8719.1 | 44.39 | 73.99 |
| 15 | 243.5 | 7.01 | 1.52 | 1108.1 | 32.02 | 7.11 | 6510.6 | 189.20 | 43.41 |
| 16 | 508.3 | 13.88 | 2.28 | 1359.6 | 38.58 | 7.85 | 5367.4 | 159.10 | 39.16 |
| 17 | 1032.5 | 27.09 | 3.95 | 2498.7 | 65.13 | 9.68 | 11930.2 | 307.74 | 47.12 |
| 18 | 907.9 | 11.93 | 5.72 | 1982.2 | 26.37 | 12.54 | 4552.8 | 61.64 | 28.98 |
| 19 | 282.5 | 2.14 | 1.96 | 2661.1 | 20.42 | 18.63 | 5705.3 | 44.72 | 40.38 |
| 20 | 3131.9 | 102.16 | 41.56 | 16080.5 | 455.62 | 226.00 | 22099.9 | 316.78 | 367.29 |
| 21 | 284.9 | 6.85 | 1.29 | 1548.9 | 36.97 | 7.09 | 3952.0 | 93.21 | 18.32 |
| 22 | 39.5 | 0.25 | 0.14 | 99.8 | 0.64 | 0.36 | 327.9 | 2.11 | 1.20 |
| 23 | 6579.1 | 43.17 | 23.65 | 15240.0 | 100.01 | 54.78 | 50590.4 | 331.99 | 181.85 |
| 24 | 623.6 | 3.95 | 2.31 | 1519.2 | 9.62 | 5.63 | 5284.9 | 33.47 | 19.60 |
| 25 | 579.7 | 3.62 | 2.18 | 1335.6 | 8.34 | 5.01 | 4145.9 | 25.89 | 15.56 |
| 26 | 4771.7 | 67.45 | 302.94 | 11266.5 | 159.22 | 715.09 | 29648.1 | 418.74 | 1880.51 |
| 27 | 101.2 | 0.61 | 0.39 | 267.2 | 1.61 | 1.03 | 977.8 | 5.88 | 3.78 |
| 28 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 |
| 29 | 363.0 | 2.11 | 1.44 | 864.6 | 5.03 | 3.43 | 3182.3 | 18.50 | .63 |
| 30 | 13.7 | 0.09 | 0.05 | 46.3 | 0.30 | 0.17 | 242.2 | 1.59 | 0.87 |
| 31 | 5806.9 | 5.45 | 116.18 | 18938.0 | 180.46 | 253.16 | 36446.2 | 413.81 | 435.80 |

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Table D.8 Water use and water pollution under MS1, 1985, 2000, 2020

| Sector | Year | Water in m3 | Water out m3 | BOD g/m3 | COD g/m3 | Suspended Solids g/m3 |
|---|---|---|---|---|---|---|
| 1 | 1985 | 363,251.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 222,913.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 112,255.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 1985 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 8.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 23.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 1985 | 124.4 | 97.7 | 24.2 | 35.2 | 59.4 |
| | 2000 | 125.9 | 98.8 | 14.0 | 19.6 | 25.9 |
| | 2020 | 120.9 | 94.9 | 6.4 | 8.5 | 8.1 |
| 13 | 1985 | 164.0 | 56.7 | 42.8 | 142.0 | 49.4 |
| | 2000 | 236.3 | 108.1 | 54.4 | 193.9 | 36.6 |
| | 2020 | 428.6 | 259.4 | 76.3 | 298.6 | 24.9 |
| 15 | 1985 | 1.5 | 1.4 | 0.0 | 0.0 | 0.0 |
| | 2000 | 3.1 | 2.9 | 0.0 | 0.0 | 0.0 |
| | 2020 | 19.2 | 18.5 | 0.2 | 0.2 | 0.1 |
| 17 | 1985 | 339.2 | 339.2 | 67.8 | 271.3 | 339.2 |
| | 2000 | 279.8 | 279.8 | 37.8 | 151.2 | 154.5 |
| | 2020 | 688.1 | 688.1 | 55.1 | 220.2 | 172.0 |
| HH | 1985 | 8,757.0 | | | | |
| | 2000 | 12,064.3 | | | | |
| | 2020 | 18,494.0 | | | | |

Note: HH = households

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Table D.9 Water use and water pollution under MS2, 1985, 2000, 2020

| Sector | Year | Water in m3 | Water out m3 | BOD g/m3 | COD g/m3 | Suspended Solids g/m3 |
|---|---|---|---|---|---|---|
| 1 | 1985 | 363,251.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 194,937.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 81,476.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 1985 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 8.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 23.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 1985 | 124.4 | 97.7 | 24.2 | 35.2 | 59.4 |
| | 2000 | 126.0 | 98.9 | 14.0 | 19.7 | 25.9 |
| | 2020 | 120.7 | 94.8 | 6.3 | 8.5 | 8.1 |
| 13 | 1985 | 164.0 | 56.7 | 42.8 | 142.0 | 49.4 |
| | 2000 | 246.1 | 112.6 | 56.7 | 201.9 | 38.1 |
| | 2020 | 418.2 | 253.1 | 74.4 | 291.4 | 24.3 |
| 15 | 1985 | 1.5 | 1.4 | 0.0 | 0.0 | 0.0 |
| | 2000 | 3.3 | 3.2 | 0.0 | 0.0 | 0.0 |
| | 2020 | 17.9 | 17.2 | 0.1 | 0.2 | 0.1 |
| 17 | 1985 | 339.2 | 339.2 | 67.8 | 271.3 | 339.2 |
| | 2000 | 299.5 | 299.5 | 40.5 | 161.8 | 165.4 |
| | 2020 | 382.9 | 382.9 | 30.6 | 122.5 | 95.7 |
| HH | 1985 | 8,757.0 | | | | |
| | 2000 | 12,064.3 | | | | |
| | 2020 | 18,494.0 | | | | |

Note: HH = households

Table D.10 Water use and water polluttion under HS1, 1985, 2000, 2020

| Sector | Year | Water in m3 | Water out m3 | BOD g/m3 | COD g/m3 | Suspended Solids g/m3 |
|---|---|---|---|---|---|---|
| 1 | 1985 | 363,250.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 206,334.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 116,993.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 1985 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 9.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 33.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 1985 | 124.4 | 97.7 | 24.2 | 35.2 | 59.4 |
| | 2000 | 133.5 | 104.8 | 14.8 | 20.8 | 27.4 |
| | 2020 | 170.0 | 133.5 | 8.9 | 12.0 | 11.4 |
| 13 | 1985 | 164.0 | 56.7 | 42.8 | 142.0 | 49.4 |
| | 2000 | 301.0 | 137.6 | 69.3 | 246.9 | 46.6 |
| | 2020 | 823.4 | 498.3 | 146.5 | 573.7 | 47.8 |
| 15 | 1985 | 1.5 | 1.4 | 0.0 | 0.0 | 0.0 |
| | 2000 | 6.8 | 6.5 | 0.1 | 0.1 | 0.0 |
| | 2020 | 50.3 | 48.3 | 0.4 | 0.7 | 0.2 |
| 17 | 1985 | 339.1 | 339.1 | 67.8 | 271.3 | 339.1 |
| | 2000 | 843.0 | 843.0 | 113.8 | 455.4 | 465.4 |
| | 2020 | 5,600.5 | 5,600.5 | 448.0 | 1,792.2 | 1,400.1 |
| HH | 1985 | 8,757.0 | | | | |
| | 2000 | 12,064.3 | | | | |
| | 2020 | 18,494.0 | | | | |

Note: HH = households

Table D.11 Water use and water polluttion under HS2, 1985, 2000, 2020

| Sector | Year | Water in m3 | Water out m3 | BOD g/m3 | COD g/m3 | Suspended Solids g/m3 |
|---|---|---|---|---|---|---|
| 1 | 1985 | 363,249.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 180,713.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 83,808.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 1985 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2000 | 9.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 2020 | 33.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 1985 | 124.4 | 97.7 | 24.2 | 35.2 | 59.4 |
| | 2000 | 133.8 | 105.0 | 14.9 | 20.9 | 27.5 |
| | 2020 | 169.3 | 132.9 | 8.9 | 12.0 | 11.3 |
| 13 | 1985 | 164.0 | 56.7 | 42.8 | 142.0 | 49.4 |
| | 2000 | 317.5 | 145.2 | 73.1 | 260.5 | 49.1 |
| | 2020 | 772.9 | 467.8 | 137.6 | 538.5 | 44.8 |
| 15 | 1985 | 1.5 | 1.4 | 0.0 | 0.0 | 0.0 |
| | 2000 | 7.2 | 6.9 | 0.1 | 0.1 | 0.0 |
| | 2020 | 46.1 | 44.3 | 0.4 | 0.6 | 0.2 |
| 17 | 1985 | 339.1 | 339.1 | 67.8 | 271.3 | 339.1 |
| | 2000 | 885.7 | 885.7 | 119.6 | 478.5 | 489.0 |
| | 2020 | 4,728.6 | 4,728.6 | 378.3 | 1,513.1 | 1,182.1 |
| HH | 1985 | 8,757.0 | | | | |
| | 2000 | 12,064.3 | | | | |
| | 2020 | 18,494.0 | | | | |

Note: HH = households

## APPENDIX E

## NRMP-IEA INPUT-OUTPUT WORKING PAPERS

### Working Papers

1 Faye Duchin and Glenn-Marie Lange, 'Case Study of Households and Industry' *NRMP-IEA Input-Output Working Paper No.* 1 (Institute for Economic Analysis, New York University, New York, September 1992)

2 Faye Duchin and Glenn-Marie Lange, 'Case Study Methodology' *NRMP-IEA Input-Output Working Paper No.* 2 (Institute for Economic Analysis, New York University, New York, November 1992)

3 Faye Duchin, 'Present and Prospective Future Water Use in Indonesia: Guidelines for a Case Study' *NRMP-IEA Input-Output Working Paper No.* 3 (Institute for Economic Analysis, New York University, New York, December 1992)

4 Clive Hamilton and Edison Hulu, 'Macroeconomic Projections for the NRMP-IEA Input-Output Model' *NRMP-IEA Input-Output Working Paper No.* 4 (Natural Resources Management Project, Jakarta, February 1993)

5 Clive Hamilton, 'Case Study of the Forestry Sector' *NRMP-IEA Input-Output Working Paper No.* 5 (Natural Resources Management Project, Jakarta, February 1993)

6 Sean Foley, 'Case Study of the Rice Sector' *NRMP-IEA Input-Output Working Paper No.* 6 (Natural Resources Management Project, Jakarta, February 1993)

7 Sean Foley, 'Case Study of the Non-rice Food Crops Sector' *NRMP-IEA Input-Output Working Paper No.* 7 (Natural Resources Management Project, Jakarta, February 1993)

8 Sean Foley, 'Case Study of the Estate Crops Sector' *NRMP-IEA Input-Output Working Paper No.* 8 (Natural Resources Management Project, Jakarta, February 1993)

9 Sean Foley, 'Case Study of the Livestock Sector' *NRMP-IEA Input-Output Working Paper No.* 9 (Natural Resources Management Project, Jakarta, February 1993)

10 Clive Hamilton and Clarita Iskandar, 'Case Study of the Pulp and Paper Industry' *NRMP-IEA Input-Output Working Paper No.* 10 (Natural Resources Management Project, Jakarta, April 1993)

11 Sean Foley and Aida Umaya, 'Case Study of the Cement Industry' *NRMP-IEA Input-Output Working Paper No.* 11 (Natural Resources Management Project, Jakarta, March 1993)

12 Sean Foley and Erabella Siswondo, 'Case Study of the Chemicals Sector' *NRMP-IEA Input-Output Working Paper No.* 12 (Natural Resources Management Project, Jakarta, April 1993)

13 Sean Foley, Aida Umaya and Suharno, 'Case Study of the Food, Beverages and Tobacco Sector' *NRMP-IEA Input-Output Working Paper No.* 13 (Natural Resources Management Project, Jakarta, April 1993)

14 Clive Hamilton and Clarita Iskandar, 'Case Study of the Textiles, Leather and Wearing Apparel Sector' *NRMP-IEA Input-Output Working Paper No.* 14 (Natural Resources Management Project, Jakarta, April 1993)

15 Clive Hamilton, 'Projecting Energy Scenarios for Indonesia' *NRMP-IEA Input-Output Working Paper No.* 15 (Natural Resources Management Project, Jakarta, April 1993)

16 Sean Foley, 'Case Study of the Basic Iron and Steel Sector' *NRMP-IEA Input-Output Working Paper No.* 16 (Natural Resources Management Project, Jakarta, April 1993)

**Reports**

1 Faye Duchin, Clive Hamilton & Glenn-Marie Lange, *Environment and Development in Indonesia: An Input-Output Analysis of Natural Resource Issues -- Interim Report* (Natural Resources Management Project, Jakarta, February 1993)

2 Faye Duchin, Clive Hamilton & Glenn-Marie Lange, *Environment and Development in Indonesia: An Input-Output Analysis of Natural Resource Issues -- Final Report* (Natural Resources Management Project, Jakarta, June 1993)

**Manuals**

1 Glenn-Marie Lange, 'Training Manual for Dynamic Input-Output Model Using "Mathematica"' (Institute for Economic Analysis, New York, November 1992)

2 Clive Hamilton, 'Procedures for Carrying Out Technological Case Studies' (Natural Resources Management Project, Jakarta, November 1992)

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