การใช้พลังงานและการปล่อยก๊าซคาร์บอนไดออกไซด์ในระบบเศรษฐกิจของประเทศไทย
การวิเคราะห์ปัจจัยการผลิตและผลผลิต

นาย เชวงศักดิ์ ศรีสหบุรี

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ENERGY CONSUMPTION AND CARBON-DIOXIDE EMISSION BY THAI ECONOMY AN INPUT-OUTPUT ANALYSIS

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(Energy Consumption and Carbon-dioxide Emission by Thai Economy-An Input-output Analysis)

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การดำเนินกิจกรรมทางเศรษฐกิจมีผลกระทบอย่างมากต่อความต้องการใช้ทรัพยากรธรรมชาติ เช่น พลังงาน พลังงานนับเป็นปัจจัยการผลิตที่สำคัญ เนื่องจากทุกกิจกรรมทางเศรษฐกิจทั้งการผลิตและการบริโภคต้องใช้พลังงานทั้งสิ้น ในปัจจุบันพลังงานที่ใช้ส่วนใหญ่ยังคงเป็นเชื้อเพลิงฟอสซิลซึ่งก่อให้เกิดก๊าซคาร์บอนไดออกไซด์อันเป็นองค์ประกอบหลักของก๊าซเรือนกระจก

ระบบเศรษฐกิจของประเทศไทยมีการเจริญเติบโตอย่างรวดเร็วตั้งแต่ปีพุทธศักราช 2538 และได้มีการเปลี่ยนแปลงโครงสร้างพื้นฐานทางเศรษฐกิจจากภาคเกษตรกรรมเป็นภาคอุตสาหกรรม การวิเคราะห์การใช้พลังงานและการเกิดก๊าซคาร์บอนไดออกไซด์จากการใช้พลังงานเพื่อการผลิตสินค้าและบริการของสาขาการผลิตต่างๆในระบบเศรษฐกิจของประเทศไทย จะช่วยให้มีข้อมูลที่เป็นประโยชน์สำหรับผู้ที่มีหน้าที่รับผิดชอบในการวางนโยบายด้านพลังงานและสิ่งแวดล้อมของประเทศ

งานวิจัยนี้เป็นการวิเคราะห์การใช้พลังงานและการเกิดก๊าซคาร์บอนไดออกไซด์ในสาขาการผลิตต่างๆในระบบเศรษฐกิจของประเทศไทย โดยใช้วิธีการวิเคราะห์ข้อมูลการใช้พลังงาน ข้อมูลปัจจัยการผลิตและผลผลิตของประเทศไทยในปีพุทธศักราช 2528 และ 2538 ผลการวิจัยพบว่าในทั้งสองปี สาขาการผลิตที่มีอัตราการใช้พลังงานและอัตราการเกิดก๊าซคาร์บอนไดออกไซด์ต่อผลผลิตสูงนั้น นอกจากสาขาการผลิตด้านพลังงานอันได้แก่ การผลิตและส่งก๊าซ การผลิตน้ำมันและผลิตภัณฑ์ปิโตรเลียม การผลิตและจำหน่ายไฟฟ้าแล้ว สาขาการผลิตอื่นที่มิใช่ด้านพลังงานก็มีอัตราการใช้พลังงานและการเกิดก๊าซคาร์บอนไดออกไซด์ต่อผลผลิตสูงเช่นเดียวกัน โดยเฉพาะอย่างยิ่ง สาขาการผลิตซีเมนต์ การก่อสร้าง การขนส่งทางบก การผลิตเครื่องดื่มและยาสูบ และการผลิตอาหาร

ถึงแม้ว่าในบางสาขาการผลิตจะสามารถลดอัตราการใช้พลังงานและการเกิดก๊าซคาร์บอนไดออกไซด์ต่อผลผลิตลงมาได้ในช่วง 10 ปีดังกล่าว แต่ก็เป็นเพียงเล็กน้อย ผลจากการศึกษาชี้ให้เห็นว่าประเทศไทยควรมุ่งเน้นการใช้วิธีการผลิตที่ใช้พลังงานอย่างมีประสิทธิภาพและการประหยัดพลังงาน โดยเน้นในสาขาการผลิตที่มีการใช้พลังงานหรือการเกิดก๊าซคาร์บอนไดออกไซด์ต่อผลผลิตสูงเป็นลำดับแรก

สาขาวิชาวิศวกรรมสิ่งแวดล้อม ลายมือชื่อนักศึกษา

ปีการศึกษา 2543 ลายมือชื่ออาจารย์ที่ปรึกษา

CHAWENGSAK SRISAHABURI: ENERGY CONSUMPTION AND CARBON-DIOXIDE EMISSION BY THAI ECONOMY-AN INPUT-OUTPUT ANALYSIS
THESIS ADVISOR: ASSIST. PROF. RAM SHARMA TIWAREE, Ph.D.
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Economic activities have a strong effect on the demand for natural resources such as energy. Energy is an important input for economic activities as there are hardly any production or consumption activities which require no energy inputs. At present, the global demand for energy is still largely met by fossil fuels which emit carbon-dioxide (CO_2), a major component of greenhouse gases.

Thailand has achieved a high economic growth since 1985 where a significant change in its economic structure from agricultural to industrial oriented economy has taken place. Accounting of total (direct and indirect) energy used in and corresponding CO_2 emission by different economic sectors of Thai economy for the production of goods and services would provide essential information for energy-environment policy maker.

In this study, an analysis based on input-output model has been done to account for embodied energy and corresponding CO_2 in various economic sectors in Thailand for the years 1985 and 1995 using national input-output tables and energy statistics. The results revealed that in addition to energy sectors such as gas distribution, oil products, and electricity generation & distribution), economic sectors especially cement, construction, land transport, drink & tobacco, and food & allied had very high total (direct plus indirect) energy or total CO_2 intensities in both years.

Some of the economic sectors were able to reduce their total energy or total CO_2 intensities in 1995, but just nominally. The study suggests that Thailand should, further, especially concentrate on the introduction of energy efficient production methods and energy saving practices in both energy and non-energy sectors with prime consideration to those sectors with high total energy or CO_2 intensities.

สาขาวิชาวิศวกรรมสิ่งแวดล้อม ลายมือชื่อนักศึกษา
ปีการศึกษา 2543 ลายมือชื่ออาจารย์ที่ปรึกษา

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Chawengsak Srisahaburi

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List of Abbreviations

฿	=	Thai Baht
BOT	=	Bank of Thailand
CO_2	=	Carbon-dioxide
DEDP	=	Department of Energy Development and Promotion
GDP	=	Gross Domestic Product
IEA	=	International Energy Agency
IPCC	=	Intergovernmental Panel on Climate Change
IPP	=	Independent Power Producer
KTOE	=	Thousand Tonnes of Oil Equivalent
$MTCO_2$	=	Million Tonnes of CO_2
MTOE	=	Million Tonnes of Oil Equivalent
NEPO	=	National Energy Policy Office
NESDB	=	Office of the National Economic and Social Development Board
SPP	=	Small Power Producer
TCO_2	=	Tonne of CO_2
TEI	=	Thailand Environment Institute
TOE	=	Tonne of Oil Equivalent
UNFCCC	=	United Nations Framework Convention on Climate Change
US$	=	United States Dollar
WRI	=	World Resources Institute

CHAPTER I

INTRODUCTION

1.1 Introduction

Economic activities have a strong effect on the demand for natural resources. Energy is an important input for economic activities since there are hardly any production or consumption activities which require no energy inputs (Battjes et al, 1998). At present, the energy requirements are largely met by fossil fuels, and the use of these fuels contributes considerably to the deterioration of the global environment, mainly, due to large emission of carbon dioxide, a major component of greenhouse gases.

Energy is not only used in an economic sector directly but also indirectly in the form of goods and services procured for use in that sector. The energy content for the total production in an economic sector is equal to the energy value of the goods and services procured and the energy directly used. This is referred to as the embodied energy. Embodied energy is consequently a measure of the total energy required to produce goods and services in a sector (Battjes et al, 1998). In other words, the embodied energy intensity of a sector is equal to the total amount of energy required to produce one unit of economic output in that sector.

The input-output model is an appropriate method for analyzing embodied energy intensities as it provides a systematic and inclusive framework in which indirect energy use is taken into account.

Thailand has achieved a high economic growth since 1985 where a significant change in its economic structures (from agricultural oriented to industrial oriented economy) has taken place. During the period 1985 to 1995, the average annual economic growth rate was 9.02 % where the share of industrial activities is high (Office of the National Economic and Social Development Board, 2000). Accordingly, the average annual growth rate of total primary (commercial and non-commercial) energy consumption and corresponding carbon dioxide emission were

10.32 % and 10.00 %, respectively (Department of Energy Development and Promotion, 1999a). Such an increase in primary energy consumption (where the share of fossil and bio-mass fuels is large) and corresponding carbon dioxide emission, has further detrimental effect on the environment, mainly, global warming.

In this regard, it is necessary to implement suitable techno-economic policies to minimize such emission of carbon dioxide in Thailand. Accounting for both direct and indirect energy consumption in and corresponding carbon dioxide emission from different economic sectors of Thai economy is an important step for this purpose. The input-output model has been considered as an important analytical tool for such an accounting.

1.2 Objectives

The major objectives of this study were:

1.2.1 To account and compare the total (direct plus indirect) energy induced by the demand of goods and services, and corresponding carbon dioxide in various economic sectors of Thailand for the years 1985 and 1995.

1.2.2 To analyze the effect of technology change or change in fuel mix on the emission of carbon dioxide from different economic sectors, and also to consider the sensitivity of the analytical model, if any.

1.3 Scope and Limitations of the Study

1.3.1 This study applied input-output analytical techniques to account for both energy and carbon dioxide embodied in each unit of goods and services produced by different economic sectors of Thai economy.

1.3.2 Data from the publications 'Input-output Table of Thailand' for the years 1985 and 1995, which were in monetary units (thousand baht) have been used to prepare required matrices or vectors as the input-output tables in physical units are not available.

CHAPTER II

LITERATURE REVIEW

2.1 Energy

2.1.1 Energy, Economy and Environment

Energy is defined as the ability to do work. The majority of the energy used by humans comes from the sun, either directly or indirectly. The atmosphere is warmed by solar energy and provides a temperature range in which organisms can survive. Photosynthetic conversion of solar energy provides humans with plant and animal food. The energy sources of coal, natural gas, and petroleum represent stored solar energy.

Schwaller and Gilberti (1996) divided sources of energy into three broad categories. These categories are renewable, nonrenewable, and nondepletable energy sources.

Renewable energy sources have been used the longest in terms of human use. Examples of renewable energy sources include animal power, human power, and the chemical energy stored in plants, animals, and organic wastes. Plants and organic wastes as energy sources are often referred to as biofuels or biomass.

Nonrenewable energy sources are exhausted or depleted once they are used. Nonrenewable energy sources include coal, geothermal heat traps, natural gas, oil shale, petroleum, tar sands, thorium, and uranium. They can be further subdivided into hydrocarbon resources and nuclear energy.

A *nondepletable energy source* is one that cannot be exhausted through collection or extraction. Thus, nondepletable energy sources are limitless and offer the greatest potential for achieving future economic and social growth. These energy sources include solar radiation, hydro power and wind power, tidal energy, geothermal energy in the mantle and deep crust of the earth, and ocean thermal energy conversion.

Energy has been decisive in both economic development and increased CO_2 emissions from the burning of fossil fuels. Energy is an essential input for economic activities. It meets directly to basic and more complicated human needs, either in the form of primary energy sources such as coal, oil, natural gas, biomass fuels, renewable energy sources, or secondary energy sources (or transformed energy) such as refined oil products or electricity (from fossil fuels, renewable energies or nuclear energy). Energy is traded commodity and also contributes indirectly to economic growth as it is an important factor in moving goods that are traded internationally (International Energy Agency, 1997b).

Since the beginning of the industrial era, fossil energy has fuelled economic growth, leading to a sharp increase in greenhouse gas emission levels and their build-up in the atmosphere. At present, fossil fuels account for 84 % and 92 % of commercial energy use in the International Energy Agency (IEA) participating countries and in the rest of the world, respectively.

The energy use and economic activity have a close link although it can be observed that the amount of energy both non-commercial (e.g., fuel wood) and commercial (traded fossil fuels and electricity) required to produce an output in terms of gross domestic product (i.e., energy intensity) tends to decrease over time (International Energy Agency, 1997b).

In practice, energy has been classified into two main forms, namely, primary energy and secondary energy.

Primary energy is defined as the non-processed energy. It is extracted from nature and prepared for market, includes coal, natural gas, crude oil and petroleum products, primary electricity (which are so called commercial energies) and renewable energy (which is non-commercial energy).

Secondary energy is defined as the processed energy and is manufactured from primary energy, such as coke, refined petroleum and electricity generated from primary energy.

Total primary energy supply (TPES) is generally expressed as indigenous production plus imports minus exports and international marine bunkers.

Energy units are commonly expressed in terms of tonne of oil equivalent (TOE), gigacalorie (Gcal), gigajoule (GJ) or British thermal unit (btu).

2.1.2 Embodied Energy and Energy Intensity

The basic idea of embodied energy is that in the consumption of any goods and services, energy is consumed, meaning that primary energy extracted from the earth is processed by the economy and finally goes to the final demand which are consumers' consumption. The energy content for the total output in an economic sector is equal to the energy embodied in the goods and services purchased and the energy used directly. The total energy requirement to produce one unit of output is called the '*energy intensity*' (Morioka and Yoshida, 1995; Battjes et al, 1998).

In computing the energy intensity of a product, it is necessary to distinguish between primary energy sectors: coal, crude oil, natural gas, primary electricity and secondary energy sectors: petroleum refinery or electricity. The secondary energy sectors use primary energy as an input and convert it into more useful forms of energy. Computational results of both the total amount of primary and secondary energy required to produce the same output must be equal, net of energy lost in converting primary energy to secondary energy forms. An example of this is electric power generation from coal (Miller and Blair, 1985).

Energy intensity varies widely across regions and countries. Physical factors such as geography and competition in domestic energy markets influence energy use across countries, through their effects on local economic activities and the availability and relative cost of energy sources.

2.1.3 Energy Consumption in Thailand

Recently, there is a significant growth of energy demand in response to industrialization, urbanization, and societal affluence in Asia, especially in south-east and east Asian countries. The principal source of energy use in this region is fossil fuel, where coal has the largest share. Thus, the intensity of carbon-dioxide emission

to primary energy consumption of this region is considerably high; 0.83 T-C/TOE (Tiwaree and Imura, 1994).

During the past few years, Thailand's energy consumption has grown in line with rapid economic expansion. This has resulted in a greater use of modern energy sources such as coal & coke, petroleum products, natural gas, and hydro electricity. The share of modern energy increased from 59 % in 1981 to 73.8 % in 1994, while the share of renewable energy decreased constantly during the same period. In the future, the structure of the energy system will continue to be dominated by modern energy sources due to insufficient renewable energy and conversion technology (Thailand Environment Institute, 1997).

Thailand's total final energy consumption increased from 15,099 KTOE in 1980 to 43,849 KTOE in 1994 (Department of Energy Development and Promotion, 1996). If the same growth rate of energy consumption continues, it will reach 155,000 KTOE by the year 2030 (Thailand Environment Institute, 1997). Final energy consumption is dominated by four economic sectors: transportation, residential & commercial, industrial, and agricultural. From 1986 onwards, the transportation sector was the largest consumer followed by industrial, residential & commercial, and agricultural sectors, respectively.

Growth in energy consumption is the leading indicator in the change from a rural or agricultural society to an urban or industrial one. The energy consumption per capita increased from 0.32 TOE in 1980 to 0.74 TOE in 1994, this reflects the improvement in standards of living of the people. In the context of energy efficiency, the energy intensity in Thailand in 1993 was 0.41 TOE/Million US$, putting it among the countries with high energy efficiency level. Japan at 0.11 TOE/Million US$ was the most highly efficient while China at 1.67 TOE/Million US$ was highly inefficient (World Bank, 1996).

2.1.4 Energy Efficient Technologies

Future economic growth without effective action to address climate change will likely lead to increasing energy-related CO_2 emissions. In the absence of specific

responses, the rate of decarbonisation of energy is unlikely to be maintained, since nuclear programmes have been slowed or halted in many countries. Ongoing economic development in developing countries will contribute to rising energy use and related CO_2 emissions at a faster rate than in developed countries.

Renewable energy technologies other than hydro are not in most cases cost competitive with major conventional energy sources. However, they have contributed to cost reductions and could further reduce the carbon content of energy. Their contribution is small at present, but current expectations on relative costs suggest that the share of renewable will grow.

The enhanced use of best available technologies could help reduce energy requirements and CO_2 emissions within the constraint of infrastructure. Along with the need to orient infrastructure towards more climate-friendly ways, the development of new technologies and processes for the future is important. In particular, switching from non-commercial to commercial energy sources in the process of economic development and more efficient production technology have led to decreasing energy intensity. A substitution of electricity for direct fossil fuel uses for many energy services would contribute to the same advantage. In overall process, energy security and environmental protection have also enhanced rational energy uses (International Energy Agency, 1997b).

Energy Efficient Technologies in Thailand

1. *Total Productive Maintenance System*

In recent years, manufacturing sector was activated to realized the loss of energy through poor condition of machines and equipment, and has been educated about the total productive maintenance system. Normally, the major points to focus on are lubrication, compressed air systems, electrical connectivity, mechanical drive systems, waste heat and cooling recovery, lighting, steam systems, housekeeping, and productive maintenance practices. The system is able to induce energy saving for both electricity and thermal energy.

2. ***Energy Conservation in Building***

The Energy Conservation and Promotion Act 1992 states that owners of particular types of building are regulated to provide the energy conservation program in the buildings, monitoring by the government authority at a certain period of time. Energy conservation in building starts from the stage of design; reducing area of glass walls or curtain walls would prevent the loss in air-condition system. Using energy control unit such as key-tag-switch, for lighting and air-condition system will conserve a significant amount of energy.

3. ***Energy Efficient Fluorescent Lamps***

The campaign for reduction of fluorescent lamps power from 40 and 20 watt to 36 and 18 watt resulting in energy saving for 1,543.7 Mkw-hr from the years 1997 to 1998. Moreover, using compact fluorescent lamps with electronic ballast instead of conventional lamps induce the energy conservation of 36 Mkw-hr in these two years (National Energy Policy Office, 1999).

4. ***High Efficiency Refrigerators and Air Conditioners***

With the efficiency improvement, high energy-efficient refrigerators and air conditioners were produced, and certified by the number 5. These appliances can save electrical power up to 740 Mkw-hr during the years 1997 and 1998 (National Energy Policy Office, 1999).

5.***Water Heater Using Waste Heat from Air Conditioner***

At present, the cost of hot water production is very high as a huge amount of energy is needed in forms of petroleum gas, oil, coal, steam or electricity. Electric water heaters are the majority among various types of water heaters because of low investment and convenient use. On the other hand, a lot of electrical power is consumed which affects the production cost and at the same time deteriorate the natural resources. In this regard, waste heat recovery by using waste heat from air conditioners is an interesting alternative production method to save the energy as well as the production cost. In this recovery system, a heat exchanger will be connected to

the air conditioner or air cooling system. In operation, the load of compressor unit is reduced resulting from better cooling mechanism, an energy reduction of 5-10 % can be achieved while hot water at 40-80°C without energy cost is obtained (Chungpakdee, 1999).

6. ***High Efficiency Motor***

The only one method to increase motor efficiency is to reduce losses. A high efficiency motor is constructed under some major improvements such as low friction rotor and stator, low resistance copper wire, high insulation, higher power factor, efficient ventilating fan. An estimation for energy saving has been carried out for a 50 hp high efficiency motor with 2.4 % higher efficiency than a normal motor. The result indicates that a power reduction of 9,088 kwh can be achieved for one year operation (i.e., 8,760 hours) (Chungpakdee, 1999).

7. *High Efficiency Welding Machine*

Conventional welding machines such as rotary type consume a great amount of energy for operating their tasks. For energy efficient use purpose, a new type of welding machine known as inverter type is invented. An inverter and a capacitor connected to the welding machine will reduce the consumption of electrical power to be approximately 50 % of the normal consumption. At the same time, they enhance the electric current regularity and the quality of products (Chungpakdee, 1999).

8. *Use of Proper Gasoline for Vehicles*

Most recently, the unnecessary use of gasoline with octane number 95 for vehicles was just revealed. Nowadays, most of the cars in the country switch to used gasoline with octane number 91 which is cheaper but no evidence of awful effects.

2.2 Carbon-dioxide

Carbon-dioxide is a colorless, tasteless gas and has been part of the earth's atmosphere from the beginning. In the year 1995, the CO_2 concentration in the world atmosphere was approximately 350 ppm. At this concentration there is no evidence of harmful effects to humans, and it is necessary for photosynthesis. Human bodies produce CO_2 as they utilize foods and emit it by exhaled breath (Nevers, 1995).

2.2.1 Carbon-dioxide Emission

Carbon dioxide is produced from consumption of fossil fuels, such as coal, oil and natural gas, and bio-mass fuels, such as fuel wood and bagasse in various economic activities, e.g., electricity generation, industry, transport, etc. The quantity of carbon dioxide emitted is directly related to the amount of fuel consumed, the fraction of the fuel that is oxidized during combustion, and the carbon content of the fuel. Among these fuels, coal has the highest carbon content ranging from 70 % to 95 %, followed by oil and natural gas which have 85 % and 76 %, respectively. Normally, during the combustion of fossil fuels, 99 % of carbon is oxidized to carbon dioxide, while the fraction of carbon oxidized during the combustion of bio-mass fuels is 90 %.

The chemical reactions that occur during the combustion is represented by the following equations:

$$C + O_2 \longrightarrow CO_2 \qquad (2\text{-}1)$$

$$2H_2 + O_2 \longrightarrow 2H_2O \qquad (2\text{-}2)$$

Carbon-dioxide is also emitted through deforestation, while the growth of trees and forests absorbs it and transforms it into plant biomass.

Prior to the industrial revolution (1750-1800), the concentration of CO_2 in the world atmosphere was about 270 ppm. As the world became more industrialized, population increase and agriculture developed, there was a dramatic increase in both

natural and human-made CO_2 in the atmosphere. In the year 1997, the concentration of CO_2 in the atmosphere was approximately 356 ppm. And it is expected to be double that of the pre-industrial level by the next century.

2.2.2 Greenhouse Gases and Global Warming

Greenhouse gases are normally found in the atmosphere in small quantities and absorb infrared radiation or heat energy, warming the atmosphere and the land, making the earth inhabitable. The major green house gases in the atmosphere are carbon dioxide, methane, nitrous oxide and ozone. Water vapor is also considered to be a significant greenhouse gas, although on a global scale its concentration are not directly affected by human activities. Greenhouse gases occur naturally in ecosystems. However, as humans have interfered with nature's processes, the concentration of these gases in the atmosphere has increased.

Energy from sunlight as short wave solar radiation, consisting of ultra-violet and visible light, passes through the earth's atmosphere and heats its surface, where energy is finally absorbed and transformed. Long-wave thermal energy or infrared radiation is emitted from the earth's surface back to the atmosphere and is absorbed by greenhouse gases or radiates upward to outer space or downward to reheat the earth. This phenomena is commonly known as the '*Greenhouse Effect*'.

In the long term, absorption of solar radiation into the atmosphere by greenhouse gases is balanced by the out-going long-wave infrared radiation. Natural greenhouse gases in the atmosphere make the earth's surface warmer about 33^oC. In addition, energy from the sun absorbed by the atmosphere, troposphere, hydrosphere and biosphere drives the earth's weather and climate system.

The term '*Global Warming Potential*' (GWP) describes the warming effect caused by a unit mass (1 kg) of a greenhouse gas relative to that of CO_2. The GWP of CH_4 and N_2O are estimated to be 21 and 310 respectively. Human-made greenhouse gases, i.e., chlorofluorocarbons, hydrochlorofluorocarbons, etc. have GWP of several hundred and up to several thousand times higher than that of CO_2 (Intergovernmental Panel on Climate Change, 1994).

In 1990, the estimated emissions of carbon-dioxide, methane, nitrous oxide, chlorofluorocarbons and hydrochlorofluorocarbons to the atmosphere were 26,000, 300, 6, 0.9, and 0.1 million tonnes, respectively. Taking global warming potential into account, the contributions of CO_2, CH_4, N_2O and chlorofluorocarbons to total global warming were 55 %, 15%, 6% and 24%, respectively (Intergovernmental Panel on Climate Change, 1994).

2.2.3 Climate Change

Prediction on how climate would change as a result of double concentration of CO_2 in the atmosphere has been made by Intergovernmental Panel on Climate Change (1990) and United Nations Framework Convention on Climate Change (1994) as follows:

- An increase in global mean temperature of approximately 2)C by the year 2100, for the mid range of 1.5-3.5)C.
- Regional temperature changes may differ significantly from the change in the global mean although it is not yet possible to describe certainly.
- The sea-level rise is estimated to range from 15 to 95 cm, with the best estimate of 50 cm by the year 2100. Sea level would continue to rise even though the global climate and the mean temperature would have stabilized.
- As a consequence of changes in temperature and water availability, a substantial fraction (a global average of one third) of the existing forest areas of the earth will face major changes in broad vegetation types.
- Developing countries will most likely be more seriously affected by climate change than developed countries, and may also have less options for adapting.

2.2.4 Comparison of Thailand's CO_2 Emission with Global Emission

Carbon dioxide emission from Thailand is compared with global emission in 1990 estimated by the World Resources Institute (WRI, 1994) as follows :

- Global CO_2 emission totaled 26,000 million tonnes, of which 22,600 million tonnes from energy and cement and 3,400 million tonnes from forest.
- Total CO_2 emission from Thailand was 164 million tonnes which accounted for 0.63 % of global emission.
- Emission from energy sector in Thailand was 0.30 % of global emission.
- Emission from land use and forestry was 0.30 % of global emission.
- Global total per capita emission of CO_2 (energy and forest) was 4.83 tonnes.
- Thailand's total per capita emission of CO_2 (energy and forest) was 2.80 tonnes.
- Global per capita emission of CO_2 from energy and cement was 4.20 tonnes.
- Thailand's per capita emission of CO_2 from energy and cement was 1.50 tonnes.
- Global per capita emission from forest was 0.63 tonnes.
- Thailand's per capita emission from forest was 1.30 tonnes.

2.2.5 CO_2 Emission and Sequestration by Sectors

In actual, all CO_2 emission came from three sources; energy, forestry, and industrial processes. In 1990, a net emission of 164 million tonnes can be divided sector wise as shown in Table 2-1 below.

The energy sector comprises energy transformation (or power plants), transportation, industries, small combustion emitted the highest amount of greenhouse gases in 1990, totaling 75 million tones of CO_2 equivalent (including fugitive emission from fuels) or 36 % of the country's warming effect (Thailand Environment Institute, 1997).

Table 2-1. CO_2 emission and sequestration from various sub-sectors in 1990.

Sectors	CO_2 Emission (Sequestration)	
	Million Tonnes	%
Forest Clearing	82	43
Energy Transformation	28	15
Transport	28	15
Change in Forest and Woody Biomass Stock	20	11
Industry	13	7
Industrial Processes	10	5
Small Combustion	8	4
Abandon of Managed Land and Reforestation	(25)	(15)
Total	164	100

Source: Thailand Environment Institute (1997).

2.2.6 Climate-Friendly Technologies and Cleaner Energies

A variety of options are available which could reduce the CO_2 impact of power generation for the same level of service provision:

- More efficient fossil technologies (such as co-generation)
- Renewable energies
- Hydropower from dams
- Nuclear power stations

Similarly, in the transportation sector, some types of non-conventional vehicles are available at varying levels of commercial variability:

- Electrical vehicles
- Natural gas vehicles
- Hybrid vehicles

– Hydrogen vehicles

Cleaner and more efficient technologies can be introduced for energy production and end-use. The development of new technologies depends on a mix of market pull and technological push. Ongoing technological progress requires long term research and development, particularly to achieve further decarboniation in power transformation (e.g., with renewables or other non-fossil energy sources), to promote CO_2 capture and storage to improve the efficiencies of fossil fuel use and energy end-use.

Cleaner Energies Consumption in Thailand

1. *Solar Energy*

Most of solar energy use in Thailand is for electricity generation, for instance, three electricity generation plants in Sakaew, Phuket, and Chiangmai are able to generation total output of 70 kw. Moreover, water pumping using solar energy is also to some extent practical. Operation of the Royal Project using solar energy in Petchaburi, Thailand can be considered as an example (National Energy Policy Office, 1999).

2. *Hydropower*

This type of energy is popularly used in electricity generation. Apart from local generation plants, the country is encouraging joint feasibility studies of hydropower projects in the Mekong Basin, Salawin Basin and other basin in neighboring countries.

3. *Wind Power*

Use of wind power as windmills for water pumping was known and widely introduced for a long time ago. Another application is electricity generation, such as a plant in Phuket with a capacity of 192 kw (National Energy Policy Office, 1999).

4. ***Natural Gas***

Natural gas is a major domestic energy source of the country with total production of 15.2 MTOE, or 38.6 % of the total indigenous energy production in 1998. The average production in this year was 1,704 million cubic feet/day, an increase of 8.9 % from the previous year (Department of Energy Development and Promotion, 1999a). As being a cleaner energy compared to other fossil fuels such as coal and oil, further development and use of natural gas is being done continuously. Natural gas consumption in power plants, industrial factories, and commercial vehicles is being sped up urgently.

5. ***Nuclear Energy***

The feasibilities and regulatory framework for the use of nuclear energy for electricity generation are under consideration.

The domestic energy consumption and the corresponding carbon dioxide emission in both industrialized and developing economies is on the rise and has a linear relationship with the economic development. The trade of energy or carbon dioxide embodied in goods and services between the two economies is increased. Since, industrialized countries have higher per capita domestic energy consumption and corresponding carbon dioxide emission than the developing countries, industrialized nations in close cooperation with developing nations should make strong effort to reduce or limit emissions of carbon dioxide and other greenhouse gases into the atmosphere (Tiwaree and Imura, 1995).

2.3 Energy Input-output Analysis

The methodology for relating economic activities to the environment by using an input-output analysis is widely known. Input-output analysis provides an effective framework for determining the energy use and other activities such as environmental pollution related to industrial production. Leontief in 1930s (Gay and Proops, 1993;

Miller and Blair, 1985) originally developed the framework to account for these activities and has been in extensive application in recent years.

Many researchers have extended the input-output framework to account for environmental pollution generation and abatement associated with interindustry activity. These extensions have been appearing since the late 1960s (Miller and Blair, 1985).

The principle problems to be resolved in environmental models is the appropriate unit of measurement of environmental or ecological quantities, for example, in monetary or physical units.

Miller and Blair (1985) classified environmental input-output models into three basic categories:

(1) *Generalized Input-Output Models*. These are formed by augmenting the technical coefficients matrix with additional rows and columns to reflect pollution generation and abatement activities.

(2) *Economic-Ecologic Models*. These models result from extending the interindustry framework to include ecosystem sectors, where flows will be recorded between economic and ecosystem sectors along the lines of an interregional input-output model.

(3) *Commodity-by-Industry Models.* Such models express environmental factors as commodities in a commodity-by-industry input-output table.

Despite the attractions of the category (2) economic-ecologic models, they do not appear yet to be generally usable. Moreover, in view of the extremely demanding data requirements of the category (2) and (3) models, it is scarcely a surprise that most environmental input-output models have made use of the more modest category (1) generalized input-output models.

Another valuable extension of input-output modeling has been the incorporation of a specific disaggregated analysis of interindustry energy flows, often in physical as well as value terms.

Energy input-output typically determines the total energy required to generate a product to final demand, both directly as the energy used by an industrial process and indirectly, as the energy embodied in that industry's input. A target product is

either a good or service, and a list of goods and services directly required to make the product is compiled. These inputs to the target production include fuels (direct energy) and non-energy goods and services. The non-energy inputs are then analyzed to determine the inputs to their production processes, which include some fuels and non- energy goods and services. The process traces input back to primary resources; the first round of energy inputs is the '*direct energy requirement*', and the subsequent rounds of energy inputs consist of the '*indirect energy requirement*'. The sum of these two is the '*total energy requirement*' (Miller and Blair, 1985).

An advantage of the input-output approach to fuel use is that only primary fuels need will be considered directly. Secondary fuels such as electricity, will be dealt automatically within the industry input structure (Gay and Proops, 1993).

The demands for data made by the basic input-output model are significantly increased when the model is extended to incorporate the generation of pollutants. These can be problems relating to the sectoral classification in the input-output table. They often over-aggregate important energy sectors and industries with significantly different pollution characteristics. There is the evidence that the sectoral classification of an input-output table can influence the sensitivity of the model (Hawdon and Pearson, 1995).

CHAPTER III

METHODOLOGY

In this research, the input-output model is used for the analysis of total (direct plus indirect) carbon dioxide produced from energy use in different economic sectors of Thailand.

3.1 General Model Structure of Input-output Analysis

The concept of input-output model was originally developed by Leontief in 1930s (Gay and Proops, 1993; Miller and Blair, 1985). The principle is based on the fact that in modern economic systems, production activities are closely interrelated. Each producing activity acts as both a supplier; selling its output to other industries and to the final consumers, and a buyer; purchasing the products, labor skills, services, natural resources, etc. which are direct and indirect inputs to an economic system.

The basic input-output relationship is

$$X_I = \Sigma_j Z_{ij} + Y_i \qquad i = 1,\ldots,n \qquad (3\text{-}1)$$

Where X_I = the total output value of goods by production sector i.

Z_{ij} = the output value of goods by production sector i consumed by economic sector j (intermediate demand).

Y_j = the output value of goods by production sector i going direct to consumers (final demand, includes private or household consumption, government consumption, gross fixed capital formation, change in stock, and export).

The relationship can be written in matrix form as:

$$X = Z\Delta + Y \qquad (3\text{-}2)$$

Where $\Delta = \begin{pmatrix} 1 \\ \vdots \\ 1 \end{pmatrix}$

$$Z_{ij} = a_{il} D_{lj} \qquad (3\text{-}3)$$

Or, $$Z = AD \qquad (3\text{-}4)$$

Where D = a diagonal matrix.

D = diag $(X_1, \ldots, X_n)$

a_{il} = a technical coefficient.

A = the technical coefficient matrix representing the industrial structure and technology of a country.

From equations (3-1) and (3-3), one can get

$$X_i = \Sigma_j (\Sigma_l a_{il} D_{lj}) + Y_I \qquad (3\text{-}5)$$

Similarly, from equations (3-2) and (3-4), one can obtain

$$X = AD\Delta + Y \qquad (3\text{-}6)$$

Note that $D\Delta = X$

Hence,

$$X = AX + Y \qquad (3\text{-}7)$$

Or,

$$X = (I\text{-}A)^{-1}Y \qquad (3\text{-}8)$$

Where I = the identity matrix.

3.2 Embodied Energy Intensity and Energy Accounting

Figure 3-1 represents the energy input-output balance for an economic sector of a country (Tiwaree and Imura, 1995):

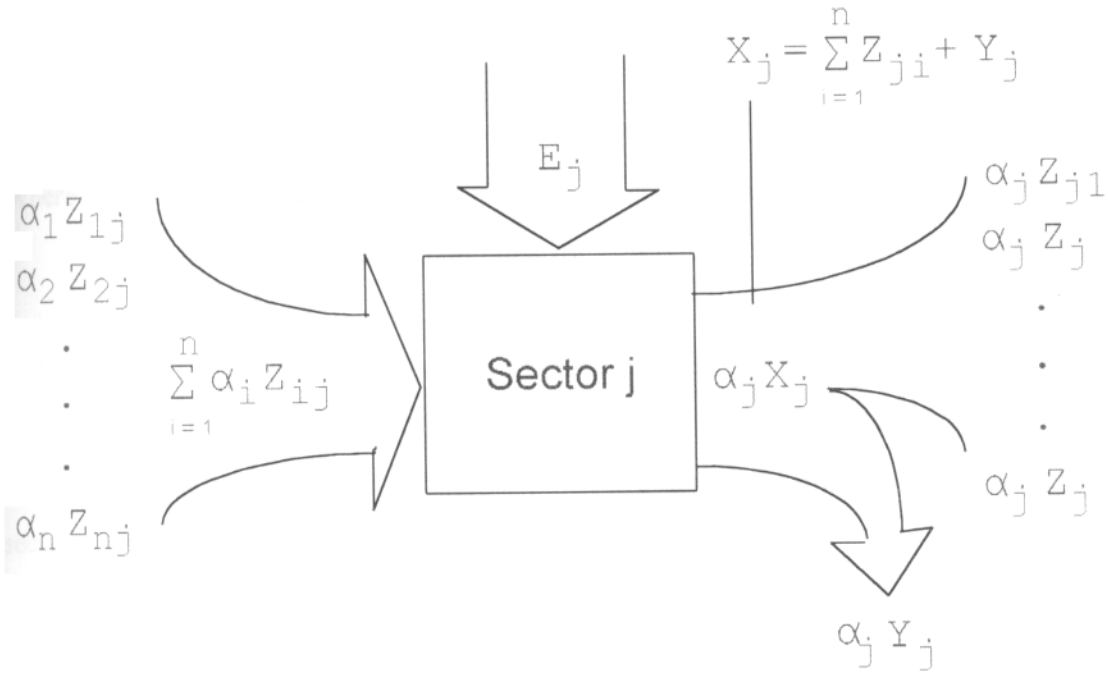

Figure 3-1. Energy input-output balance for an economic sector.

The economic sector j of an economy requires the direct primary energy E_j and energy embodied in the goods and services received from i sectors, to produce its output. Then the energy embodied in this output is consumed by its final consumers, Y_j, and other inter-industry sectors of the economy in terms of goods and services, Z_{ji}.

The input-output framework can be used to establish matrices of energy intensities for an economy in terms of energy per monetary unit of output. Two basic types of energy intensity are total energy intensity and direct energy intensity. The first type imputes total energy use, E, to total output by the economy, X. The second type imputes total energy use to final demand, Y.

first type imputes total energy use, E, to total output by the economy, X. The second type imputes total energy use to final demand, Y.

Hence,

$$\sigma.\text{diag}\,(X_1,\ldots,X_n) = E \qquad (3\text{-}9)$$

Where σ = a m×n matrix represents the direct energy required to produce one monetary unit of goods and services, i.e., direct energy intensity.

and,

$$\alpha Y = E \qquad (3\text{-}10)$$

Where α = a m×n matrix represents the total (direct plus indirect) energy required to produce one value unit of goods and services, i.e., total energy intensity.

E = the total primary energy input (excluding residential sector) which is equal to aggregate embodied energy (final demand) in an economy.

To obtain σ, total productive energy use is allocated between the production sectors. Sector j might purchase energy E_j for its production processes. Thus, considering all n economic sectors in the economy, $E = \Sigma_j E_j$ where j = 1,….,n.

Sector j has total output of value X_j, so σ is defined by

$$\sigma_{ij} = E_{ij} .1/ X_j \qquad i=1,\ldots,m;\ j=1,\ldots,n$$

or,

$$\sigma = E\,[\text{diag}(X_1,\ldots,X_n)]^{-1} \qquad (3\text{-}11)$$

The α can be derived from equations (3-8), (3-9), and (3-10) as follows. Substituting equation into equation, one gets

$$\sigma (I-A)^{-1}Y = E \qquad (3\text{-}12)$$

Finally, comparing (3-10) with (3-12) gives

$$\alpha = \sigma (I-A)^{-1}$$
$$= E\,[\mathrm{diag}(X_1,\ldots,X_n)]^{-1} (I-A)^{-1} \qquad (3\text{-}13)$$

The embodied energy intensity can also be expressed as

$$\alpha = \sigma + \beta \qquad (3\text{-}14)$$

and then,

$$\beta = (\alpha - \sigma) \qquad (3\text{-}15)$$
$$= AE\,[\mathrm{diag}(X_1,\ldots,X_n)]^{-1} (I-A)^{-1}$$
$$= A\alpha \qquad (3\text{-}16)$$

The matrices σ and β are referred to as direct and indirect energy consumption intensities respectively.

3.3 Embodied Carbon-dioxide Calculation

When matrices σ, α and β mentioned in equations (3-11), (3-13), (3-16) are multiplied by the vector of carbon dioxide emission per unit of fuel burnt ($\in$), the corresponding matrices for carbon dioxide intensity can be obtained:

$$\in\alpha = \alpha' \qquad (3\text{-}17)$$
$$\in\beta = \beta' \qquad (3\text{-}18)$$
$$\in\sigma = \sigma' \qquad (3\text{-}19)$$
$$\in E = E' \qquad (3\text{-}20)$$

Where α' = the matrix of cumulative carbon dioxide intensity while σ' and β' are the matrices of direct and indirect carbon dioxide intensity respectively relating to the consumption of fossil fuel based energy.

E' = the embodied carbon dioxide in the final demand (Tiwaree and Imura, 1994).

3.4 Analysis Procedure

At first, data of 179 economic sectors from the publications 'Input-output Table of Thailand ' for 1985 and 1995 were compiled and were converted into the tabular form as depicted by Table 3-1.

Table 3-1. Input-output table structure of Thailand (1985 and 1995).

unit: thousand baht

Intermediate Demand								Final	Gross
Sector	1	2	3	.	.	179	Sum	Demand	Output
1									
2									
3									
.									
.									
179									

3.4.1 Preparation of the Matrix A

From the modified I-O table, the gross output values were converted into diagonal matrix and then the A matrix was derived by dividing the inter-industry flow matrix Z by the respective gross-output diagonal matrix X.

3.4.2 Preparation of the Matrix σ

Eight types of primary energy consumption data measured in physical unit for each economic sector of an economy has been used to prepare the matrix E. In this regard, the E matrix was prepared by converting the rows of energy sectors from the I-O table into equivalent physical units assuming that the price of primary energy is uniform throughout the economy. The energy matrix prepared in this way (such as 8×179) was, finally, divided by the corresponding gross-output values and, a matrix σ was obtained.

3.4.3 Calculation of the Energy Intensities

The values of α, σ and β were then computed according to the relevant equations stated in Section 3.3 above.

3.4.4 Calculation of embodied energy (final demand)

The α calculated above was then summed into one row and transposed to be a column vector. The embodied energy (final demand) was the product of α (transposed) multiplied by final demand (Y).

3.4.5 Calculation of Carbon Dioxide Intensity and Emission

The amount of carbon dioxide emission corresponding to energy consumption was calculated using the equations (3-17) to (3-20) in Section 3.3 above.

To evaluate the carbon dioxide emission, information regarding emission factor for each primary energy type excluding primary electricity as well as oxidation fraction of fuel during combustion is necessary. In this study, emission factors (T-CO_2/TOE) considered were: coal = 4.247, crude oil = 3.096, natural gas = 2.370, fuel wood = 4.136, paddy husk = 4.072 and bagasse = 4.072 in 1985, and coal = 4.213, crude oil = 3.096, natural gas = 2.370, fuel wood = 4.136, paddy husk = 4.072 and

bagasse = 4.072 in 1995. The average emission factors for coal in 1985 and 1995 were different due to differences in emission factors for lignite and bituminous coal or coking coal as well as their proportion in each year. The emission factor for lignite was 4.275 T-CO_2/TOE while that for bituminous coal and/or coking coal was 3.996 T-CO_2/TOE. The share of lignite in the total coal consumption in 1985 was 90.03 % while the share of the same in 1995 was 77.78 %. Similarly, oxidation fraction considered were 99 % for coal, oil, gas and 90 % for fuel wood, paddy husk and bagasse (Thailand Environment Institute, 1997) for both the years 1985 and 1995.

3.4.5 Economic Sectors Aggregation

Finally, the results of the input-output analysis of the 179 economic sectors were aggregated into 35 appropriate sectors for the years 1985 and 1995 so that it was possible to make their interpretation clearly and concisely.

3.4.6 Modification of Input-Output Monetary Units

For meaningful comparison of energy and CO_2 intensities between the years 1985 and 1995, it is necessary to modify the input-output table for the year 1995 to the 1985 constant prices. Modification has been made using the single value annual consumer price index of Thailand provided by the Bank of Thailand (2000) for all the sectors since no sector-wise information for this purpose was available. Thus a factor of 0.638 (67.5/105.8) was used to convert the data of 1995 input-output table into 1985 constant price. The information obtained from the Bank of Thailand has been presented in annex V.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Embodied Energy in 1985

4.1.1 Total Energy Intensities

Table 4-1 illustrates the total (direct plus indirect) energy intensities (TOE/฿ 10,000) of various economic sectors for the year 1985. The ranked top 10 economic sectors with high total energy intensities were gas distribution (1.53), oil products (0.97), electricity generation & distribution (0.89), cement (0.54), land transport (0.47), bricks & tiles, air & water transport, ceramics, oil & natural gas, and building materials & glasses. At the same time, the bottom 5 economic sectors with low total energy intensities were electrical engineering (0.04), wholesale & retail (0.04), mechanical engineering (0.03), ship & train & aircraft (0.03), and charcoal & fuel wood (0.01), respectively. It can be noticed from Table 4-2 and Figure 4-1 that a great majority of the 35 economic sectors were responsible for much more energy consumption indirectly than directly to produce a monetary unit of goods and services.

4.1.2 Direct Energy Intensities

Table 4-3 represents the ranked sector wise direct energy intensities (TOE/฿ 10,000) of 35 economic sectors. It is notable that 7 of the top 10 economic sectors with high direct energy intensities were among top 10 economic sectors with high total energy intensities in the same year. The economic sectors not included were drink & tobacco, food & allied, and chemicals & fertilizers. Gas distribution (1.27),

oil products (0.81) and electricity generation & distribution (0.41) were top sectors in both direct energy intensities ranking and total energy intensities ranking.

Table 4-1. Total energy intensities in 1985.

Unit : TOE/ ฿10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	1.53
2	14	Oil products	0.97
3	27	Electricity generation, distribution	0.89
4	18	Cement	0.54
5	33	Land transport	0.47
6	17	Bricks and tiles	0.21
7	34	Air and water transport	0.21
8	16	Ceramics	0.20
9	4	Oil and natural gas	0.19
10	19	Building materials, glasses	0.17
11	7	Food and allied	0.16
12	30	Construction	0.16
13	3	Coal mining	0.15
14	8	Drink and tobacco	0.14
15	29	Water supply and sanitation	0.14
16	6	Non-metallic mineral	0.14
17	21	Non ferrous metal	0.13
18	32	Hotel and restaurant	0.12
19	5	Metallic mineral	0.12
20	1	Agricultural, forestry, fishing	0.10
21	13	Chemicals and fertilizers	0.09
22	9	Textile	0.08
23	12	Pulp, paper and printing	0.08
24	20	Iron and steel	0.08
25	11	Timber and its product	0.07
26	10	Leather, etc.	0.07
27	15	Rubber and plastics	0.06
28	25	Automobiles, bicycles	0.06
29	26	Other manufacturing	0.04
30	35	Other services	0.04
31	23	Electrical engineering	0.04
32	31	Wholesale and retail	0.04
33	22	Mechanical engineering	0.03
34	24	Ship, train, aircraft	0.03

35	2	Charcoal and fuel wood	0.01
		Overall	0.13

Table 4-2. Direct and indirect energy intensities in 1985.

Unit : TOE/฿ 10,000

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	0.10	0.02	0.08
2	Charcoal and fuel wood	0.01	0.00	0.01
3	Coal mining	0.15	0.02	0.13
4	Oil and natural gas	0.19	0.16	0.03
5	Metallic mineral	0.12	0.02	0.10
6	Non-metallic mineral	0.14	0.02	0.12
7	Food and allied	0.16	0.08	0.08
8	Drink and tobacco	0.14	0.08	0.06
9	Textile	0.08	0.00	0.08
10	Leather, etc.	0.07	0.00	0.07
11	Timber and its product	0.07	0.00	0.07
12	Pulp, paper and printing	0.08	0.01	0.07
13	Chemicals and fertilizers	0.09	0.04	0.05
14	Oil products	0.97	0.81	0.16
15	Rubber and plastics	0.06	0.01	0.05
16	Ceramics	0.20	0.04	0.16
17	Bricks and tiles	0.21	0.05	0.16
18	Cement	0.54	0.14	0.40
19	Building materials, glasses	0.17	0.01	0.16
20	Iron and steel	0.08	0.01	0.07
21	Non ferrous metal	0.13	0.03	0.10
22	Mechanical engineering	0.03	0.00	0.03
23	Electrical engineering	0.04	0.00	0.04
24	Ship, train, aircraft	0.03	0.00	0.03
25	Automobiles, bicycles	0.06	0.00	0.06
26	Other manufacturing	0.04	0.00	0.04
27	Electricity generation, distribution	0.89	0.41	0.48
28	Gas distribution	1.53	1.27	0.26
29	Water supply and sanitation	0.14	0.02	0.12
30	Construction	0.16	0.00	0.16
31	Wholesale and retail	0.04	0.00	0.04
32	Hotel and restaurant	0.12	0.02	0.10
33	Land transport	0.47	0.09	0.38
34	Air and water transport	0.21	0.04	0.17

35	Other services	0.04	0.01	0.03
	Overall	0.13	0.04	0.09
		%	28.25	71.75

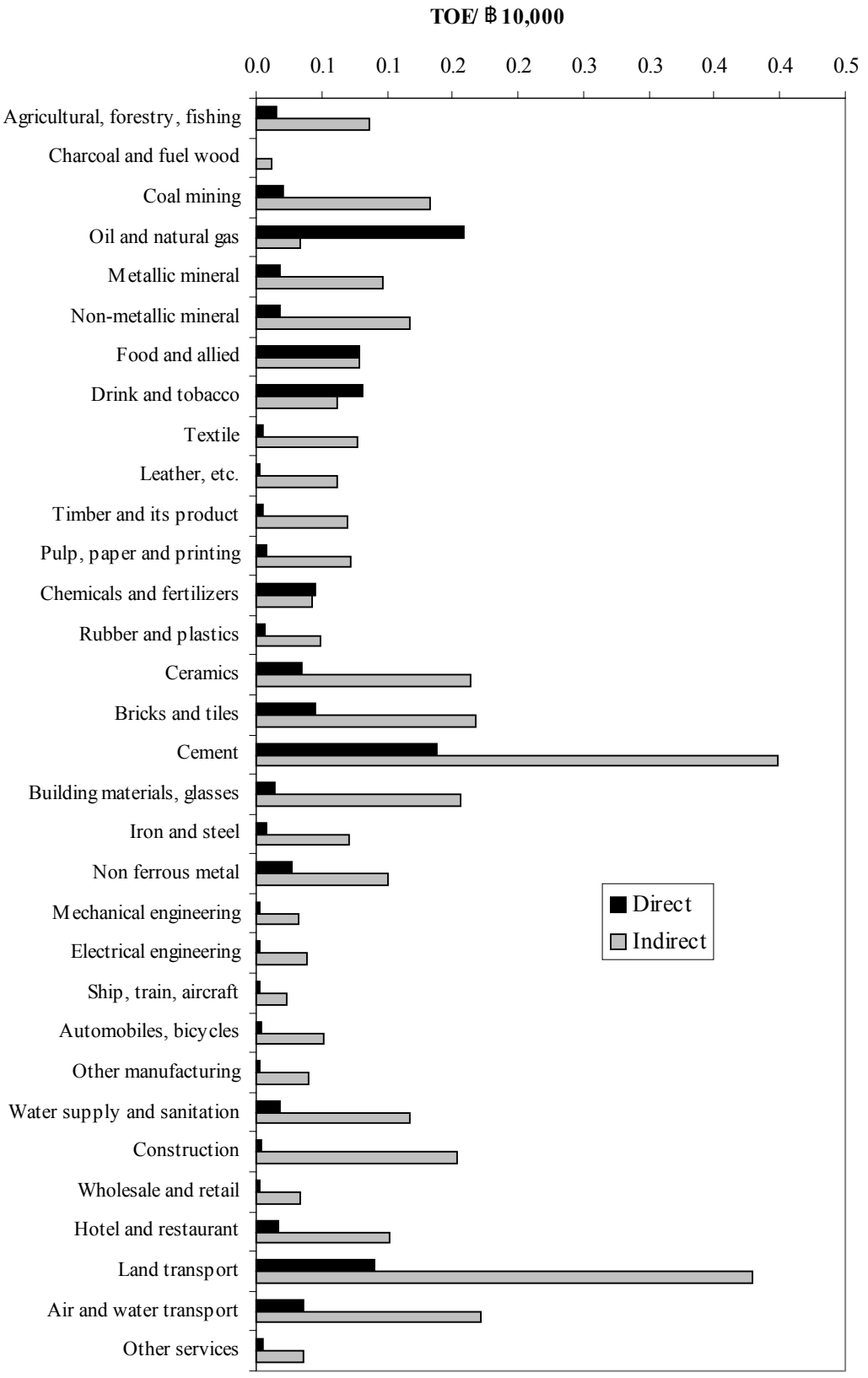

Figure 4-1. Direct and indirect energy intensities in 1985.

Table 4-3. Direct energy intensities in 1985.

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	1.27
2	14	Oil products	0.81
3	27	Electricity generation, distribution	0.41
4	4	Oil and natural gas	0.16
5	18	Cement	0.14
6	33	Land transport	0.09
7	8	Drink and tobacco	0.08
8	7	Food and allied	0.08
9	17	Bricks and tiles	0.05
10	13	Chemicals and fertilizers	0.04
11	34	Air and water transport	0.04
12	16	Ceramics	0.04
13	21	Non ferrous metal	0.03
14	3	Coal mining	0.02
15	5	Metallic mineral	0.02
16	29	Water supply and sanitation	0.02
17	6	Non-metallic mineral	0.02
18	32	Hotel and restaurant	0.02
19	1	Agricultural, forestry, fishing	0.02
20	19	Building materials, glasses	0.01
21	12	Pulp, paper and printing	0.01
22	20	Iron and steel	0.01
23	15	Rubber and plastics	0.01
24	35	Other services	0.01
25	11	Timber and its product	0.00
26	9	Textile	0.00
27	25	Automobiles, bicycles	0.00
28	30	Construction	0.00
29	10	Leather, etc.	0.00
30	26	Other manufacturing	0.00
31	31	Wholesale and retail	0.00
32	22	Mechanical engineering	0.00
33	24	Ship, train, aircraft	0.00
34	23	Electrical engineering	0.00
35	2	Charcoal and fuel wood	0.00
		Overall	0.04

The share of direct energy intensities in total energy intensities was 28.25 %, while indirect energy intensities took a share of 71.75 %.

4.1.3 Embodied Energy (Final Demand)

The embodied energy or direct embodied energy of an economic sector is obtainable by multiplying the total or direct energy intensity by the final demand for goods and services of that sector. With reference to Table 4-4, the embodied energy (final demand) excluding residential sector in the year 1985 was summed to 17,654.22 thousand TOE. The top 10 economic sectors with substantial high values (1000 TOE) in the year 1985 were land transport (3,750), food & allied (2,787), construction (2,116), oil production (1,402), hotel & restaurant (1,062), rest services, electricity generation & distribution, air & water transport, textile, and drink & tobacco, respectively. While the lowest 5 economic sectors were metallic mineral (12.51), coal mining (8.41), bricks and tiles (5.73), charcoal and fuel wood (4.98), and gas distribution (0.09), respectively. It is interesting to note that 4 of the top 10 economic sectors with high total energy intensities were among top 10 economic sectors with high embodied energy (final demand) in the same year. The economic sectors not included were gas distribution, cement, bricks & tiles, ceramics, oil & natural gas, and building materials & glasses. It is noteworthy that as in the year 1985, the overall indirect embodied energy (final demand) of Thai economy had a large share, which was 71.75 % of embodied energy (final demand) as show in Table 4-5 and Figure 4-2.

4.1.4 Direct Embodied Energy (Final Demand)

Table 4-6 exhibits the ranking of direct embodied energy in final demand (1000 TOE) of the 35 economic sectors for the year 1985. It is noticeable that 8 of top 10 economic sectors with high embodied energy (final demand) were in top 10 economic sectors with high direct embodied energy (final demand) in the same year. The two

economic sectors excluded were construction and textile that ranked 12th and 13th position respectively.

Table 4-4. Embodied energy (final demand) in 1985.

Unit : 1000 TOE

Rank	Sector	Sector Description	Energy
1	33	Land transport	3,750.39
2	7	Food and allied	2,787.17
3	30	Construction	2,116.28
4	14	Oil products	1,402.31
5	32	Hotel and restaurant	1,061.60
6	35	Other services	930.31
7	27	Electricity generation, distribution	923.87
8	34	Air and water transport	816.91
9	9	Textile	732.69
10	8	Drink and tobacco	582.08
11	1	Agricultural, forestry, fishing	543.53
12	31	Wholesale and retail	461.67
13	25	Automobiles, bicycles	210.82
14	13	Chemicals and fertilizers	210.78
15	22	Mechanical engineering	196.25
16	23	Electrical engineering	136.96
17	26	Other manufacturing	125.48
18	4	Oil and natural gas	110.52
19	15	Rubber and plastics	100.24
20	11	Timber and its product	91.81
21	21	Non ferrous metal	76.02
22	12	Pulp, paper and printing	70.67
23	10	Leather, etc.	58.80
24	18	Cement	42.94
25	29	Water supply and sanitation	39.83
26	19	Building materials, glasses	36.73
27	24	Ship, train, aircraft	28.06
28	20	Iron and steel	25.93
29	6	Non-metallic mineral	20.82
30	16	Ceramics	18.85
31	5	Metallic mineral	12.51
32	3	Coal mining	8.41
33	17	Bricks and tiles	5.73
34	2	Charcoal and fuel wood	4.98
35	28	Gas distribution	0.09
		Grand Total	17,654.22

Table 4-5. Direct and indirect embodied energy (final demand) in 1985.

Unit : 1000 TOE

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	543.53	83.70	459.83
2	Charcoal and fuel wood	4.98	0.00	4.98
3	Coal mining	8.41	1.10	7.31
4	Oil and natural gas	110.52	90.95	19.57
5	Metallic mineral	12.51	2.00	10.51
6	Non-metallic mineral	20.82	2.76	18.06
7	Food and allied	2,787.17	1,389.14	1,398.03
8	Drink and tobacco	582.08	330.45	251.63
9	Textile	732.69	41.88	690.81
10	Leather, etc.	58.80	2.78	56.02
11	Timber and its product	91.81	6.15	85.66
12	Pulp, paper and printing	70.67	6.82	63.85
13	Chemicals and fertilizers	210.78	107.71	103.07
14	Oil products	1,402.31	1,176.74	225.57
15	Rubber and plastics	100.24	12.44	87.80
16	Ceramics	18.85	3.32	15.53
17	Bricks and tiles	5.73	1.22	4.51
18	Cement	42.94	11.04	31.90
19	Building materials, glasses	36.73	3.05	33.68
20	Iron and steel	25.93	2.48	23.45
21	Non ferrous metal	76.02	16.16	59.86
22	Mechanical engineering	196.25	14.90	181.35
23	Electrical engineering	136.96	6.82	130.14
24	Ship, train, aircraft	28.06	2.57	25.49
25	Automobiles, bicycles	210.82	16.63	194.19
26	Other manufacturing	125.48	8.84	116.64
27	Electricity generation, distribution	923.87	423.35	500.52
28	Gas distribution	0.09	0.08	0.01
29	Water supply and sanitation	39.83	5.39	34.44
30	Construction	2,116.28	46.32	2,069.96
31	Wholesale and retail	461.67	37.86	423.81
32	Hotel and restaurant	1,061.60	151.33	910.27
33	Land transport	3,750.39	720.28	3,030.11
34	Air and water transport	816.91	141.25	675.66
35	Other services	930.31	120.16	810.15
	Overall	17,654.22	4,987.65	12,666.57
		%	28.25	71.75

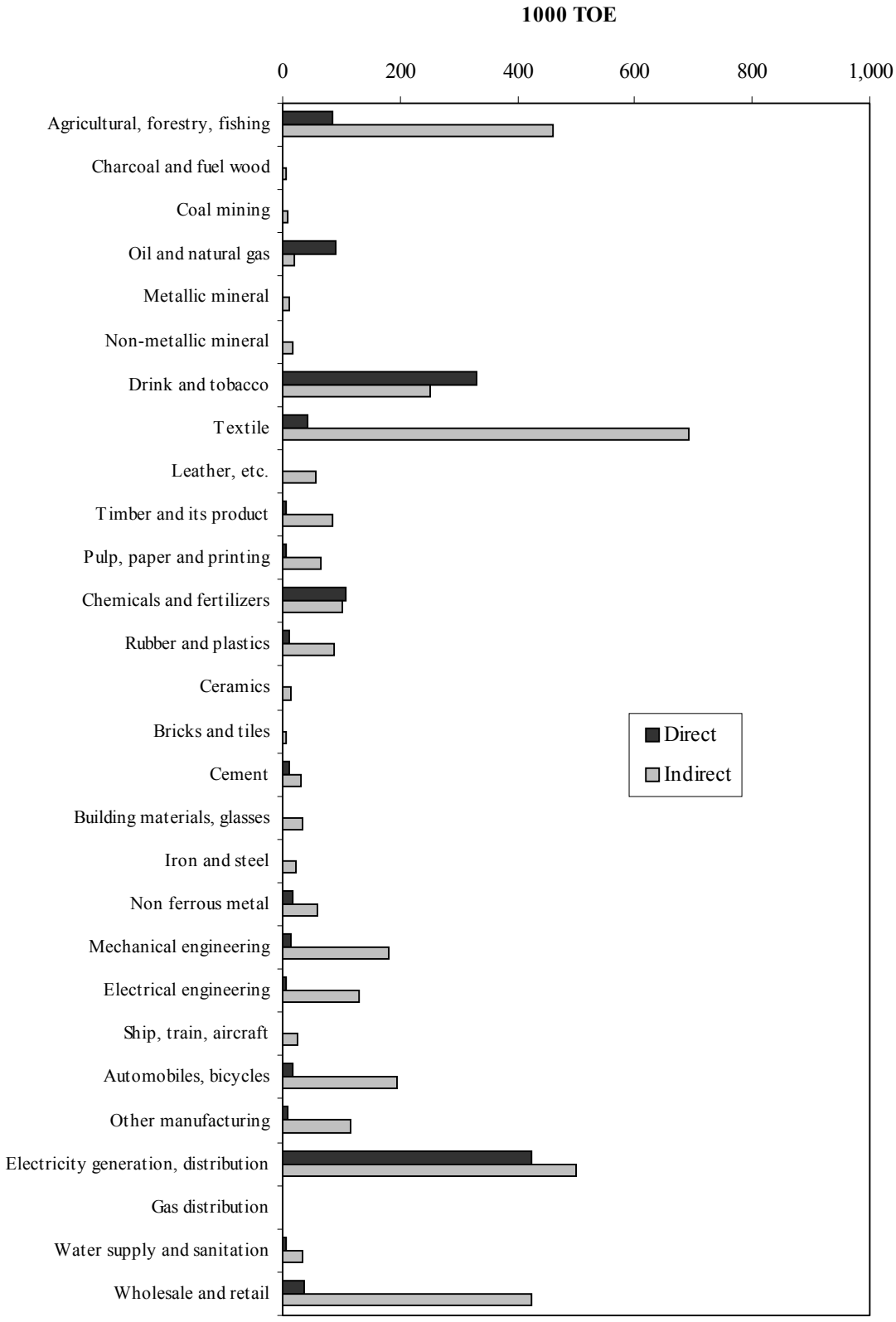

Figure 4-2. Direct and indirect embodied energy (final demand) in 1985.

Table 4-6. Direct embodied energy (final demand) in 1985.

Unit : 1000 TOE

Rank	Sector	Sector Description	Energy
1	7	Food and allied	1,389.14
2	14	Oil products	1,176.74
3	33	Land transport	720.28
4	27	Electricity generation, distribution	423.35
5	8	Drink and tobacco	330.45
6	32	Hotel and restaurant	151.33
7	34	Air and water transport	141.25
8	35	Other services	120.16
9	13	Chemicals and fertilizers	107.71
10	4	Oil and natural gas	90.95
11	1	Agricultural, forestry, fishing	83.70
12	30	Construction	46.32
13	9	Textile	41.88
14	31	Wholesale and retail	37.86
15	25	Automobiles, bicycles	16.63
16	21	Non ferrous metal	16.16
17	22	Mechanical engineering	14.90
18	15	Rubber and plastics	12.44
19	18	Cement	11.04
20	26	Other manufacturing	8.84
21	12	Pulp, paper and printing	6.82
22	23	Electrical engineering	6.82
23	11	Timber and its product	6.15
24	29	Water supply and sanitation	5.39
25	16	Ceramics	3.32
26	19	Building materials, glasses	3.05
27	10	Leather, etc.	2.78
28	6	Non-metallic mineral	2.76
29	24	Ship, train, aircraft	2.57
30	20	Iron and steel	2.48
31	5	Metallic mineral	2.00
32	17	Bricks and tiles	1.22
33	3	Coal mining	1.10
34	28	Gas distribution	0.08
35	2	Charcoal and fuel wood	0.00
		Overall	4,987.65

4.2 Embodied Energy in 1995

4.2.1 Total Energy Intensities

Table 4-7 illustrates the total energy intensities in terms of TOE/฿ 10,000 of various economic sectors for the year 1995. The ranked top 10 economic sectors with high total energy intensities were gas distribution (2.28), oil products (1.00), electricity generation & distribution (0.78), cement (0.55), land transport (0.34), bricks & tiles, air & water transport, ceramics, building materials & glasses, and coal mining, respectively. Where as, the 5 economic sectors with lowest total energy intensities were mechanical engineering (0.02), electrical engineering (0.02), non ferrous metal (0.01), charcoal & fuel wood (0.01), and ship & train & aircraft (0.01), respectively. Table 4-8 and Figure 4-3 reveal that in 1995, the majority of the 35 economic sectors were much more responsible for indirect energy consumption than direct consumption to produce a monetary unit of their goods and services.

4.2.2 Direct Energy Intensities

Table 4-9 illustrates the ranked sector wise direct energy intensities (TOE/฿ 10,000) of 35 economic sectors in the year 1995. It is notable that out of the top 10 economic sectors with high direct energy intensities, 8 were among the top 10 economic sectors with high total energy intensities, except for drink & tobacco, oil & natural gas sectors. Gas distribution (2.00) and oil products (0.95) were top 2 sectors in both total energy intensities and direct energy intensity rankings. Direct energy intensities took a share of 31.24 % in total energy intensities and the rest 68.76 % was taken by indirect energy intensities.

Table 4-7. Total energy intensities in 1995.

Unit : TOE/ ฿ 10,000

Rank	Sector	Sector Description	1995
1	28	Gas distribution	2.28
2	14	Oil products	1.00
3	27	Electricity generation, distribution	0.78
4	18	Cement	0.55
5	33	Land transport	0.34
6	17	Bricks and tiles	0.29
7	34	Air and water transport	0.23
8	16	Ceramics	0.21
9	19	Building materials, glasses	0.16
10	3	Coal mining	0.13
11	8	Drink and tobacco	0.12
12	7	Food and allied	0.11
13	32	Hotel and restaurant	0.10
14	30	Construction	0.10
15	6	Non-metallic mineral	0.09
16	29	Water supply and sanitation	0.08
17	1	Agricultural, forestry, fishing	0.08
18	4	Oil and natural gas	0.08
19	9	Textile	0.07
20	12	Pulp, paper and printing	0.07
21	15	Rubber and plastics	0.06
22	5	Metallic mineral	0.05
23	13	Chemicals and fertilizers	0.05
24	11	Timber and its product	0.04
25	20	Iron and steel	0.04
26	10	Leather, etc.	0.04
27	25	Automobiles, bicycles	0.03
28	31	Wholesale and retail	0.03
29	35	Other services	0.03
30	26	Other manufacturing	0.02
31	22	Mechanical engineering	0.02
32	23	Electrical engineering	0.02
33	21	Non ferrous metal	0.01
34	2	Charcoal and fuel wood	0.01
35	24	Ship, train, aircraft	0.01
		Overall	0.08

Table 4-8. Direct and indirect energy intensities in 1995.

Unit : TOE/฿ 10,000

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	0.08	0.02	0.06
2	Charcoal and fuel wood	0.01	0.00	0.01
3	Coal mining	0.13	0.03	0.10
4	Oil and natural gas	0.08	0.04	0.04
5	Metallic mineral	0.05	0.01	0.04
6	Non-metallic mineral	0.09	0.02	0.07
7	Food and allied	0.11	0.04	0.07
8	Drink and tobacco	0.12	0.08	0.04
9	Textile	0.07	0.00	0.07
10	Leather, etc.	0.04	0.00	0.04
11	Timber and its product	0.04	0.00	0.04
12	Pulp, paper and printing	0.06	0.01	0.05
13	Chemicals and fertilizers	0.05	0.02	0.03
14	Oil products	1.00	0.95	0.05
15	Rubber and plastics	0.07	0.01	0.06
16	Ceramics	0.21	0.05	0.16
17	Bricks and tiles	0.29	0.10	0.19
18	Cement	0.55	0.37	0.18
19	Building materials, glasses	0.16	0.02	0.14
20	Iron and steel	0.04	0.01	0.03
21	Non ferrous metal	0.01	0.00	0.01
22	Mechanical engineering	0.02	0.00	0.02
23	Electrical engineering	0.02	0.00	0.02
24	Ship, train, aircraft	0.01	0.00	0.01
25	Automobiles, bicycles	0.03	0.00	0.03
26	Other manufacturing	0.02	0.00	0.02
27	Electricity generation, distribution	0.78	0.35	0.43
28	Gas distribution	2.28	2.00	0.28
29	Water supply and sanitation	0.08	0.01	0.07
30	Construction	0.10	0.00	0.10
31	Wholesale and retail	0.03	0.00	0.03
32	Hotel and restaurant	0.10	0.01	0.09
33	Land transport	0.34	0.09	0.25
34	Air and water transport	0.23	0.06	0.17
35	Other services	0.03	0.00	0.03
	Overall	0.08	0.03	0.05
		%	31.18	68.82

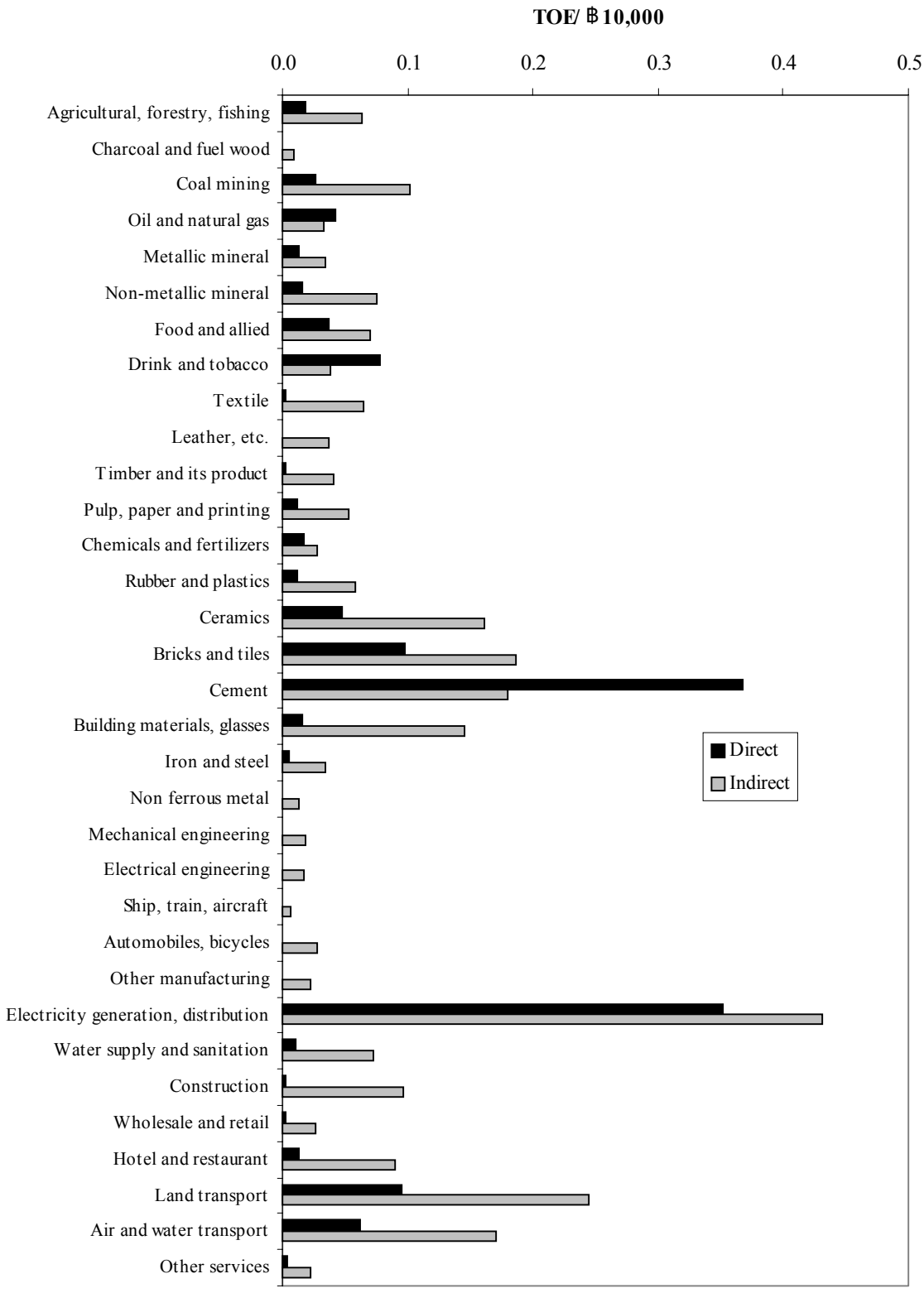

Figure 4-3. Direct and indirect energy intensities in 1995.

Table 4-9. Direct energy intensities in 1995.

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	2.00
2	14	Oil products	0.95
3	18	Cement	0.37
4	27	Electricity generation, distribution	0.35
5	17	Bricks and tiles	0.10
6	33	Land transport	0.09
7	8	Drink and tobacco	0.08
8	34	Air and water transport	0.06
9	16	Ceramics	0.05
10	4	Oil and natural gas	0.04
11	7	Food and allied	0.04
12	3	Coal mining	0.03
13	1	Agricultural, forestry, fishing	0.02
14	13	Chemicals and fertilizers	0.02
15	19	Building materials, glasses	0.02
16	6	Non-metallic mineral	0.02
17	5	Metallic mineral	0.01
18	32	Hotel and restaurant	0.01
19	12	Pulp, paper and printing	0.01
20	15	Rubber and plastics	0.01
21	29	Water supply and sanitation	0.01
22	20	Iron and steel	0.01
23	35	Other services	0.00
24	9	Textile	0.00
25	31	Wholesale and retail	0.00
26	11	Timber and its product	0.00
27	30	Construction	0.00
28	26	Other manufacturing	0.00
29	22	Mechanical engineering	0.00
30	25	Automobiles, bicycles	0.00
31	10	Leather, etc.	0.00
32	21	Non ferrous metal	0.00
33	24	Ship, train, aircraft	0.00
34	23	Electrical engineering	0.00
35	2	Charcoal and fuel wood	0.00
		Overall	0.03

4.2.3 Embodied Energy (Final Demand)

Table 4-10 represents the embodied energy (final demand) in the year 1995 (excluding residential sector), which was in the sum of 53,535.35 thousand TOE. The top 10 economic sectors with high embodied energy (final demand) (in 1000 TOE) in 1995 were construction (8,021), land transport (6,765), oil products (6,561), food & allied (4,763), hotel & restaurant (3,702), electricity generation & distribution, textile, air & water transport, other services, and wholesale & retail. At the same time, the bottom 5 economic sectors were oil & natural gas (8.81), coal mining (2.84), charcoal & fuel wood (2.29), metallic mineral (1.71), and non-metallic mineral (-25.07), respectively. It is interesting to notify that 4 of the 10 economic sectors with high total energy intensities were among top 10 economic sectors with high embodied energy (final demand) in the same year. The economic sectors not included were gas distribution, cement bricks & tiles, ceramics, building materials & glasses, and coal mining. It is shown in Table 4-11 and Figure 4-4 that in the year 1995 the overall indirect embodied energy (final demand) of Thai economy had a large share of 68.76 % in the overall embodied energy in the final demand.

4.2.4 Direct Embodied Energy (Final Demand)

Table 4-12 shows the ranked direct embodied energy (final demand) of 35 economic sectors for 1995. It is noticeable that top 10 economic sectors with high embodied energy (final demand) were among top 15 economic sector with high direct embodied energy. At the same time, it can be noted that bottom 10 economic sectors with low embodied energy (final demand) were the same as the ones with low direct embodied energy. This indicates a strong relationship between embodied energy (final demand) and direct embodied energy (final demand) in economic sectors.

Table 4-10. Embodied energy (final demand) in 1995.

Unit : 1000 TOE

Rank	Sector	Sector Description	Energy
1	30	Construction	8,020.59
2	33	Land transport	6,764.64
3	14	Oil products	6,561.44
4	7	Food and allied	4,762.68
5	32	Hotel and restaurant	3,701.91
6	27	Electricity generation, distribution	2,875.30
7	9	Textile	2,761.83
8	34	Air and water transport	2,521.78
9	35	Other services	2,242.34
10	31	Wholesale and retail	1,754.81
11	8	Drink and tobacco	1,705.44
12	28	Gas distribution	1,663.40
13	25	Automobiles, bicycles	1,310.79
14	1	Agricultural, forestry, fishing	1,262.74
15	22	Mechanical engineering	1,033.05
16	23	Electrical engineering	778.37
17	15	Rubber and plastics	772.24
18	26	Other manufacturing	724.31
19	10	Leather, etc.	552.99
20	13	Chemicals and fertilizers	402.08
21	11	Timber and its product	358.69
22	12	Pulp, paper and printing	308.54
23	18	Cement	171.55
24	16	Ceramics	161.06
25	19	Building materials, glasses	123.65
26	24	Ship, train, aircraft	96.77
27	29	Water supply and sanitation	66.63
28	20	Iron and steel	59.04
29	21	Non ferrous metal	14.27
30	17	Bricks and tiles	11.81
31	4	Oil and natural gas	8.81
32	3	Coal mining	2.84
33	2	Charcoal and fuel wood	2.29
34	5	Metallic mineral	1.71
35	6	Non-metallic mineral	-25.07
		Grand Total	53,535.35

Table 4-11. Direct and indirect embodied energy (final demand) in 1995.

Unit : 1000 TOE

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	1,262.74	289.95	972.79
2	Charcoal and fuel wood	2.29	0.00	2.29
3	Coal mining	2.84	0.59	2.25
4	Oil and natural gas	8.81	4.94	3.87
5	Metallic mineral	1.71	0.47	1.24
6	Non-metallic mineral	-25.07	-4.36	-20.71
7	Food and allied	4,762.68	1,652.45	3,110.23
8	Drink and tobacco	1,705.44	1,139.31	566.13
9	Textile	2,761.83	124.47	2,637.36
10	Leather, etc.	552.99	21.77	531.22
11	Timber and its product	358.69	18.37	340.32
12	Pulp, paper and printing	308.54	58.76	249.78
13	Chemicals and fertilizers	402.08	153.58	248.50
14	Oil products	6,561.44	6,267.75	293.69
15	Rubber and plastics	772.24	140.34	631.90
16	Ceramics	161.06	36.99	124.07
17	Bricks and tiles	11.81	4.06	7.75
18	Cement	171.55	115.20	56.35
19	Building materials, glasses	123.65	12.25	111.40
20	Iron and steel	59.04	7.54	51.50
21	Non ferrous metal	14.27	1.02	13.25
22	Mechanical engineering	1,033.05	82.79	950.26
23	Electrical engineering	778.37	16.43	761.94
24	Ship, train, aircraft	96.77	12.03	84.74
25	Automobiles, bicycles	1,310.79	69.26	1,241.53
26	Other manufacturing	724.31	52.05	672.26
27	Electricity generation, distribution	2,875.30	1,292.60	1,582.70
28	Gas distribution	1,663.40	1,463.88	199.52
29	Water supply and sanitation	66.63	8.05	58.58
30	Construction	8,020.59	179.25	7,841.34
31	Wholesale and retail	1,754.81	154.15	1,600.66
32	Hotel and restaurant	3,701.91	469.67	3,232.24
33	Land transport	6,764.64	1,891.35	4,873.29
34	Air and water transport	2,521.78	675.34	1,846.44
35	Other services	2,242.34	309.99	1,932.35
	Overall	53,535.35	16,722.28	36,813.07
		%	31.24	68.76

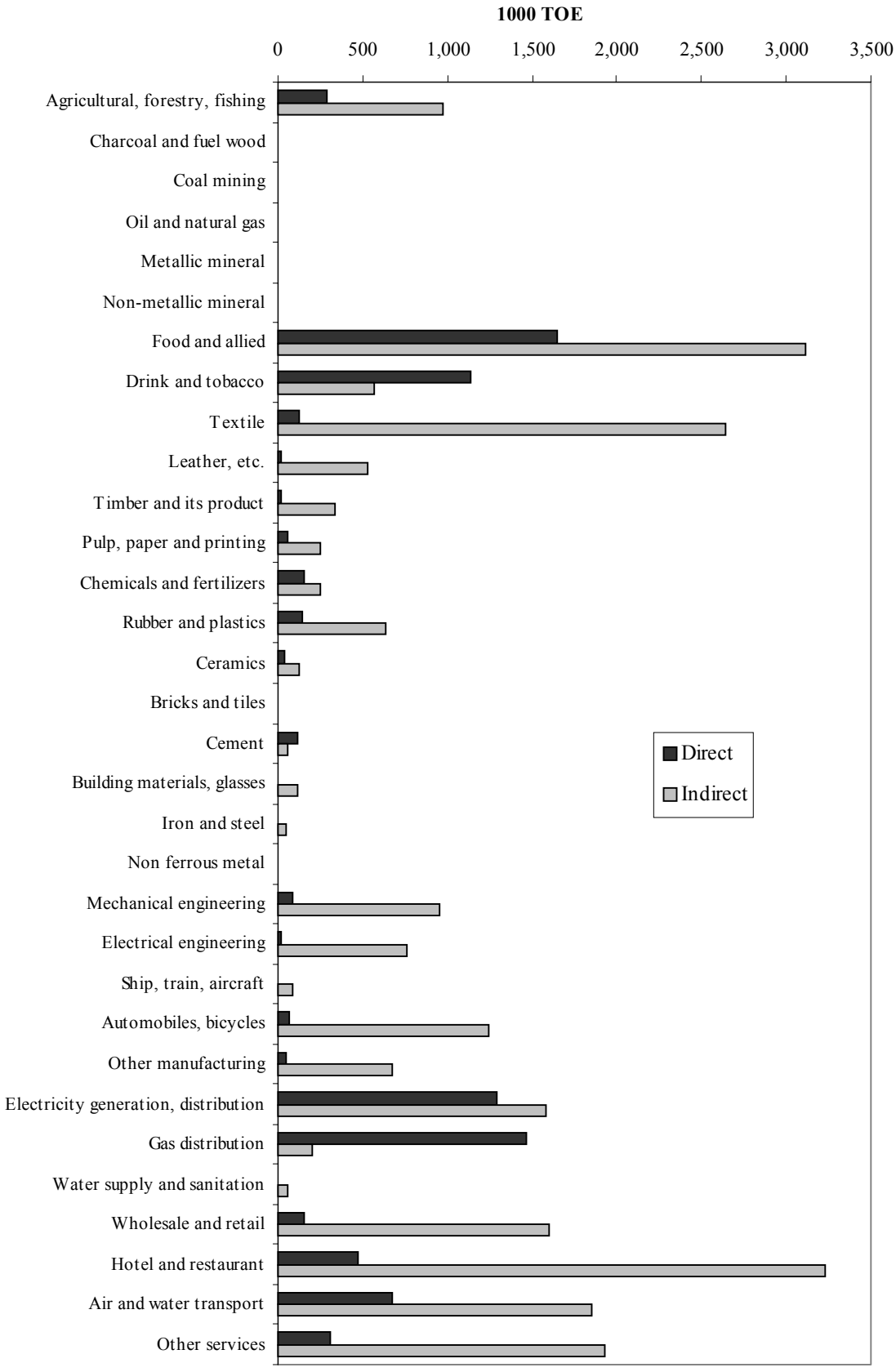

Figure 4-4. Direct and indirect embodied energy (final demand) in 1995.

Table 4-12. Direct embodied energy (final demand) in 1995.

Unit : 1000 TOE

Rank	Sector	Sector Description	Energy
1	14	Oil products	6,267.75
2	33	Land transport	1,891.35
3	7	Food and allied	1,652.45
4	28	Gas distribution	1,463.88
5	27	Electricity generation, distribution	1,292.60
6	8	Drink and tobacco	1,139.31
7	34	Air and water transport	675.34
8	32	Hotel and restaurant	469.67
9	35	Other services	309.99
10	1	Agricultural, forestry, fishing	289.95
11	30	Construction	179.25
12	31	Wholesale and retail	154.15
13	13	Chemicals and fertilizers	153.58
14	15	Rubber and plastics	140.34
15	9	Textile	124.47
16	18	Cement	115.20
17	22	Mechanical engineering	82.79
18	25	Automobiles, bicycles	69.26
19	12	Pulp, paper and printing	58.76
20	26	Other manufacturing	52.05
21	16	Ceramics	36.99
22	10	Leather, etc.	21.77
23	11	Timber and its product	18.37
24	23	Electrical engineering	16.43
25	19	Building materials, glasses	12.25
26	24	Ship, train, aircraft	12.03
27	29	Water supply and sanitation	8.05
28	20	Iron and steel	7.54
29	4	Oil and natural gas	4.94
30	17	Bricks and tiles	4.06
31	21	Non ferrous metal	1.02
32	3	Coal mining	0.59
33	5	Metallic mineral	0.47
34	2	Charcoal and fuel wood	0.00
35	6	Non-metallic mineral	-4.36
		Overall	16,722.28

4.2.5 Energy Intensities in 1995 with Modification

The monetary units in the input-output table for the year 1995 were modified to 1985 constant prices, based on the annual customer price indices of Thailand. Since no sector-wise information was available, one value was used for all.

Table 4-13 and 4-14 represent modified total energy intensities and modified direct energy intensities (TOE/฿ 10,000), respectively, for the year 1995. There is no change in the rankings of all the 35 sectors. However, intensity values were changed according to the difference of customer price indices uniformly for all sectors. Hence, the overall total energy intensities was changed from 0.08 TOE/฿ 10,000 to 0.13 TOE/฿ 10,000, and the overall direct energy intensities was changed from 0.03 TOE/฿ 10,000 to 0.04 TOE/฿ 10,000 accordingly. Note that the shares of direct and indirect energy intensities in total energy intensities remained the same.

4.3 Comparison of embodied energy between 1985 and 1995

4.3.1 Total Energy Intensities

Table 4-15 and Figure 4-5 illustrate the total energy intensities (TOE/฿ 10,000) of various economic sectors for the years 1985 and 1995. It is notable that 9 of the top 10 economic sectors with high total energy intensities in 1995 were among top 10 economic sectors with high total energy intensities in 1985. The economic sector not included was oil & natural gas that ranked 9th in 1985 but fell to 18th position in 1995 with large reduction in its total energy intensity.

Although the overall total energy intensity as well as total energy intensities of many economic sectors were decreased, there was an increase of the same for some sectors such as gas distribution, bricks & tiles, air & water transport in 1995 compared to 1985. The reason was the increase in direct energy intensities in these three sectors.

Table 4-13. Total energy intensities in 1995 (modified).

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	3.57
2	14	Oil products	1.56
3	27	Electricity generation, distribution	1.23
4	18	Cement	0.86
5	33	Land transport	0.53
6	17	Bricks and tiles	0.45
7	34	Air and water transport	0.37
8	16	Ceramics	0.33
9	19	Building materials, glasses	0.25
10	3	Coal mining	0.20
11	8	Drink and tobacco	0.18
12	7	Food and allied	0.17
13	32	Hotel and restaurant	0.16
14	30	Construction	0.15
15	6	Non-metallic mineral	0.14
16	29	Water supply and sanitation	0.13
17	1	Agricultural, forestry, fishing	0.13
18	4	Oil and natural gas	0.12
19	9	Textile	0.11
20	12	Pulp, paper and printing	0.11
21	15	Rubber and plastics	0.10
22	5	Metallic mineral	0.07
23	13	Chemicals and fertilizers	0.07
24	11	Timber and its product	0.07
25	20	Iron and steel	0.06
26	10	Leather, etc.	0.06
27	25	Automobiles, bicycles	0.05
28	31	Wholesale and retail	0.05
29	35	Other services	0.04
30	26	Other manufacturing	0.04
31	22	Mechanical engineering	0.03
32	23	Electrical engineering	0.03
33	21	Non ferrous metal	0.02
34	2	Charcoal and fuel wood	0.01
35	24	Ship, train, aircraft	0.01
		Overall	0.13

Table 4-14. Direct energy intensities in 1995 (modified).

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	3.14
2	14	Oil products	1.49
3	18	Cement	0.58
4	27	Electricity generation, distribution	0.55
5	17	Bricks and tiles	0.15
6	33	Land transport	0.15
7	8	Drink and tobacco	0.12
8	34	Air and water transport	0.10
9	16	Ceramics	0.08
10	4	Oil and natural gas	0.07
11	7	Food and allied	0.06
12	3	Coal mining	0.04
13	1	Agricultural, forestry, fishing	0.03
14	13	Chemicals and fertilizers	0.03
15	19	Building materials, glasses	0.02
16	6	Non-metallic mineral	0.02
17	5	Metallic mineral	0.02
18	32	Hotel and restaurant	0.02
19	12	Pulp, paper and printing	0.02
20	15	Rubber and plastics	0.02
21	29	Water supply and sanitation	0.02
22	20	Iron and steel	0.01
23	35	Other services	0.01
24	9	Textile	0.00
25	31	Wholesale and retail	0.00
26	11	Timber and its product	0.00
27	30	Construction	0.00
28	26	Other manufacturing	0.00
29	22	Mechanical engineering	0.00
30	25	Automobiles, bicycles	0.00
31	10	Leather, etc.	0.00
32	21	Non ferrous metal	0.00
33	24	Ship, train, aircraft	0.00
34	23	Electrical engineering	0.00
35	2	Charcoal and fuel wood	0.00
		Overall	0.04

Table 4-15. Total energy intensities in 1985 and 1995.

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	1985	1995	Rank
1	28	Gas distribution	1.53	2.28	1
2	14	Oil products	0.97	1.00	2
3	27	Electricity generation, distribution	0.89	0.78	3
4	18	Cement	0.54	0.55	4
5	33	Land transport	0.47	0.34	5
6	17	Bricks and tiles	0.21	0.29	6
7	34	Air and water transport	0.21	0.23	7
8	16	Ceramics	0.20	0.21	8
9	4	Oil and natural gas	0.19	0.08	18
10	19	Building materials, glasses	0.17	0.16	9
11	7	Food and allied	0.16	0.11	12
12	30	Construction	0.16	0.10	14
13	3	Coal mining	0.15	0.13	10
14	8	Drink and tobacco	0.14	0.12	11
15	29	Water supply and sanitation	0.14	0.08	16
16	6	Non-metallic mineral	0.14	0.09	15
17	32	Hotel and restaurant	0.13	0.01	33
18	5	Metallic mineral	0.12	0.10	13
19	1	Agricultural, forestry, fishing	0.12	0.05	22
20	13	Chemicals and fertilizers	0.10	0.08	17
21	9	Textile	0.09	0.05	23
22	12	Pulp, paper and printing	0.08	0.07	20
23	11	Timber and its product	0.08	0.06	21
24	10	Leather, etc.	0.08	0.04	25
25	15	Rubber and plastics	0.07	0.04	24
26	25	Automobiles, bicycles	0.07	0.04	26
27	26	Other manufacturing	0.06	0.07	19
28	35	Other services	0.06	0.03	27
29	23	Electrical engineering	0.04	0.02	30
30	20	Iron and steel	0.04	0.03	29
31	31	Wholesale and retail	0.04	0.02	32
32	22	Mechanical engineering	0.04	0.03	28
33	24	Ship, train, aircraft	0.03	0.02	31
34	2	Charcoal and fuel wood	0.03	0.01	35
35	21	Non ferrous metal	0.01	0.01	34
		Overall	0.13	0.08	

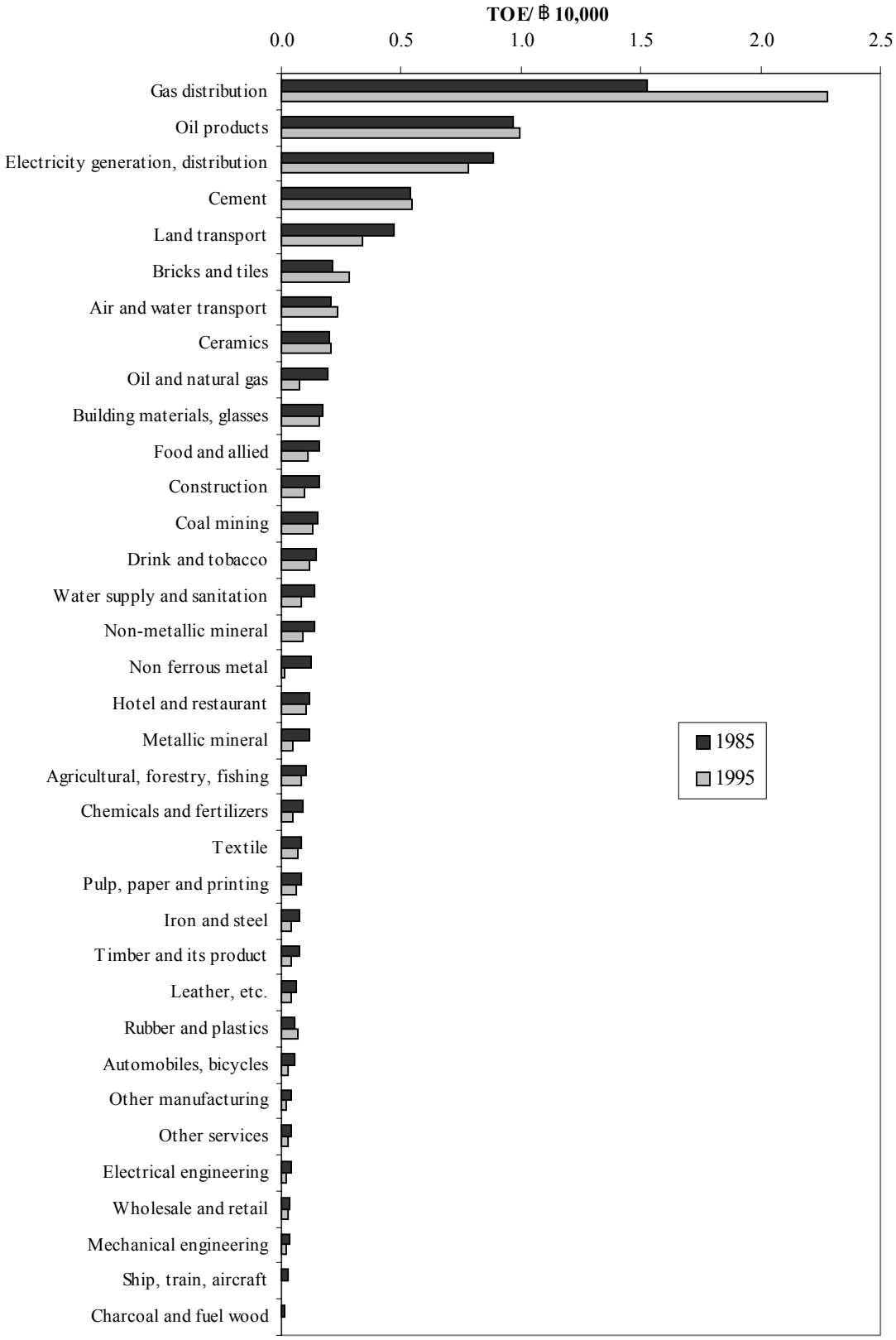

Figure 4-5. Total energy intensities in 1985 and 1995.

Among the sectors with increased total energy intensities in 1995, gas distribution sector's increase is quite remarkable. It's direct energy intensity share increased from 83.31 % of total energy intensity in 1985 to 88.01 % in 1995. This sector's total energy intensity ranked first in both the years 1985 and 1995.

4.3.2 Direct Energy Intensities

Table 4-16 and Figure 4-6 represent direct energy intensities (TOE/฿ 10,000) of 35 economic sectors for 1985 and 1995. It can be noticed that 7 of the top 10 economic sectors with high direct energy intensities in 1995 were in the top 10 economic sectors with high direct energy intensities in 1985. The sectors not included were food & allied, and chemicals & fertilizers that ranked 8th and 10th respectively, they fell to 11th and 14th positions in 1995, respectively, with substantial reduction in their direct energy intensities.

Besides a decrease in overall direct energy intensity as well as in direct energy intensities of many economic sectors, increase of the same for some sector such as gas distribution, oil products, cement, bricks & tiles, air & water transport, and ceramics is notable in 1995 compared to 1985. Among the sectors with such increased direct energy intensities, gas distribution, cement, and bricks & tiles sectors' increase is quite notable. At the same time, it is also noteworthy that as in both years, a great majority of the 35 economic sectors were responsible for much more energy consumption indirectly than directly to produce a monetary unit of goods and services.

In case of modified monetary units for the year 1995, 20 of the 35 economic sectors' intensities were increased although the overall total energy intensity was still decreased. The three economic sectors mentioned above are notable to have a higher increase.

4.3.3 Embodied Energy (Final Demand)

The embodied energy (final demand) for the years 1985 and 1995 (excluding residential sector) are shown in Table 4-19 and Figure 4-7, in terms of 1000 TOE. It is interesting to note that land transport, food & allied, construction, oil products, and hotel & restaurant sectors were top 5 sectors with high embodied energy (final demand) in both years. Although most of the economic sectors increased their embodied energy (final demand) due to the economic growth during the period of ten years, there were some economic sectors that decreased embodied energy (final demand), such as oil & natural gas, non-metallic mineral, metallic mineral, coal mining, and charcoal & fuel wood sectors. At the same time, gas distribution sector had a substantial increase in its embodied energy (final demand) in 1995 compared to 1985.

4.3.4 Direct Embodied Energy (Final Demand)

Table 4-20 illustrates direct embodied energy in the final demand of Thai economic sectors for the years 1985 and 1995. Food & allied, oil products, and land transport were top 3 sectors with high direct embodied energy (final demand) in both years. Similar to embodied energy (final demand), most of the economic sectors had increased direct embodied energy (final demand) except for some sectors, which were oil & natural gas, non-ferrous metal, non-metallic mineral, metallic mineral, and coal mining sectors. Although the share of the overall direct embodied energy (final demand) increased in 1995 compared to 1985 (31.24 % from 28.25 %), overall indirect embodied energy (final demand) of Thai economy has still large share in 1995 (68.76 %) as in 1985 (71.75 %). This has clearly indicated that economic and environmental interdependence among different economic sectors of Thai economy is very strong.

Table 4-16. Direct energy intensities in 1985 and 1995.

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	1985	1995	Rank
1	28	Gas distribution	1.27	2.00	1
2	14	Oil products	0.81	0.95	2
3	27	Electricity generation, distribution	0.41	0.35	4
4	4	Oil and natural gas	0.16	0.04	10
5	18	Cement	0.14	0.37	3
6	33	Land transport	0.09	0.09	6
7	8	Drink and tobacco	0.08	0.08	7
8	7	Food and allied	0.08	0.04	11
9	17	Bricks and tiles	0.05	0.10	5
10	13	Chemicals and fertilizers	0.04	0.02	14
11	34	Air and water transport	0.04	0.06	8
12	16	Ceramics	0.04	0.05	9
13	21	Non ferrous metal	0.03	0.00	32
14	3	Coal mining	0.02	0.03	12
15	5	Metallic mineral	0.02	0.01	17
16	29	Water supply and sanitation	0.02	0.01	21
17	6	Non-metallic mineral	0.02	0.02	16
18	32	Hotel and restaurant	0.02	0.01	18
19	1	Agricultural, forestry, fishing	0.02	0.02	13
20	19	Building materials, glasses	0.01	0.02	15
21	12	Pulp, paper and printing	0.01	0.01	19
22	20	Iron and steel	0.01	0.01	22
23	15	Rubber and plastics	0.01	0.01	20
24	35	Other services	0.01	0.00	23
25	11	Timber and its product	0.00	0.00	26
26	9	Textile	0.00	0.00	24
27	25	Automobiles, bicycles	0.00	0.00	30
28	30	Construction	0.00	0.00	27
29	10	Leather, etc.	0.00	0.00	31
30	26	Other manufacturing	0.00	0.00	28
31	31	Wholesale and retail	0.00	0.00	25
32	22	Mechanical engineering	0.00	0.00	29
33	24	Ship, train, aircraft	0.00	0.00	33
34	23	Electrical engineering	0.00	0.00	34
35	2	Charcoal and fuel wood	0.00	0.00	35
		Overall	0.04	0.03	

Table 4-17. Total energy intensities in 1985 and 1995 (modified).

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	1985	1995 Mod.	Rank
1	28	Gas distribution	1.53	3.57	1
2	14	Oil products	0.97	1.56	2
3	27	Electricity generation, distribution	0.89	1.23	3
4	18	Cement	0.54	0.86	4
5	33	Land transport	0.47	0.53	5
6	17	Bricks and tiles	0.21	0.45	6
7	34	Air and water transport	0.21	0.37	7
8	16	Ceramics	0.20	0.33	8
9	4	Oil and natural gas	0.19	0.12	18
10	19	Building materials, glasses	0.17	0.25	9
11	7	Food and allied	0.16	0.17	12
12	30	Construction	0.16	0.15	14
13	3	Coal mining	0.15	0.20	10
14	8	Drink and tobacco	0.14	0.18	11
15	29	Water supply and sanitation	0.14	0.13	16
16	6	Non-metallic mineral	0.14	0.14	15
17	32	Hotel and restaurant	0.13	0.02	33
18	5	Metallic mineral	0.12	0.16	13
19	1	Agricultural, forestry, fishing	0.12	0.07	22
20	13	Chemicals and fertilizers	0.10	0.13	17
21	9	Textile	0.09	0.07	23
22	12	Pulp, paper and printing	0.08	0.11	20
23	11	Timber and its product	0.08	0.10	21
24	10	Leather, etc.	0.08	0.06	25
25	15	Rubber and plastics	0.07	0.07	24
26	25	Automobiles, bicycles	0.07	0.06	26
27	26	Other manufacturing	0.06	0.11	19
28	35	Other services	0.06	0.05	27
29	23	Electrical engineering	0.04	0.04	30
30	20	Iron and steel	0.04	0.04	29
31	31	Wholesale and retail	0.04	0.03	32
32	22	Mechanical engineering	0.04	0.05	28
33	24	Ship, train, aircraft	0.03	0.03	31
34	2	Charcoal and fuel wood	0.03	0.01	35
35	21	Non ferrous metal	0.01	0.01	34
		Overall	0.13	0.13	

Table 4-18. Direct energy intensities in 1985 and 1995 (modified).

Unit : TOE/฿ 10,000

Rank	Sector	Sector Description	1985	1995 Mod.	Rank
1	28	Gas distribution	1.27	3.14	1
2	14	Oil products	0.81	1.49	2
3	27	Electricity generation, distribution	0.41	0.55	4
4	4	Oil and natural gas	0.16	0.07	10
5	18	Cement	0.14	0.58	3
6	33	Land transport	0.09	0.15	6
7	8	Drink and tobacco	0.08	0.12	7
8	7	Food and allied	0.08	0.06	11
9	17	Bricks and tiles	0.05	0.15	5
10	13	Chemicals and fertilizers	0.04	0.03	14
11	34	Air and water transport	0.04	0.10	8
12	16	Ceramics	0.04	0.08	9
13	21	Non ferrous metal	0.03	0.00	32
14	3	Coal mining	0.02	0.04	12
15	5	Metallic mineral	0.02	0.02	17
16	29	Water supply and sanitation	0.02	0.02	21
17	6	Non-metallic mineral	0.02	0.02	16
18	32	Hotel and restaurant	0.02	0.02	18
19	1	Agricultural, forestry, fishing	0.02	0.03	13
20	19	Building materials, glasses	0.01	0.02	15
21	12	Pulp, paper and printing	0.01	0.02	19
22	20	Iron and steel	0.01	0.01	22
23	15	Rubber and plastics	0.01	0.02	20
24	35	Other services	0.01	0.01	23
25	11	Timber and its product	0.00	0.00	26
26	9	Textile	0.00	0.00	24
27	25	Automobiles, bicycles	0.00	0.00	30
28	30	Construction	0.00	0.00	27
29	10	Leather, etc.	0.00	0.00	31
30	26	Other manufacturing	0.00	0.00	28
31	31	Wholesale and retail	0.00	0.00	25
32	22	Mechanical engineering	0.00	0.00	29
33	24	Ship, train, aircraft	0.00	0.00	33
34	23	Electrical engineering	0.00	0.00	34
35	2	Charcoal and fuel wood	0.00	0.00	35
		Overall	0.04	0.04	

Table 4-19. Total embodied energy (final demand) in 1985 and 1995.

Unit : 1000 TOE

Rank	Sector	Sector Description	1985	1995	Rank
1	33	Land transport	3,750.39	6,764.64	2
2	7	Food and allied	2,787.17	4,762.68	4
3	30	Construction	2,116.28	8,020.59	1
4	14	Oil products	1,402.31	6,561.44	3
5	32	Hotel and restaurant	1,061.60	3,701.91	5
6	35	Other services	930.31	2,242.34	9
7	27	Electricity generation, distribution	923.87	2,875.30	6
8	34	Air and water transport	816.91	2,521.78	8
9	9	Textile	732.69	2,761.83	7
10	8	Drink and tobacco	582.08	1,705.44	11
11	1	Agricultural, forestry, fishing	543.53	1,262.74	14
12	31	Wholesale and retail	461.67	1,754.81	10
13	25	Automobiles, bicycles	210.82	1,310.79	13
14	13	Chemicals and fertilizers	210.78	402.08	20
15	22	Mechanical engineering	196.25	1,033.05	15
16	23	Electrical engineering	136.96	778.37	16
17	26	Other manufacturing	125.48	724.31	18
18	4	Oil and natural gas	110.52	8.81	31
19	15	Rubber and plastics	100.24	772.24	17
20	11	Timber and its product	91.81	358.69	21
21	12	Pulp, paper and printing	70.67	308.54	22
22	10	Leather, etc.	58.80	552.99	19
23	18	Cement	42.94	171.55	23
24	29	Water supply and sanitation	39.83	66.63	27
25	19	Building materials, glasses	36.73	123.65	25
26	24	Ship, train, aircraft	28.06	96.77	26
27	6	Non-metallic mineral	20.82	-25.07	35
28	16	Ceramics	18.85	161.06	24
29	5	Metallic mineral	12.51	1.71	34
30	20	Iron and steel	12.34	59.04	28
31	3	Coal mining	8.41	2.84	32
32	17	Bricks and tiles	5.73	11.81	30
33	2	Charcoal and fuel wood	4.98	2.29	33
34	21	Non ferrous metal	1.80	14.27	29
35	28	Gas distribution	0.09	1,663.40	12
		Grand Total	17,654.22	53,535.35	

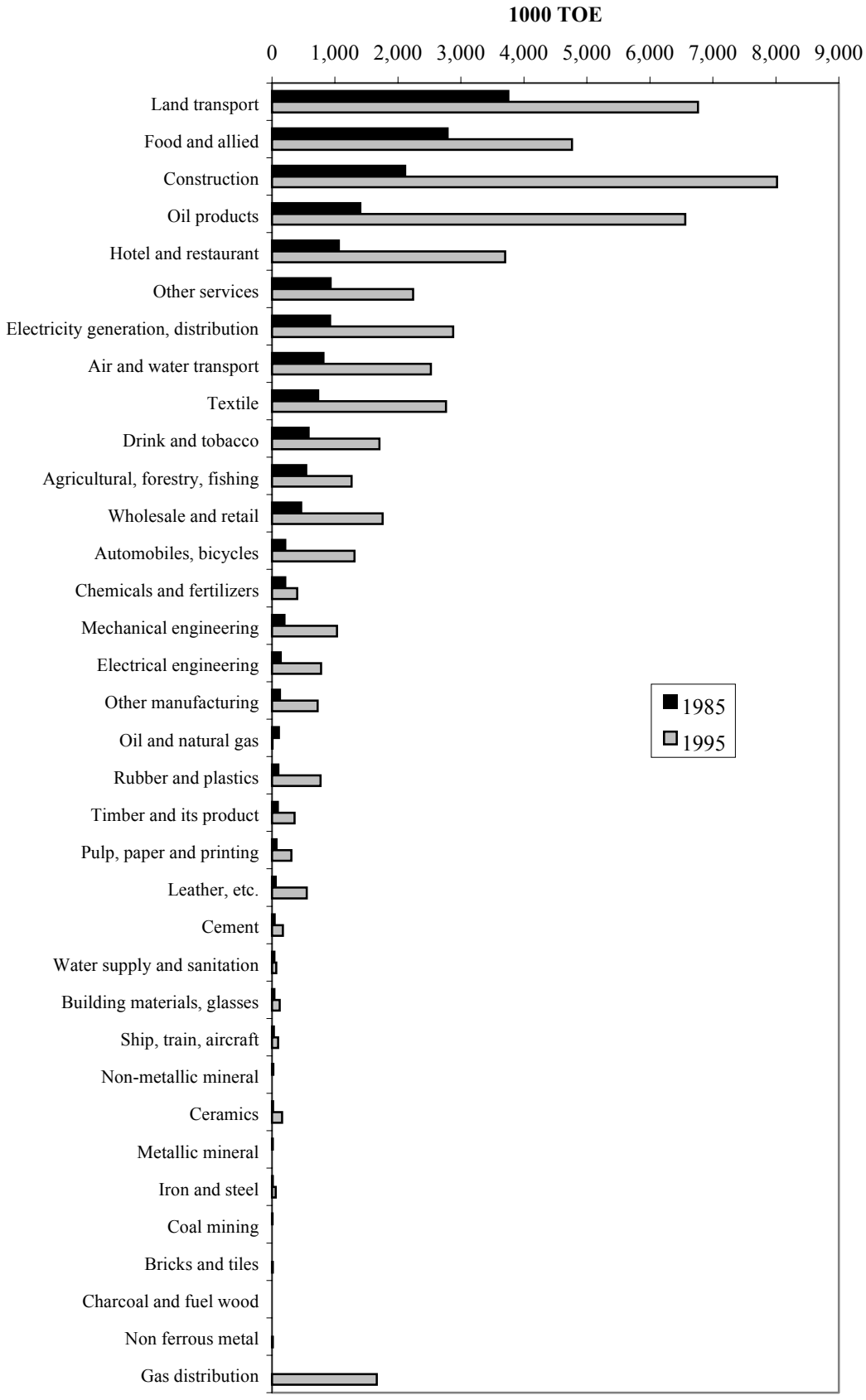

Figure 4-7. Embodied energy (final demand) in 1985 and 1995.

Table 4-20. Direct embodied energy (final demand) in 1985 and 1995.

Unit : 1000 TOE

Rank	Sector	Sector Description	1985	1995	Rank
1	7	Food and allied	1,389.14	1,652.45	3
2	14	Oil products	1,176.74	6,267.75	1
3	33	Land transport	720.28	1,891.35	2
4	27	Electricity generation, distribution	423.35	1,292.60	5
5	8	Drink and tobacco	330.45	1,139.31	6
6	32	Hotel and restaurant	151.33	469.67	8
7	34	Air and water transport	141.25	675.34	7
8	35	Other services	120.16	309.99	9
9	13	Chemicals and fertilizers	107.71	153.58	13
10	4	Crude oil and natural gas	90.95	4.94	29
11	1	Agricultural, forestry, fishing	83.70	289.95	10
12	30	Construction	46.32	179.25	11
13	9	Textile	41.88	124.47	15
14	31	Wholesale and retail	37.86	154.15	12
15	25	Automobiles, bicycles	16.63	69.26	18
16	21	Non ferrous metal	16.16	1.02	31
17	22	Mechanical engineering	14.90	82.79	17
18	15	Rubber and plastics	12.44	140.34	14
19	18	Cement	11.04	115.20	16
20	26	Other manufacturing	8.84	52.05	20
21	12	Pulp, paper and printing	6.82	58.76	19
22	23	Electrical engineering	6.82	16.43	24
23	11	Timber and its product	6.15	18.37	23
24	29	Water supply and sanitation	5.39	8.05	27
25	16	Ceramics	3.32	36.99	21
26	19	Building materials, glasses	3.05	12.25	25
27	10	Leather, etc.	2.78	21.77	22
28	6	Non-metallic mineral	2.76	-4.36	35
29	24	Ship, train, aircraft	2.57	12.03	26
30	20	Iron and steel	2.48	7.54	28
31	5	Metallic mineral	2.00	0.47	33
32	17	Bricks and tiles	1.22	4.06	30
33	3	Coal mining	1.10	0.59	32
34	28	Gas distribution	0.08	1,463.88	4
35	2	Charcoal and fuel wood	0.00	0.00	34
		Overall	4,987.65	16,722.28	

4.4 Embodied Carbon-dioxide in 1985

4.4.1 Total Carbon-dioxide Intensities

Table 4-21 illustrates the total (direct plus indirect) CO_2 intensities (TCO_2 /฿ 10,000) of various economic sectors for the year 1985. The ranked top 10 economic sectors with high total CO_2 emission were gas distribution (4.40), electricity generation, distribution (3.05), oil products (2.79), cement (1.65), land transport (1.35), bricks & tiles, air & water transport, ceramics, oil & natural gas, and food & allied. Meanwhile, the bottom 5 economic sectors with low CO_2 intensities were electrical engineering (0.12), wholesale & retail (0.11), mechanical engineering (0.10), ship & train & aircraft (0.07), and charcoal & fuel wood (0.04), respectively. It is notable that a great majority of the 35 economic sector took responsibility for CO_2 emission indirectly much more than directly in producing a monetary unit of goods and services, as shown in Table 4-22 and Figure 4-8.

4.4.2 Direct Carbon-dioxide Intensities

Table 4-23 represents the ranked sector wise direct CO_2 intensities (TCO_2 /฿ 10,000) of Thai economic sectors. It is notable that 8 of the top 10 economic sectors with high direct CO_2 intensities were among top 10 economic sectors with high total CO_2 intensities. The sectors not included were drink & tobacco and chemicals & fertilizers. Gas distribution (3.67), oil products (2.34), electricity generation & distribution (1.65), and cement (0.47) were top 4 sectors in both direct and total CO_2 intensities rankings. The share of direct CO_2 intensities in 1985 was 29.36 % and the rest 70.64 % was taken by indirect CO_2 intensities.

Table 4-21. Total carbon-dioxide intensities in 1985.

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	4.40
2	27	Electricity generation, distribution	3.05
3	14	Oil products	2.79
4	18	Cement	1.65
5	33	Land transport	1.35
6	17	Bricks and tiles	0.64
7	34	Air and water transport	0.60
8	16	Ceramics	0.58
9	4	Oil and natural gas	0.55
10	7	Food and allied	0.52
11	19	Building materials, glasses	0.50
12	8	Drink and tobacco	0.50
13	30	Construction	0.46
14	3	Coal mining	0.44
15	29	Water supply and sanitation	0.40
16	21	Non ferrous metal	0.39
17	6	Non-metallic mineral	0.39
18	32	Hotel and restaurant	0.37
19	5	Metallic mineral	0.33
20	1	Agricultural, forestry, fishing	0.30
21	13	Chemicals and fertilizers	0.29
22	9	Textile	0.24
23	12	Pulp, paper and printing	0.24
24	20	Iron and steel	0.23
25	11	Timber and its product	0.22
26	10	Leather, etc.	0.19
27	15	Rubber and plastics	0.17
28	25	Automobiles, bicycles	0.16
29	26	Other manufacturing	0.13
30	35	Other services	0.13
31	23	Electrical engineering	0.12
32	31	Wholesale and retail	0.11
33	22	Mechanical engineering	0.10
34	24	Ship, train, aircraft	0.07
35	2	Charcoal and fuel wood	0.04
		Overall	0.40

Table 4-22. Direct and indirect carbon-dioxide intensities in 1985.

Unit : TCO_2/฿ 10,000

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	0.30	0.05	0.25
2	Charcoal and fuel wood	0.04	0.00	0.04
3	Coal mining	0.44	0.06	0.38
4	Oil and natural gas	0.55	0.46	0.09
5	Metallic mineral	0.33	0.05	0.28
6	Non-metallic mineral	0.39	0.04	0.35
7	Food and allied	0.52	0.28	0.24
8	Drink and tobacco	0.50	0.30	0.20
9	Textile	0.24	0.01	0.23
10	Leather, etc.	0.19	0.01	0.18
11	Timber and its product	0.22	0.01	0.21
12	Pulp, paper and printing	0.24	0.02	0.22
13	Chemicals and fertilizers	0.29	0.16	0.13
14	Oil products	2.79	2.34	0.45
15	Rubber and plastics	0.17	0.02	0.15
16	Ceramics	0.58	0.10	0.48
17	Bricks and tiles	0.64	0.14	0.50
18	Cement	1.65	0.47	1.18
19	Building materials, glasses	0.50	0.04	0.46
20	Iron and steel	0.23	0.01	0.22
21	Non ferrous metal	0.39	0.10	0.29
22	Mechanical engineering	0.10	0.01	0.09
23	Electrical engineering	0.12	0.00	0.12
24	Ship, train, aircraft	0.07	0.01	0.06
25	Automobiles, bicycles	0.16	0.01	0.15
26	Other manufacturing	0.13	0.01	0.12
27	Electricity generation, distribution	3.05	1.65	1.40
28	Gas distribution	4.40	3.67	0.73
29	Water supply and sanitation	0.40	0.02	0.38
30	Construction	0.46	0.01	0.45
31	Wholesale and retail	0.11	0.00	0.11
32	Hotel and restaurant	0.37	0.05	0.32
33	Land transport	1.35	0.26	1.09
34	Air and water transport	0.60	0.11	0.49
35	Other services	0.13	0.01	0.12
	Overall	0.40	0.12	0.28
		%	29.36	70.64

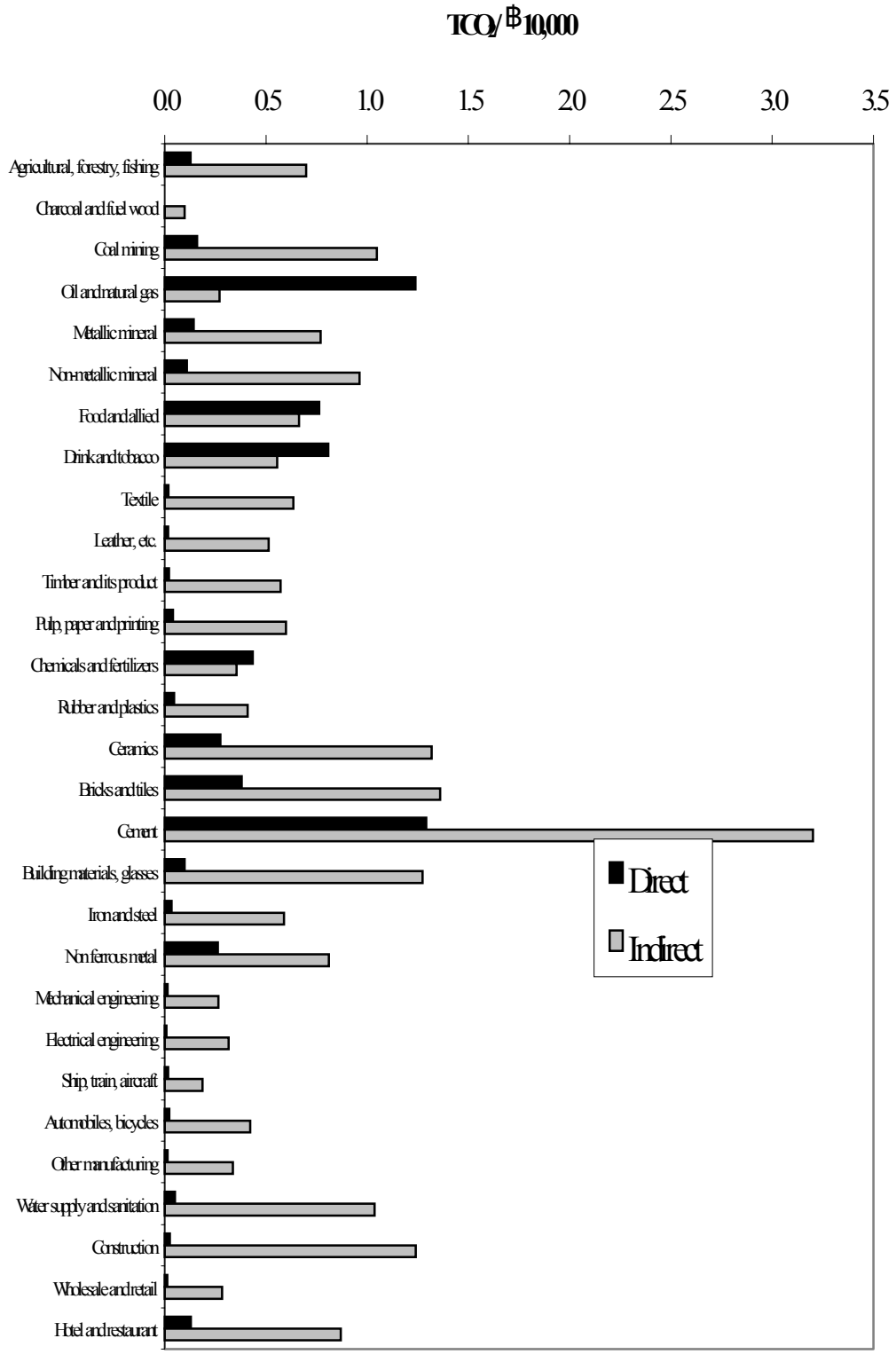

Figure 4-8. Direct and indirect carbon-dioxide intensities in 1985.

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	3.67
2	14	Oil products	2.34
3	27	Electricity generation, distribution	1.65
4	18	Cement	0.47
5	4	Oil and natural gas	0.46
6	8	Drink and tobacco	0.30
7	7	Food and allied	0.28
8	33	Land transport	0.26
9	13	Chemicals and fertilizers	0.16
10	17	Bricks and tiles	0.14
11	34	Air and water transport	0.11
12	16	Ceramics	0.10
13	21	Non ferrous metal	0.10
14	3	Coal mining	0.06
15	5	Metallic mineral	0.05
16	32	Hotel and restaurant	0.05
17	1	Agricultural, forestry, fishing	0.05
18	6	Non-metallic mineral	0.04
19	19	Building materials, glasses	0.04
20	29	Water supply and sanitation	0.02
21	15	Rubber and plastics	0.02
22	12	Pulp, paper and printing	0.02
23	20	Iron and steel	0.01
24	35	Other services	0.01
25	30	Construction	0.01
26	25	Automobiles, bicycles	0.01
27	11	Timber and its product	0.01
28	9	Textile	0.01
29	10	Leather, etc.	0.01
30	24	Ship, train, aircraft	0.01
31	26	Other manufacturing	0.01
32	22	Mechanical engineering	0.01
33	31	Wholesale and retail	0.00
34	23	Electrical engineering	0.00
35	2	Charcoal and fuel wood	0.00
		Overall	0.12

4.4.3 Ratio of Embodied Carbon-dioxide to Embodied Energy (Final Demand)

The ratio of embodied CO_2 to embodied energy (final demand) indicates the amount of CO_2 emitted from an economic sector in the consumption of one unit of energy. The ratio is obtained by dividing the CO_2 intensity by the energy intensity of the same economic sector.

Table 4-24 shows the embodied CO_2 to embodied energy (final demand) ratio (TCO_2/TOE) in ranked sector wise for the year 1985. The top 10 economic sectors with high ratio were drink & tobacco (3.51), electricity generation & distribution (3.45), food & allied (3.32), chemicals & fertilizers, non ferrous metal, hotel & restaurant, cement, charcoal & fuel wood, other services, and bricks & tiles, respectively. The bottom 5 sectors with low ratio were land transport (2.89), ship & train & aircraft (2.89), oil & natural gas (2.89), oil products (2.88), and gas distribution (2.88). It is noticeable that 3 of the top 10 economic sectors with high ratio were among top 10 sectors with high total CO_2 intensities; which were electricity generation & distribution, food & allied, and cement. The overall ratio for the year 1985 was 3.07 TCO_2/TOE.

4.4.4 Embodied Carbon-dioxide (Final Demand)

CO_2 emissions depend on fuel mix ratios and the amount of carbon-intensive fuels being used.

Table 4-25 illustrates total embodied CO_2 in final demand (1000 TCO_2) from various economic sectors in Thailand for the year 1985 (excluding residential sectors). The top 10 economic sectors with high total embodied CO_2 (final demand) were land transport (10,839), food & allied (9,267), construction (6,261), oil products (4,040), hotel & restaurant (3,281) electricity generation & distribution, other services, air & water transport, textile, and drink & tobacco, respectively. At the same time, 5 sectors with the lowest values were metallic mineral (36), coal mining (24), bricks & tiles (17), charcoal & fuel wood (15), gas distribution (0.3), respectively.

Table 4-24. Ratio of embodied carbon-dioxide to embodied energy (final demand) in 1985.

Unit : TCO_2/TOE

Rank	Sector	Sector Description	Ratio
1	8	Drink and tobacco	3.51
2	27	Electricity generation, distribution	3.45
3	7	Food and allied	3.32
4	13	Chemicals and fertilizers	3.32
5	21	Non ferrous metal	3.10
6	32	Hotel and restaurant	3.09
7	18	Cement	3.07
8	2	Charcoal and fuel wood	3.02
9	35	Other services	3.02
10	17	Bricks and tiles	3.02
11	10	Leather, etc.	2.98
12	15	Rubber and plastics	2.97
13	1	Agricultural, forestry, fishing	2.97
14	31	Wholesale and retail	2.97
15	30	Construction	2.96
16	26	Other manufacturing	2.96
17	19	Building materials, glasses	2.95
18	23	Electrical engineering	2.95
19	29	Water supply and sanitation	2.95
20	9	Textile	2.95
21	22	Mechanical engineering	2.94
22	16	Ceramics	2.94
23	11	Timber and its product	2.94
24	25	Automobiles, bicycles	2.93
25	12	Pulp, paper and printing	2.93
26	20	Iron and steel	2.93
27	6	Non-metallic mineral	2.91
28	34	Air and water transport	2.90
29	3	Coal mining	2.90
30	5	Metallic mineral	2.89
31	33	Land transport	2.89
32	24	Ship, train, aircraft	2.89
33	4	Oil and natural gas	2.89
34	14	Oil products	2.88
35	28	Gas distribution	2.88
		Overall	3.07

Table 4-25. Embodied carbon-dioxide (final demand) in 1985.

Unit : 1000 TCO_2

Rank	Sector	Sector Description	Emission
1	33	Land transport	10,838.89
2	7	Food and allied	9,267.12
3	30	Construction	6,260.84
4	14	Oil products	4,040.41
5	32	Hotel and restaurant	3,280.76
6	27	Electricity generation, distribution	3,183.00
7	35	Other services	2,806.60
8	34	Air and water transport	2,372.88
9	9	Textile	2,161.97
10	8	Drink and tobacco	2,042.02
11	1	Agricultural, forestry, fishing	1,614.00
12	31	Wholesale and retail	1,369.87
13	13	Chemicals and fertilizers	700.51
14	25	Automobiles, bicycles	618.63
15	22	Mechanical engineering	577.70
16	23	Electrical engineering	404.58
17	26	Other manufacturing	371.07
18	4	Oil and natural gas	319.18
19	15	Rubber and plastics	298.21
20	11	Timber and its product	269.59
21	21	Non ferrous metal	235.79
22	12	Pulp, paper and printing	207.37
23	10	Leather, etc.	174.96
24	18	Cement	132.03
25	29	Water supply and sanitation	117.62
26	19	Building materials, glasses	108.51
27	24	Ship, train, aircraft	81.05
28	20	Iron and steel	75.94
29	6	Non-metallic mineral	60.62
30	16	Ceramics	55.40
31	5	Metallic mineral	36.16
32	3	Coal mining	24.39
33	17	Bricks and tiles	17.29
34	2	Charcoal and fuel wood	15.02
35	28	Gas distribution	0.26
		Overall	54,140.23

It is notable that the positions of economic sectors in the embodied CO_2 (final demand) ranking were almost same as in the embodied energy (final demand) ranking except for a minor change. This indicated a strong interdependence of embodied energy (final demand) and the corresponding CO_2 in economic sectors. It is also interesting to note that 5 of the top 10 economic sectors with high embodied CO_2 (final demand) were among the top 10 sectors with high total CO_2 intensities in the same year.

The overall embodied CO_2 (final demand) in Thai economy in 1985, excluding residential sector, was 54,140 thousand tonnes. In case of residential sector included, the overall emission was summed to 89,800 thousand tonnes.

4.4.5 Direct Carbon-dioxide Emissions

Table 4-26 and 4-27 exhibit direct and indirect CO_2 emission from various economic sectors for 1985. It is notable that 8 of top 10 sectors with high direct CO_2 emissions were also among top 10 sectors with high total CO_2 emission, except for non ferrous metal and chemicals & fertilizers sectors. It is also noteworthy that as in 1985, most of the 35 economic sectors were responsible for more CO_2 emission indirectly than directly. Indirect emissions shared 71.75 % of total emissions compared to 28.25 % shared by direct emissions.

4.5 Embodied Carbon-dioxide in 1995

4.5.1 Total Carbon-dioxide Intensities

Table 4-28 demonstrates the total CO_2 intensities (TCO_2 /฿ 10,000) of Thai economic sectors for 1995. The top 10 economic sectors with high total CO_2 intensities were gas distribution (6.55), oil products (2.87), electricity generation & distribution (2.65), cement (2.05), land transport (0.99), bricks and tiles, air & water transport, ceramics, building materials & glasses, and drink & tobacco, respectively.

Table 4-26. Direct embodied carbon-dioxide (final demand) in 1985.

Unit : 1000 TCO_2

Rank	Sector	Sector Description	Emission
1	7	Food and allied	4,618.76
2	14	Oil products	3,390.47
3	21	Non ferrous metal	2,122.07
4	33	Land transport	2,081.67
5	27	Electricity generation, distribution	1,458.58
6	8	Drink and tobacco	1,159.28
7	32	Hotel and restaurant	467.66
8	34	Air and water transport	410.28
9	35	Other services	362.52
10	13	Chemicals and fertilizers	357.98
11	4	Oil and natural gas	262.66
12	1	Agricultural, forestry, fishing	248.54
13	30	Construction	137.04
14	9	Textile	123.57
15	31	Wholesale and retail	112.34
16	25	Automobiles, bicycles	48.79
17	22	Mechanical engineering	43.85
18	15	Rubber and plastics	37.00
19	18	Cement	33.93
20	26	Other manufacturing	26.13
21	23	Electrical engineering	20.14
22	12	Pulp, paper and printing	20.01
23	11	Timber and its product	18.07
24	29	Water supply and sanitation	15.90
25	20	Iron and steel	15.28
26	16	Ceramics	9.74
27	19	Building materials, glasses	9.03
28	10	Leather, etc.	8.28
29	6	Non-metallic mineral	8.02
30	24	Ship, train, aircraft	7.44
31	5	Metallic mineral	5.78
32	17	Bricks and tiles	3.67
33	3	Coal mining	3.19
34	28	Gas distribution	0.22
35	2	Charcoal and fuel wood	0.00
		Overall	15,295.63

Table 4-27. Direct and indirect embodied carbon-dioxide (final demand) in 1985.

Unit : 1000 TCO_2

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	1,614.00	248.54	1,365.46
2	Charcoal and fuel wood	15.02	0.00	15.02
3	Coal mining	24.39	3.19	21.20
4	Oil and natural gas	319.18	262.66	56.52
5	Metallic mineral	36.16	5.78	30.38
6	Non-metallic mineral	60.62	8.02	52.60
7	Food and allied	9,267.12	4,618.76	4,648.36
8	Drink and tobacco	2,042.02	1,159.28	882.74
9	Textile	2,161.97	123.57	2,038.40
10	Leather, etc.	174.96	8.28	166.68
11	Timber and its product	269.59	18.07	251.52
12	Pulp, paper and printing	207.37	20.01	187.36
13	Chemicals and fertilizers	700.51	357.98	342.53
14	Oil products	4,040.41	3,390.47	649.94
15	Rubber and plastics	298.21	37.00	261.21
16	Ceramics	55.40	9.74	45.66
17	Bricks and tiles	17.29	3.67	13.62
18	Cement	132.03	33.93	98.10
19	Building materials, glasses	108.51	9.03	99.48
20	Iron and steel	75.94	15.28	60.66
21	Non ferrous metal	235.79	2,122.07	-1,886.28
22	Mechanical engineering	577.70	43.85	533.85
23	Electrical engineering	404.58	20.14	384.44
24	Ship, train, aircraft	81.05	7.44	73.61
25	Automobiles, bicycles	618.63	48.79	569.84
26	Other manufacturing	371.07	26.13	344.94
27	Electricity generation, distribution	3,183.00	1,458.58	1,724.42
28	Gas distribution	0.26	0.22	0.04
29	Water supply and sanitation	117.62	15.90	101.72
30	Construction	6,260.84	137.04	6,123.80
31	Wholesale and retail	1,369.87	112.34	1,257.53
32	Hotel and restaurant	3,280.76	467.66	2,813.10
33	Land transport	10,838.89	2,081.67	8,757.22
34	Air and water transport	2,372.88	410.28	1,962.60
35	Other services	2,806.60	362.52	2,444.08
	Overall	54,140.23	15,295.63	38,844.60
		%	28.25	71.75

Table 4-28. Total carbon-dioxide intensities in 1995.

Unit: TCO_2/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	6.55
2	14	Oil products	2.87
3	27	Electricity generation, distribution	2.65
4	18	Cement	2.05
5	33	Land transport	0.99
6	17	Bricks and tiles	0.90
7	34	Air and water transport	0.69
8	16	Ceramics	0.65
9	19	Building materials, glasses	0.51
10	8	Drink and tobacco	0.41
11	3	Coal mining	0.38
12	7	Food and allied	0.35
13	32	Hotel and restaurant	0.32
14	30	Construction	0.32
15	6	Non-metallic mineral	0.27
16	29	Water supply and sanitation	0.26
17	1	Agricultural, forestry, fishing	0.25
18	12	Pulp, paper and printing	0.22
19	4	Oil and natural gas	0.22
20	9	Textile	0.21
21	15	Rubber and plastics	0.19
22	13	Chemicals and fertilizers	0.14
23	5	Metallic mineral	0.14
24	11	Timber and its product	0.13
25	20	Iron and steel	0.12
26	10	Leather, etc.	0.12
27	25	Automobiles, bicycles	0.09
28	31	Wholesale and retail	0.09
29	35	Other services	0.08
30	26	Other manufacturing	0.07
31	22	Mechanical engineering	0.06
32	23	Electrical engineering	0.05
33	21	Non ferrous metal	0.04
34	2	Charcoal and fuel wood	0.03
35	24	Ship, train, aircraft	0.02
		Overall	0.25

Table 4-29. Direct and indirect carbon-dioxide intensities in 1995.

Unit : TCO_2/฿ 10,000

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	0.25	0.06	0.19
2	Charcoal and fuel wood	0.03	0.00	0.03
3	Coal mining	0.38	0.08	0.30
4	Oil and natural gas	0.22	0.12	0.10
5	Metallic mineral	0.14	0.04	0.10
6	Non-metallic mineral	0.27	0.04	0.23
7	Food and allied	0.35	0.13	0.22
8	Drink and tobacco	0.41	0.29	0.12
9	Textile	0.21	0.01	0.20
10	Leather, etc.	0.12	0.00	0.12
11	Timber and its product	0.13	0.00	0.13
12	Pulp, paper and printing	0.22	0.05	0.17
13	Chemicals and fertilizers	0.14	0.05	0.09
14	Oil products	2.87	2.74	0.13
15	Rubber and plastics	0.19	0.04	0.15
16	Ceramics	0.65	0.16	0.49
17	Bricks and tiles	0.90	0.34	0.56
18	Cement	2.05	1.48	0.57
19	Building materials, glasses	0.51	0.05	0.46
20	Iron and steel	0.12	0.01	0.11
21	Non ferrous metal	0.04	0.00	0.04
22	Mechanical engineering	0.06	0.00	0.06
23	Electrical engineering	0.05	0.00	0.05
24	Ship, train, aircraft	0.02	0.00	0.02
25	Automobiles, bicycles	0.09	0.00	0.09
26	Other manufacturing	0.07	0.01	0.06
27	Electricity generation, distribution	2.65	1.38	1.27
28	Gas distribution	6.55	5.76	0.79
29	Water supply and sanitation	0.26	0.02	0.24
30	Construction	0.32	0.01	0.31
31	Wholesale and retail	0.09	0.01	0.08
32	Hotel and restaurant	0.32	0.04	0.28
33	Land transport	0.99	0.29	0.70
34	Air and water transport	0.69	0.19	0.50
35	Other services	0.08	0.01	0.07
	Overall	0.25	0.08	0.17
		%	31.43	68.57

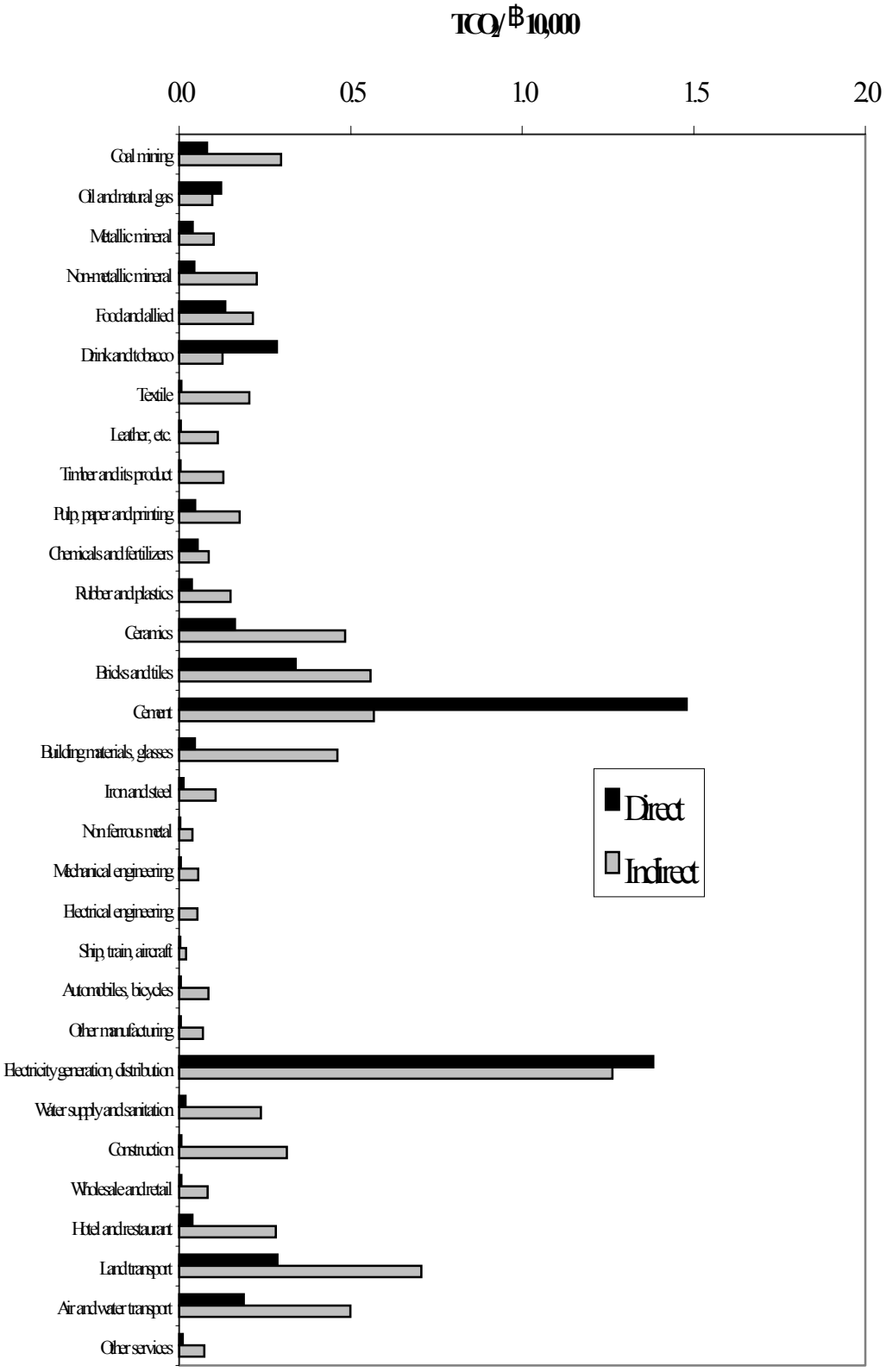

Figure 4-9. Direct and indirect carbon-dioxide intensities in 1995.

On the other hand, the bottom 5 sectors with low intensities were mechanical engineering (0.06), electrical engineering (0.05), non ferrous metal (0.04), charcoal & fuel wood (0.03), and ship & train & aircraft (0.02), respectively. Table 4-29 and Figure 4-9 reveal that a majority of the 35 economic sectors were responsible for indirect embodied CO_2 much more than direct embodied CO_2 in producing their products.

4.5.2 Direct Carbon-dioxide Intensities

Referred to Table 4-29 and Table 4-30, it is noticeable that 9 of the top 10 sectors with high direct CO_2 intensities were among the top 10 sectors with high total CO_2 intensities except food & allied sector. Gas distribution and oil products were in the first and second positions respectively in both intensity rankings. In 1995, the shares of direct and indirect CO_2 intensities were 31.43 % and 68.57 % of total intensities, respectively.

4.5.3 Embodied Carbon-dioxide to Embodied Energy Ratio

Table 4-31 illustrates the embodied CO_2 to embodied energy (final demand) ratio (TCO_2/TOE) for the year 1995. The top 10 economic sectors with high ratio were cement (3.73), drink & tobacco (3.51), pulp & paper & printing (3.46), electricity generation & distribution (3.38), construction (3.26), food & allied, charcoal & fuel wood, building materials & glassed, bricks & tiles, and hotel & restaurant, respectively. It is notable that 5 of the top 10 sectors with high ratio were in the top 10 sectors with high total CO_2 intensities as well. The sectors not included were pulp & paper & printing, construction, food & allied, charcoal & fuel wood, and hotel & restaurant. The overall ratio for the year 1995 was 3.09 TCO_2/TOE.

4.5.4 Embodied Carbon-dioxide (Final Demand)

With reference to Table 4-32, the top 10 economic sectors with high embodied

Table 4-30. Direct carbon-dioxide intensities in 1995.

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	5.76
2	14	Oil products	2.74
3	18	Cement	1.48
4	27	Electricity generation, distribution	1.38
5	17	Bricks and tiles	0.34
6	33	Land transport	0.29
7	8	Drink and tobacco	0.29
8	34	Air and water transport	0.19
9	16	Ceramics	0.16
10	7	Food and allied	0.13
11	4	Oil and natural gas	0.12
12	3	Coal mining	0.08
13	1	Agricultural, forestry, fishing	0.06
14	13	Chemicals and fertilizers	0.05
15	12	Pulp, paper and printing	0.05
16	19	Building materials, glasses	0.05
17	6	Non-metallic mineral	0.04
18	5	Metallic mineral	0.04
19	32	Hotel and restaurant	0.04
20	15	Rubber and plastics	0.04
21	29	Water supply and sanitation	0.02
22	20	Iron and steel	0.01
23	35	Other services	0.01
24	9	Textile	0.01
25	30	Construction	0.01
26	31	Wholesale and retail	0.01
27	26	Other manufacturing	0.01
28	22	Mechanical engineering	0.00
29	10	Leather, etc.	0.00
30	25	Automobiles, bicycles	0.00
31	11	Timber and its product	0.00
32	21	Non ferrous metal	0.00
33	24	Ship, train, aircraft	0.00
34	23	Electrical engineering	0.00
35	2	Charcoal and fuel wood	0.00
		Overall	0.08

Table 4-31. Ratio of embodied carbon-dioxide to embodied energy (final demand) in 1995.

Unit : TCO_2/TOE

Rank	Sector	Sector Description	Ratio
1	18	Cement	3.73
2	8	Drink and tobacco	3.51
3	12	Pulp, paper and printing	3.46
4	27	Electricity generation, distribution	3.38
5	30	Construction	3.26
6	7	Food and allied	3.22
7	2	Charcoal and fuel wood	3.17
8	19	Building materials, glasses	3.15
9	17	Bricks and tiles	3.15
10	32	Hotel and restaurant	3.13
11	13	Chemicals and fertilizers	3.12
12	35	Other services	3.10
13	26	Other manufacturing	3.10
14	9	Textile	3.09
15	29	Water supply and sanitation	3.09
16	16	Ceramics	3.09
17	31	Wholesale and retail	3.08
18	10	Leather, etc.	3.07
19	22	Mechanical engineering	3.06
20	20	Iron and steel	3.05
21	23	Electrical engineering	3.04
22	11	Timber and its product	3.03
23	15	Rubber and plastics	3.02
24	25	Automobiles, bicycles	3.00
25	21	Non ferrous metal	2.98
26	6	Non-metallic mineral	2.97
27	1	Agricultural, forestry, fishing	2.96
28	5	Metallic mineral	2.95
29	24	Ship, train, aircraft	2.95
30	34	Air and water transport	2.94
31	3	Coal mining	2.93
32	33	Land transport	2.92
33	4	Oil and natural gas	2.92
34	14	Oil products	2.88
35	28	Gas distribution	2.88
		Overall	3.09

Table 4-32. Embodied carbon-dioxide (final demand) in 1995.

Unit : 1000 TCO_2

Rank	Sector	Sector Description	Emission
1	30	Construction	26,148.04
2	33	Land transport	19,768.97
3	14	Oil products	18,892.02
4	7	Food and allied	15,356.51
5	32	Hotel and restaurant	11,574.85
6	27	Electricity generation, distribution	9,713.27
7	9	Textile	8,543.72
8	34	Air and water transport	7,407.16
9	35	Other services	6,959.97
10	8	Drink and tobacco	5,989.42
11	31	Wholesale and retail	5,399.60
12	28	Gas distribution	4,787.64
13	25	Automobiles, bicycles	3,933.36
14	1	Agricultural, forestry, fishing	3,734.51
15	22	Mechanical engineering	3,164.04
16	23	Electrical engineering	2,368.52
17	15	Rubber and plastics	2,331.13
18	26	Other manufacturing	2,242.58
19	10	Leather, etc.	1,698.26
20	13	Chemicals and fertilizers	1,252.74
21	11	Timber and its product	1,087.11
22	12	Pulp, paper and printing	1,066.19
23	18	Cement	640.60
24	16	Ceramics	497.88
25	19	Building materials, glasses	389.31
26	24	Ship, train, aircraft	285.14
27	29	Water supply and sanitation	206.08
28	20	Iron and steel	179.83
29	21	Non ferrous metal	42.59
30	17	Bricks and tiles	37.19
31	4	Oil and natural gas	25.72
32	3	Coal mining	8.31
33	2	Charcoal and fuel wood	7.27
34	5	Metallic mineral	5.05
35	6	Non-metallic mineral	-74.48
		Overall	165,670.08

CO_2 emission (1000 TCO_2) in 1995 were construction (26,148), land transport (19,769), oil products (18,892), food and allied (15,357), hotel & restaurant (11,575), electricity generation & distribution, textile, air and water transport, other services, and drink & tobacco, respectively. Similar to the year 1985, it is notable that there was a strong relationship between energy consumption and CO2 emission as the positions of economic sectors in total energy output ranking and CO2 emission ranking were the same. It is interesting to notify that among top 10 sectors with high CO_2 intensities, 5 sectors were also in the top 10 positions with high CO_2 emissions.

The overall total CO_2 emission from Thai economic sectors in 1995 (excluding residential sectors) was 165,670 thousand tonnes. The overall amount including residential sector appeared to be 234,886 thousand tonnes.

4.5.5 Direct Embodied Carbon-dioxide (Final demand)

Table 4-33 and 4-34 show direct and indirect embodied CO_2 in the final demand of 35 economic sectors in 1995. It is noticeable that 8 out of top 10 sectors with high direct embodied CO_2 were among top 10 sectors with high total embodied CO_2. The sectors not included were gas distribution and agriculture, forestry & fishing. It is also interesting to note that in this year a majority of the 35 economic sectors were responsible for much more embodied CO_2 indirectly than directly. The shares of indirect and direct embodied CO_2 were in percentages of 68.76 % and 31.24 %, respectively.

4.5.6 Carbon-dioxide Intensities in 1995 with Modification

Table 4-35 and 4-36 present modified total and direct CO_2 intensities for the year 1995, based on 1985 constant price monetary units. The total and direct intensities of each economic sector were changed accordingly as well as the overall values. However, the position of each sector in the rankings and the shares of direct and indirect CO_2 intensities remained the same.

Table 4-33. Direct embodied carbon-dioxide (final demand) in 1995.

Unit : 1000 TCO_2

Rank	Sector	Sector Description	Emission
1	14	Oil products	18,046.42
2	33	Land transport	5,527.26
3	7	Food and allied	5,328.04
4	27	Electricity generation, distribution	4,366.63
5	28	Gas distribution	4,213.37
6	8	Drink and tobacco	4,001.18
7	34	Air and water transport	1,983.67
8	32	Hotel and restaurant	1,468.51
9	35	Other services	962.16
10	1	Agricultural, forestry, fishing	857.53
11	30	Construction	584.39
12	13	Chemicals and fertilizers	478.51
13	31	Wholesale and retail	474.32
14	18	Cement	430.18
15	15	Rubber and plastics	423.65
16	9	Textile	385.04
17	22	Mechanical engineering	253.56
18	25	Automobiles, bicycles	207.84
19	12	Pulp, paper and printing	203.03
20	26	Other manufacturing	161.16
21	16	Ceramics	114.34
22	10	Leather, etc.	66.87
23	11	Timber and its product	55.67
24	23	Electrical engineering	49.98
25	19	Building materials, glasses	38.57
26	24	Ship, train, aircraft	35.46
27	29	Water supply and sanitation	24.89
28	20	Iron and steel	22.96
29	4	Oil and natural gas	14.40
30	17	Bricks and tiles	12.79
31	21	Non ferrous metal	3.04
32	3	Coal mining	1.74
33	5	Metallic mineral	1.38
34	2	Charcoal and fuel wood	0.00
35	6	Non-metallic mineral	-12.96
		Overall	51,748.63

Table 4-34. Direct and indirect embodied carbon-dioxide (final demand) in 1995.

Unit : 1000 TCO_2

Sector	Sector Description	Total	Direct	Indirect
1	Agricultural, forestry, fishing	3,734.51	857.53	2,876.98
2	Charcoal and fuel wood	7.27	0.00	7.27
3	Coal mining	8.31	1.74	6.57
4	Oil and natural gas	25.72	14.40	11.32
5	Metallic mineral	5.05	1.38	3.67
6	Non-metallic mineral	-74.48	-12.96	-61.52
7	Food and allied	15,356.51	5,328.04	10,028.47
8	Drink and tobacco	5,989.42	4,001.18	1,988.24
9	Textile	8,543.72	385.04	8,158.68
10	Leather, etc.	1,698.26	66.87	1,631.39
11	Timber and its product	1,087.11	55.67	1,031.44
12	Pulp, paper and printing	1,066.19	203.03	863.16
13	Chemicals and fertilizers	1,252.74	478.51	774.23
14	Oil products	18,892.02	18,046.42	845.60
15	Rubber and plastics	2,331.13	423.65	1,907.48
16	Ceramics	497.88	114.34	383.54
17	Bricks and tiles	37.19	12.79	24.40
18	Cement	640.60	430.18	210.42
19	Building materials, glasses	389.31	38.57	350.74
20	Iron and steel	179.83	22.96	156.87
21	Non ferrous metal	42.59	3.04	39.55
22	Mechanical engineering	3,164.04	253.56	2,910.48
23	Electrical engineering	2,368.52	49.98	2,318.54
24	Ship, train, aircraft	285.14	35.46	249.68
25	Automobiles, bicycles	3,933.36	207.84	3,725.52
26	Other manufacturing	2,242.58	161.16	2,081.42
27	Electricity generation, distribution	9,713.27	4,366.63	5,346.64
28	Gas distribution	4,787.64	4,213.37	574.27
29	Water supply and sanitation	206.08	24.89	181.19
30	Construction	26,148.04	584.39	25,563.65
31	Wholesale and retail	5,399.60	474.32	4,925.28
32	Hotel and restaurant	11,574.85	1,468.51	10,106.34
33	Land transport	19,768.97	5,527.26	14,241.71
34	Air and water transport	7,407.16	1,983.67	5,423.49
35	Other services	6,959.97	962.16	5,997.81
	Overall	165,670.08	51,748.63	113,921.45
		%	31.24	68.76

Table 4-35. Total carbon-dioxide intensities in 1995 (modified).

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	10.27
2	14	Oil products	4.50
3	27	Electricity generation, distribution	4.15
4	18	Cement	3.21
5	33	Land transport	1.55
6	17	Bricks and tiles	1.41
7	34	Air and water transport	1.08
8	16	Ceramics	1.01
9	19	Building materials, glasses	0.79
10	8	Drink and tobacco	0.64
11	3	Coal mining	0.59
12	7	Food and allied	0.55
13	32	Hotel and restaurant	0.50
14	30	Construction	0.50
15	6	Non-metallic mineral	0.42
16	29	Water supply and sanitation	0.40
17	1	Agricultural, forestry, fishing	0.38
18	12	Pulp, paper and printing	0.35
19	4	Oil and natural gas	0.34
20	9	Textile	0.33
21	15	Rubber and plastics	0.29
22	13	Chemicals and fertilizers	0.22
23	5	Metallic mineral	0.22
24	11	Timber and its product	0.21
25	20	Iron and steel	0.19
26	10	Leather, etc.	0.18
27	25	Automobiles, bicycles	0.14
28	31	Wholesale and retail	0.14
29	35	Other services	0.13
30	26	Other manufacturing	0.12
31	22	Mechanical engineering	0.09
32	23	Electrical engineering	0.08
33	21	Non ferrous metal	0.07
34	2	Charcoal and fuel wood	0.04
35	24	Ship, train, aircraft	0.04
		Overall	0.40

Table 4-36. Direct carbon-dioxide intensities in 1995 (modified).

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	Intensities
1	28	Gas distribution	9.03
2	14	Oil products	4.30
3	18	Cement	2.32
4	27	Electricity generation, distribution	2.17
5	17	Bricks and tiles	0.53
6	33	Land transport	0.45
7	8	Drink and tobacco	0.45
8	34	Air and water transport	0.30
9	16	Ceramics	0.26
10	7	Food and allied	0.21
11	4	Oil and natural gas	0.19
12	3	Coal mining	0.13
13	1	Agricultural, forestry, fishing	0.09
14	13	Chemicals and fertilizers	0.08
15	12	Pulp, paper and printing	0.07
16	19	Building materials, glasses	0.07
17	6	Non-metallic mineral	0.07
18	5	Metallic mineral	0.06
19	32	Hotel and restaurant	0.06
20	15	Rubber and plastics	0.06
21	29	Water supply and sanitation	0.03
22	20	Iron and steel	0.02
23	35	Other services	0.02
24	9	Textile	0.01
25	30	Construction	0.01
26	31	Wholesale and retail	0.01
27	26	Other manufacturing	0.01
28	22	Mechanical engineering	0.01
29	10	Leather, etc.	0.01
30	25	Automobiles, bicycles	0.01
31	11	Timber and its product	0.01
32	21	Non ferrous metal	0.00
33	24	Ship, train, aircraft	0.00
34	23	Electrical engineering	0.00
35	2	Charcoal and fuel wood	0.00
		Overall	0.12

4.6 Comparison of Embodied Carbon-dioxide between 1985 and 1995

4.6.1 Total Carbon-dioxide Intensities

Table 4-37 and Figure 4-10 illustrate the comparison of total CO_2 intensities of 35 economic sectors for 1985 and 1995. It is clearly noticeable that 8 of the top 10 sectors with high total CO_2 intensities in 1995 were among top 10 sectors of the same in 1985. The economic sectors not included were oil & natural gas and food & allied. Oil & natural gas and non ferrous metal sectors that ranked 9th and 16th in1985 fell to 19th and 33rd position in 1995 with large reduction in their total CO_2 intensities.

Although there was a decrease in overall total CO_2 intensities as well as intensities of many economic sectors, increase for some sectors such as gas distribution, cement, and bricks & tiles is clearly notable in 1995. The main cause was the substantial increase in direct CO_2 intensities in these sectors. Among the sectors with increased total CO_2 in 1995 compared to 1985, the increase of gas distribution sector is quite remarkable and it's total intensity ranked the first for both years.

4.6.2 Direct Carbon-dioxide Intensities

With reference to Table 4-38 and Figure 4-11, it can be pointed out that among top 10 economic sectors with high direct CO_2 intensities in 1985, 7 sectors were in top 10 positions in 1995. While some sectors such as oil & natural gas, chemicals & fertilizers, and non ferrous metal had a substantial reduction in their direct CO_2 intensities.

A decrease in overall direct intensities as well as in direct intensities of many sectors can be observed, however, an increase in some sectors is noticeable such as gas distribution, cement and bricks & tiles. Gas distribution ranked in the first position for both years with a remarkable increase of direct CO_2 intensity as well as

Table 4-37. Total carbon-dioxide intensities in 1985 and 1995.

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	1985	1995	Rank
1	28	Gas distribution	4.40	6.55	1
2	27	Electricity generation, distribution	3.05	2.65	3
3	14	Oil products	2.79	2.87	2
4	18	Cement	1.65	2.05	4
5	33	Land transport	1.35	0.99	5
6	17	Bricks and tiles	0.64	0.90	6
7	34	Air and water transport	0.60	0.69	7
8	16	Ceramics	0.58	0.65	8
9	4	Oil and natural gas	0.55	0.22	19
10	7	Food and allied	0.52	0.35	12
11	19	Building materials, glasses	0.50	0.51	9
12	8	Drink and tobacco	0.50	0.41	10
13	30	Construction	0.46	0.32	14
14	3	Coal mining	0.44	0.38	11
15	29	Water supply and sanitation	0.40	0.26	16
16	21	Non ferrous metal	0.39	0.04	33
17	6	Non-metallic mineral	0.39	0.27	15
18	32	Hotel and restaurant	0.37	0.32	13
19	5	Metallic mineral	0.33	0.14	23
20	1	Agricultural, forestry, fishing	0.30	0.25	17
21	13	Chemicals and fertilizers	0.29	0.14	22
22	9	Textile	0.24	0.21	20
23	12	Pulp, paper and printing	0.24	0.22	18
24	20	Iron and steel	0.23	0.12	25
25	11	Timber and its product	0.22	0.13	24
26	10	Leather, etc.	0.19	0.12	26
27	15	Rubber and plastics	0.17	0.19	21
28	25	Automobiles, bicycles	0.16	0.09	27
29	26	Other manufacturing	0.13	0.07	30
30	35	Other services	0.13	0.08	29
31	23	Electrical engineering	0.12	0.05	32
32	31	Wholesale and retail	0.11	0.09	28
33	22	Mechanical engineering	0.10	0.06	31
34	24	Ship, train, aircraft	0.07	0.02	35
35	2	Charcoal and fuel wood	0.04	0.03	34
		Overall	0.40	0.25	

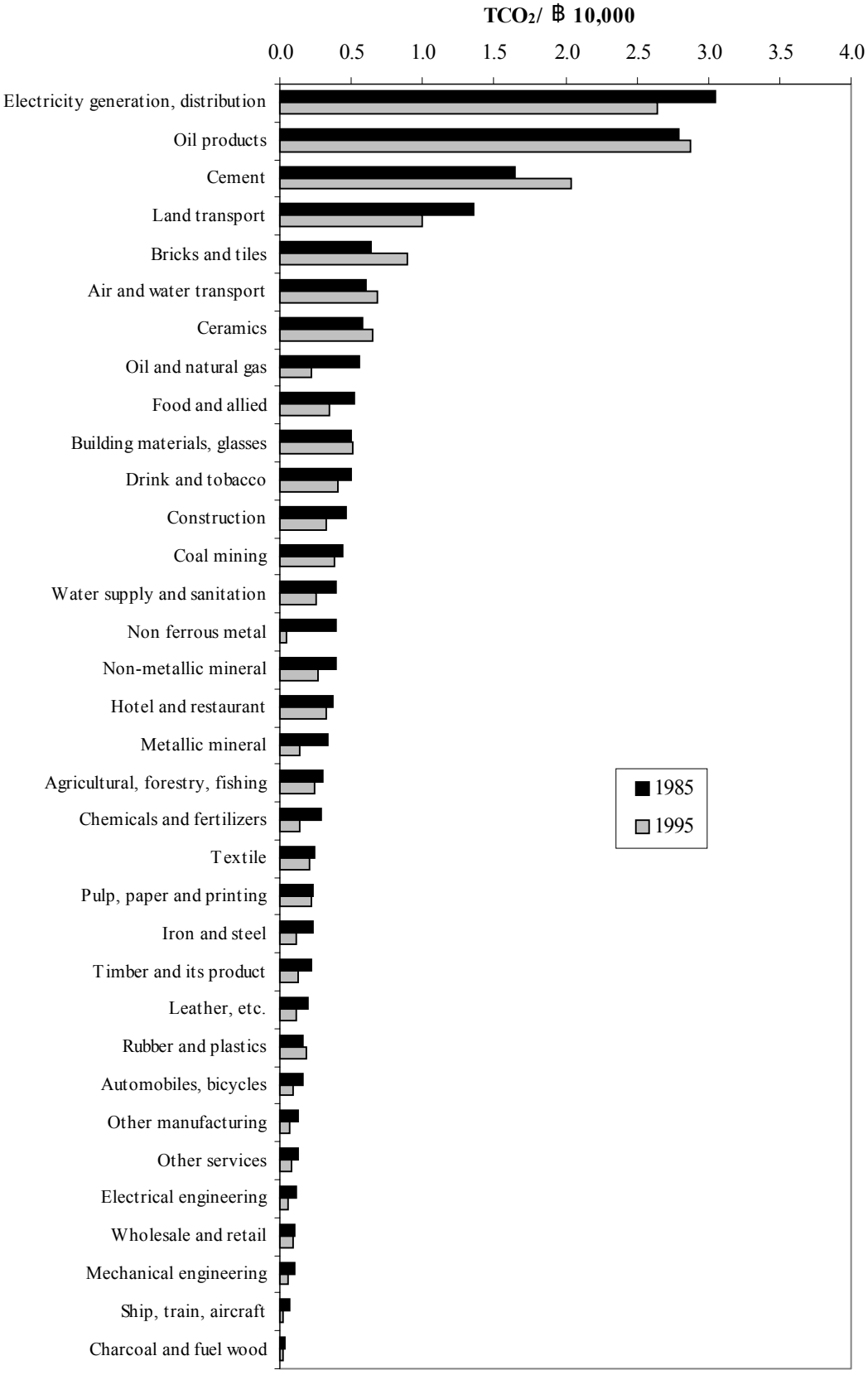

Figure 4-10. Total cabon-dioxide intensities in 1985 and 1995.

Table 4-38. Direct carbon-dioxide intensities in 1985 and 1995.

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	1985	1995	Rank
1	28	Gas distribution	3.67	5.76	1
2	14	Oil products	2.34	2.74	2
3	27	Electricity generation, distribution	1.65	1.38	4
4	18	Cement	0.47	1.48	3
5	4	Oil and natural gas	0.46	0.12	11
6	8	Drink and tobacco	0.30	0.29	7
7	7	Food and allied	0.28	0.13	10
8	33	Land transport	0.26	0.29	6
9	13	Chemicals and fertilizers	0.16	0.05	14
10	17	Bricks and tiles	0.14	0.34	5
11	34	Air and water transport	0.11	0.19	8
12	16	Ceramics	0.10	0.16	9
13	21	Non ferrous metal	0.10	0.00	32
14	3	Coal mining	0.06	0.08	12
15	5	Metallic mineral	0.05	0.04	18
16	32	Hotel and restaurant	0.05	0.04	19
17	1	Agricultural, forestry, fishing	0.05	0.06	13
18	6	Non-metallic mineral	0.04	0.04	17
19	19	Building materials, glasses	0.04	0.05	16
20	29	Water supply and sanitation	0.02	0.02	21
21	15	Rubber and plastics	0.02	0.04	20
22	12	Pulp, paper and printing	0.02	0.05	15
23	20	Iron and steel	0.01	0.01	22
24	35	Other services	0.01	0.01	23
25	30	Construction	0.01	0.01	25
26	25	Automobiles, bicycles	0.01	0.00	30
27	11	Timber and its product	0.01	0.00	31
28	9	Textile	0.01	0.01	24
29	10	Leather, etc.	0.01	0.00	29
30	24	Ship, train, aircraft	0.01	0.00	33
31	26	Other manufacturing	0.01	0.01	27
32	22	Mechanical engineering	0.01	0.00	28
33	31	Wholesale and retail	0.00	0.01	26
34	23	Electrical engineering	0.00	0.00	34
35	2	Charcoal and fuel wood	0.00	0.00	35
		Overall	0.12	0.08	

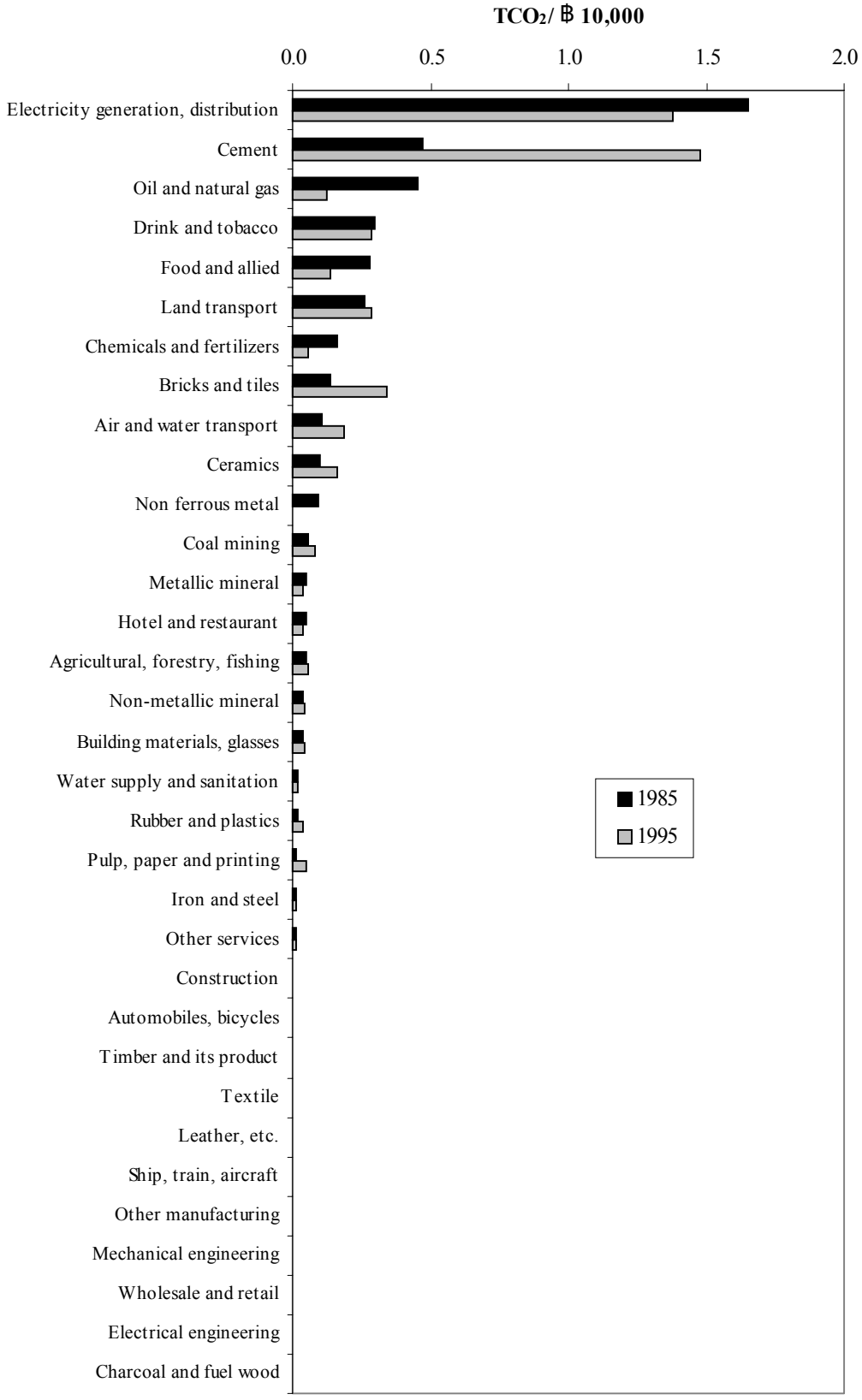

Figure 4-11. Direct carbon-dioxide intensities in 1985 and 1995.

total CO_2 intensity. At the same time, it is worthy to note that although the share of direct CO_2 intensities increased in 1995 compared to 1985, the overall indirect intensities had still a large share in 1995 (68.57 %) as in 1985 (70.64 %).

4.6.3 Ratio of Embodied Carbon-dioxide to Embodied Energy (Final Demand)

Due to increased used of carbon-intensive fuels (including bio-mass fuels) in economic sectors, the overall embodied carbon-dioxide to embodied energy (final demand) ratio increased from 3.07 TCO_2/TOE in 1985 to 3.09 TCO_2/TOE in 1995 as well as the ratios for many economic sectors, as shown in Table 4-41 and Figure 4-12. This was the reflection of changes in their fuel mix ratios or embodied CO_2 to embodied energy (final demand) ratios in those sectors.

4.6.4 Embodied Carbon-dioxide (Final Demand)

Table 4-42 and Figure 4-13 illustrate embodied CO_2 (final demand) for the year 1985 and 1995. The overall embodied CO_2 as well as embodied CO_2 in almost all economic sectors enormously increased in 1995 compared to 1985 due to economic growth in the ten-year period. However, their were some sectors with decreased embodied CO_2 such as non ferrous metal, oil & natural gas, coal mining, charcoal and fuel wood, metallic mineral, and non-metallic mineral. It is interesting to note that the top 10 sectors with high embodied CO_2 were exactly the same in both years with a slight change in ranking. Apart from an increase in energy consumption, changing in fuel mix ratios in economic sectors that increased embodied CO_2 to embodied energy ratios, as mentioned early, had an important role in inducing greater embodied CO_2 in the economy.

Table 4-39. Total carbon-dioxide intensities in 1985 and 1995 (modified).

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	1985	1995 Mod.	Rank
1	28	Gas distribution	4.40	10.27	1
2	27	Electricity generation, distribution	3.05	4.15	3
3	14	Oil products	2.79	4.50	2
4	18	Cement	1.65	3.21	4
5	33	Land transport	1.35	1.55	5
6	17	Bricks and tiles	0.64	1.41	6
7	34	Air and water transport	0.60	1.08	7
8	16	Ceramics	0.58	1.01	8
9	4	Oil and natural gas	0.55	0.34	19
10	7	Food and allied	0.52	0.55	12
11	19	Building materials, glasses	0.50	0.79	9
12	8	Drink and tobacco	0.50	0.64	10
13	30	Construction	0.46	0.50	14
14	3	Coal mining	0.44	0.59	11
15	29	Water supply and sanitation	0.40	0.40	16
16	21	Non ferrous metal	0.39	0.07	33
17	6	Non-metallic mineral	0.39	0.42	15
18	32	Hotel and restaurant	0.37	0.50	13
19	5	Metallic mineral	0.33	0.22	23
20	1	Agricultural, forestry, fishing	0.30	0.38	17
21	13	Chemicals and fertilizers	0.29	0.22	22
22	9	Textile	0.24	0.33	20
23	12	Pulp, paper and printing	0.24	0.35	18
24	20	Iron and steel	0.23	0.19	25
25	11	Timber and its product	0.22	0.21	24
26	10	Leather, etc.	0.19	0.18	26
27	15	Rubber and plastics	0.17	0.29	21
28	25	Automobiles, bicycles	0.16	0.14	27
29	26	Other manufacturing	0.13	0.12	30
30	35	Other services	0.13	0.13	29
31	23	Electrical engineering	0.12	0.08	32
32	31	Wholesale and retail	0.11	0.14	28
33	22	Mechanical engineering	0.10	0.09	31
34	24	Ship, train, aircraft	0.07	0.04	35
35	2	Charcoal and fuel wood	0.04	0.04	34
		Overall	0.40	0.40	

Table 4-40. Direct carbon-dioxide intensities in 1985 and 1995 (modified).

Unit : TCO_2/฿ 10,000

Rank	Sector	Sector Description	1985	1995 Mod.	Rank
1	28	Gas distribution	3.67	9.03	1
2	14	Oil products	2.34	4.30	2
3	27	Electricity generation, distribution	1.65	2.17	4
4	18	Cement	0.47	2.32	3
5	4	Oil and natural gas	0.46	0.19	11
6	8	Drink and tobacco	0.30	0.45	7
7	7	Food and allied	0.28	0.21	10
8	33	Land transport	0.26	0.45	6
9	13	Chemicals and fertilizers	0.16	0.08	14
10	17	Bricks and tiles	0.14	0.53	5
11	34	Air and water transport	0.11	0.30	8
12	16	Ceramics	0.10	0.26	9
13	21	Non ferrous metal	0.10	0.00	32
14	3	Coal mining	0.06	0.13	12
15	5	Metallic mineral	0.05	0.06	18
16	32	Hotel and restaurant	0.05	0.06	19
17	1	Agricultural, forestry, fishing	0.05	0.09	13
18	6	Non-metallic mineral	0.04	0.07	17
19	19	Building materials, glasses	0.04	0.07	16
20	29	Water supply and sanitation	0.02	0.03	21
21	15	Rubber and plastics	0.02	0.06	20
22	12	Pulp, paper and printing	0.02	0.07	15
23	20	Iron and steel	0.01	0.02	22
24	35	Other services	0.01	0.02	23
25	30	Construction	0.01	0.01	25
26	25	Automobiles, bicycles	0.01	0.01	30
27	11	Timber and its product	0.01	0.01	31
28	9	Textile	0.01	0.01	24
29	10	Leather, etc.	0.01	0.01	29
30	24	Ship, train, aircraft	0.01	0.00	33
31	26	Other manufacturing	0.01	0.01	27
32	22	Mechanical engineering	0.01	0.01	28
33	31	Wholesale and retail	0.00	0.01	26
34	23	Electrical engineering	0.00	0.00	34
35	2	Charcoal and fuel wood	0.00	0.00	35
		Overall	0.12	0.12	

Table 4-41. Embodied carbon dioxide to embodied energy (final demand) ratio in 1985 and 1995.

Unit : TCO_2/TOE

Rank	Sector	Sector Description	1985	1995	Rank
1	8	Drink and tobacco	3.51	3.51	2
2	27	Electricity generation, distribution	3.45	3.38	4
3	7	Food and allied	3.32	3.22	6
4	13	Chemicals and fertilizers	3.32	3.12	11
5	21	Non ferrous metal	3.10	2.98	25
6	32	Hotel and restaurant	3.09	3.13	10
7	18	Cement	3.07	3.73	1
8	2	Charcoal and fuel wood	3.02	3.17	7
9	35	Other services	3.02	3.10	12
10	17	Bricks and tiles	3.02	3.15	9
11	10	Leather, etc.	2.98	3.07	18
12	15	Rubber and plastics	2.97	3.02	23
13	1	Agricultural, forestry, fishing	2.97	2.96	27
14	31	Wholesale and retail	2.97	3.08	17
15	30	Construction	2.96	3.26	5
16	26	Other manufacturing	2.96	3.10	13
17	19	Building materials, glasses	2.95	3.15	8
18	23	Electrical engineering	2.95	3.04	21
19	29	Water supply and sanitation	2.95	3.09	15
20	9	Textile	2.95	3.09	14
21	22	Mechanical engineering	2.94	3.06	19
22	16	Ceramics	2.94	3.09	16
23	11	Timber and its product	2.94	3.03	22
24	25	Automobiles, bicycles	2.93	3.00	24
25	12	Pulp, paper and printing	2.93	3.46	3
26	20	Iron and steel	2.93	3.05	20
27	6	Non-metallic mineral	2.91	2.97	26
28	34	Air and water transport	2.90	2.94	30
29	3	Coal mining	2.90	2.93	31
30	5	Metallic mineral	2.89	2.95	28
31	33	Land transport	2.89	2.92	32
32	24	Ship, train, aircraft	2.89	2.95	29
33	4	Oil and natural gas	2.89	2.92	33
34	14	Oil products	2.88	2.88	34
35	28	Gas distribution	2.88	2.88	35
		Overall	3.07	3.09	

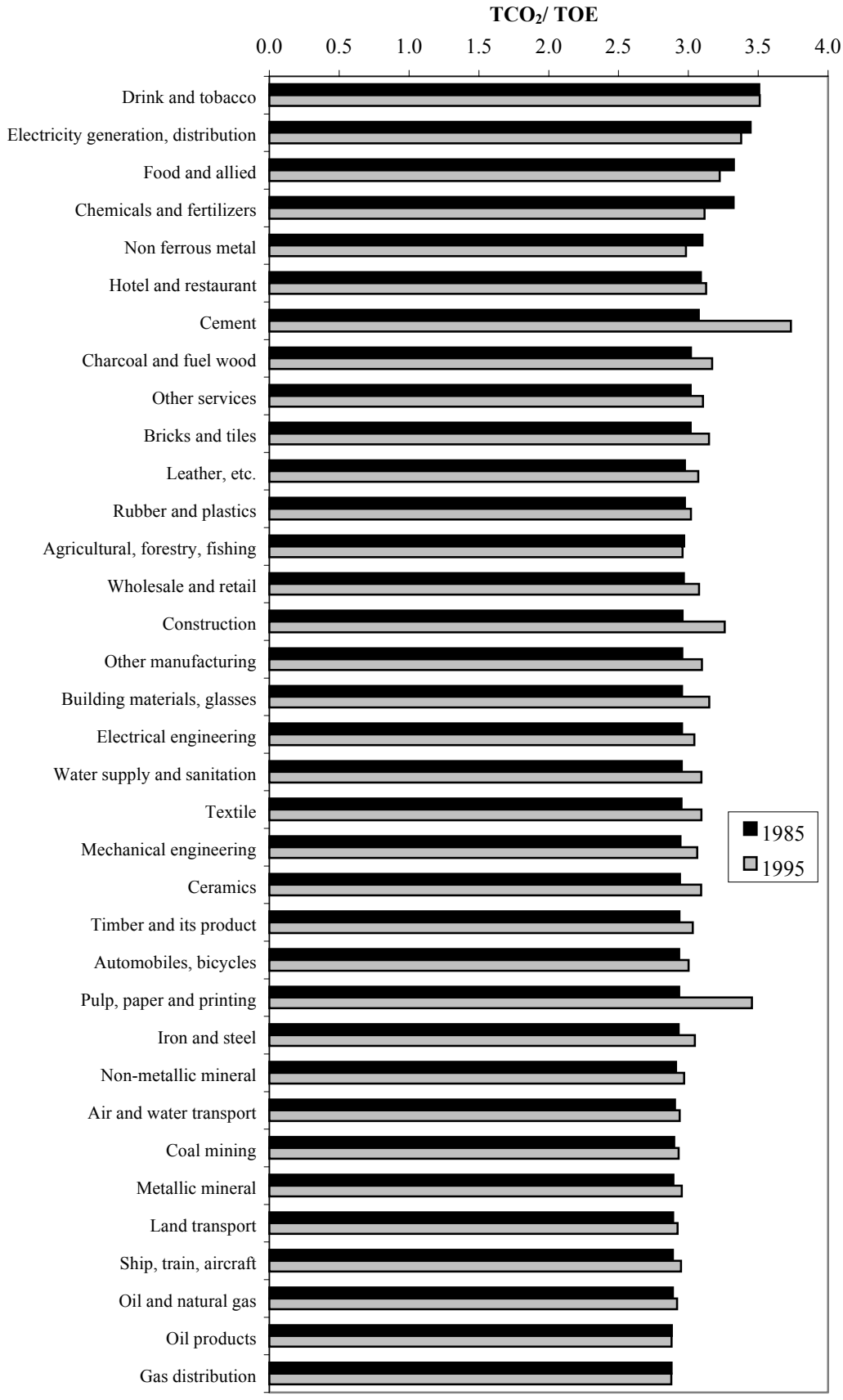

Figure 4-12. Embodied carbon-dioxide to embodied energy (final demand) ratio in 1985 and 1995.

Table 4-42. Embodied carbon-dioxide (final demand) in 1985 and 1995.

Unit : 1000 TCO_2

Rank	Sector	Sector Description	1985	1995	Rank
1	33	Land transport	10,838.89	19,768.97	2
2	7	Food and allied	9,267.12	15,356.51	4
3	30	Construction	6,260.84	26,148.04	1
4	14	Oil products	4,040.41	18,892.02	3
5	32	Hotel and restaurant	3,280.76	11,574.85	5
6	27	Electricity generation, distribution	3,183.00	9,713.27	6
7	35	Other services	2,806.60	6,959.97	9
8	34	Air and water transport	2,372.88	7,407.16	8
9	9	Textile	2,161.97	8,543.72	7
10	8	Drink and tobacco	2,042.02	5,989.42	10
11	1	Agricultural, forestry, fishing	1,614.00	3,734.51	14
12	31	Wholesale and retail	1,369.87	5,399.60	11
13	13	Chemicals and fertilizers	700.51	1,252.74	20
14	25	Automobiles, bicycles	618.63	3,933.36	13
15	22	Mechanical engineering	577.70	3,164.04	15
16	23	Electrical engineering	404.58	2,368.52	16
17	26	Other manufacturing	371.07	2,242.58	18
18	4	Oil and natural gas	319.18	25.72	31
19	15	Rubber and plastics	298.21	2,331.13	17
20	11	Timber and its product	269.59	1,087.11	21
21	21	Non ferrous metal	235.79	42.59	29
22	12	Pulp, paper and printing	207.37	1,066.19	22
23	10	Leather, etc.	174.96	1,698.26	19
24	18	Cement	132.03	640.60	23
25	29	Water supply and sanitation	117.62	206.08	27
26	19	Building materials, glasses	108.51	389.31	25
27	24	Ship, train, aircraft	81.05	285.14	26
28	20	Iron and steel	75.94	179.83	28
29	6	Non-metallic mineral	60.62	-74.48	35
30	16	Ceramics	55.40	497.88	24
31	5	Metallic mineral	36.16	5.05	34
32	3	Coal mining	24.39	8.31	32
33	17	Bricks and tiles	17.29	37.19	30
34	2	Charcoal and fuel wood	15.02	7.27	33
35	28	Gas distribution	0.26	4,787.64	12
		Overall	54,140.23	165,670.08	

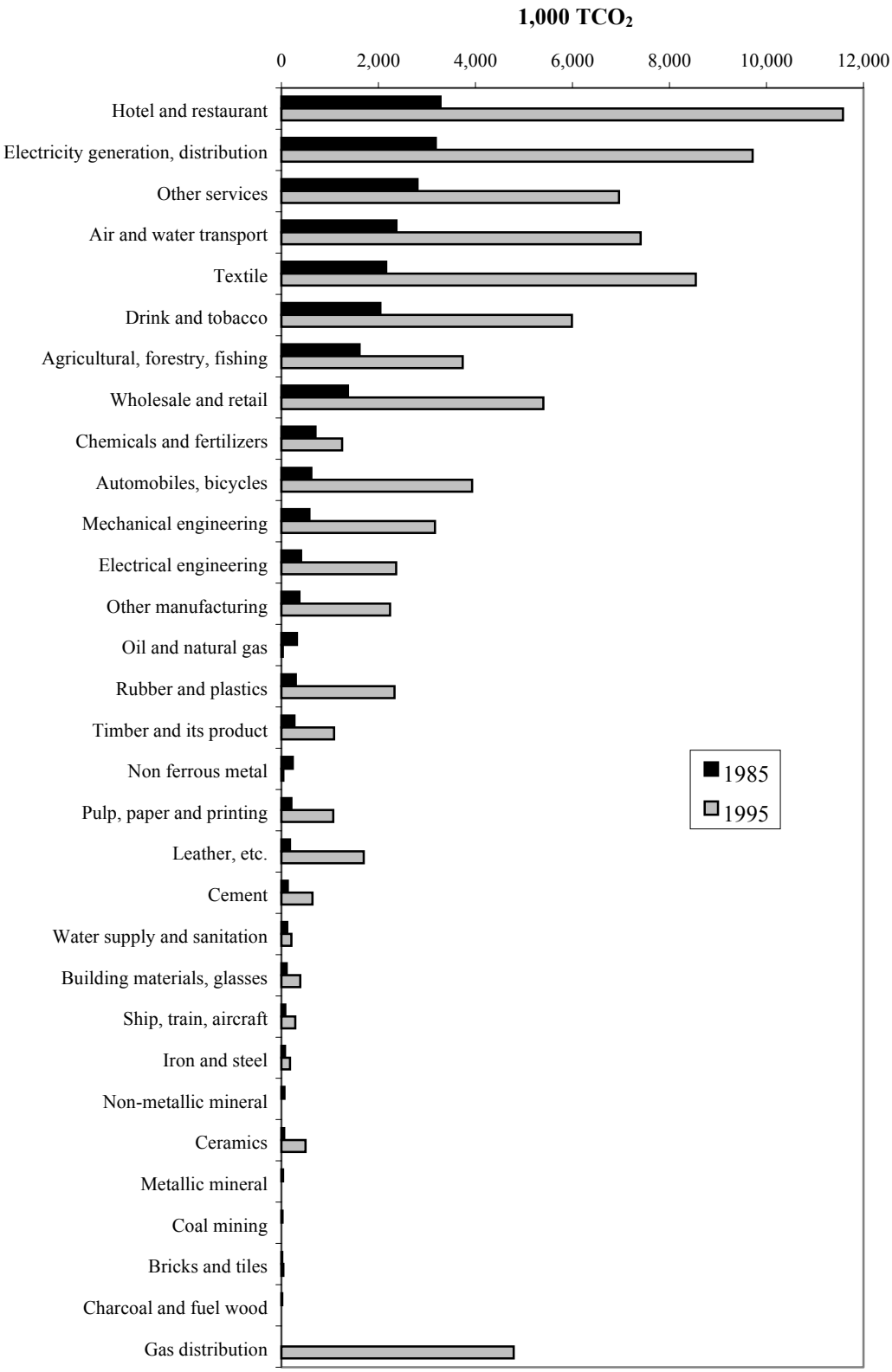

Figure 4-13. Embodied carbon-dioxide (final demand) in 1985 and 1995.

4.6.5 Direct Embodied Carbon-dioxide (Final Demand)

With reference to Table 4-43, it is notable that 8 of the top 10 economic sectors with high direct embodied CO_2 (final demand) in 1995 were among top 10 sectors with the same in 1985. The sectors not included were gas distribution and agriculture & forestry & fishing. Gas distribution sector that ranked 34th in 1985 jumped up to 5th position in 1995 with a large increase in direct embodied CO_2 (final demand). It is also worthy to note that although the share of overall direct embodied CO_2 (final demand) increased in 1995 (31.24 %) compared to 1985 (28.25 %), overall indirect embodied CO_2 (final demand) still had a large share in 1995 (68.76 %). This indicated a strong economic and environmental interdependence among various economic sectors of the country.

Table 4-43. Direct embodied carbon-dioxide (final demand) in 1985 and 1995.

Unit : 1000 TCO_2

Rank	Sector	Sector Description	1985	1995	Rank
1	7	Food and allied	4,618.76	5,328.04	3
2	14	Oil products	3,390.47	18,046.42	1
3	21	Non ferrous metal	2,122.07	3.04	31
4	33	Land transport	2,081.67	5,527.26	2
5	27	Electricity generation, distribution	1,458.58	4,366.63	4
6	8	Drink and tobacco	1,159.28	4,001.18	6
7	32	Hotel and restaurant	467.66	1,468.51	8
8	34	Air and water transport	410.28	1,983.67	7
9	35	Other services	362.52	962.16	9
10	13	Chemicals and fertilizers	357.98	478.51	12
11	4	Oil and natural gas	262.66	14.40	29
12	1	Agricultural, forestry, fishing	248.54	857.53	10
13	30	Construction	137.04	584.39	11
14	9	Textile	123.57	385.04	16
15	31	Wholesale and retail	112.34	474.32	13
16	25	Automobiles, bicycles	48.79	207.84	18
17	22	Mechanical engineering	43.85	253.56	17
18	15	Rubber and plastics	37.00	423.65	15
19	18	Cement	33.93	430.18	14
20	26	Other manufacturing	26.13	161.16	20
21	23	Electrical engineering	20.14	49.98	24
22	12	Pulp, paper and printing	20.01	203.03	19
23	11	Timber and its product	18.07	55.67	23
24	29	Water supply and sanitation	15.90	24.89	27
25	20	Iron and steel	15.28	22.96	28
26	16	Ceramics	9.74	114.34	21
27	19	Building materials, glasses	9.03	38.57	25
28	10	Leather, etc.	8.28	66.87	22
29	6	Non-metallic mineral	8.02	-12.96	35
30	24	Ship, train, aircraft	7.44	35.46	26
31	5	Metallic mineral	5.78	1.38	33
32	17	Bricks and tiles	3.67	12.79	30
33	3	Coal mining	3.19	1.74	32
34	28	Gas distribution	0.22	4,213.37	5
35	2	Charcoal and fuel wood	0.00	0.00	34
		Overall	15,295.63	51,748.63	

4.7 Comparison between Thailand and other Countries for Energy and CO_2

4.7.1 Energy and Corresponding Carbon-dioxide Intensities

Tiwaree and Imura (1994) applied an input-output model to analyze the energy consumption and corresponding CO_2 emission in countries within the Asia-Pacific region and the United States of America for the year 1985. Here, the comparable results from Indonesia, China, Japan and USA for total energy and CO_2 intensities are extracted and compared with those of Thailand for the same year, as shown in Tables 4-44 and 4-45, respectively. The data for Thailand were converted into US$ using the conversion factors of 27.21 ฿/US$ in 1985 and 24.94 ฿/US$ in 1995 (Bank of Thailand, 1996).

Table 4-44.Comparison of total energy intensities between different countries in 1985.

Unit : TOE/US$ 1000

Sectors	Thailand	Indonesia *	China *	Japan *	USA *
Oil products	2.64	2.68	14.26	3.73	5.21
Electricity generation, distribution	2.41	7.33	11.52	1.13	2.42
Land transport	1.27	0.25	1.72	0.18	0.3
Food and allied	0.43	0.1	0.69	0.16	0.33
Construction	0.43	0.21	3.02	0.43	0.43
Coal mining	0.42	0.46	40.74	10.32	12.71
Non-metallic mineral	0.37	0.64	4.9	1.33	1.39
Non ferrous metal	0.35	0.57	4.88	0.41	0.77
Agricultural, forestry, fishing	0.28	0.12	0.59	0.2	0.49
Chemicals and fertilizers	0.24	0.73	3.86	0.45	1.15
Textile	0.22	0.23	1.12	0.2	0.39
Pulp, paper and printing	0.22	0.37	1.5	0.24	0.36
Rubber and plastics	0.15	0.26	1.25	0.24	0.47
Other services	0.11	0.13	1.1	0.11	0.1
Mechanical engineering	0.09	0.12	2.01	0.19	0.24
Overall	0.36	0.38	1.96	0.25	0.42

* Source: Tiwaree and Imura (1994).

Table 4-45. Comparison of total CO_2 intensities between different countries in 1985.

Unit : TCO_2/US$ 1000

Sector Description	Thailand	Indonesia *	China *	Japan *	USA *
Electricity generation, distribution	8.31	18.18	33.51	1.36	5.35
Oil products	7.60	7.37	42.49	10.52	13.67
Land transport	3.69	0.70	5.46	0.48	0.77
Food and allied	1.43	0.26	2.27	0.40	0.88
Construction	1.26	0.59	10.26	1.32	1.32
Coal mining	1.21	1.47	147.78	37.14	45.93
Non-metallic mineral	1.07	1.72	15.95	4.40	4.58
Non ferrous metal	1.07	1.54	16.75	1.06	2.42
Agricultural, forestry, fishing	0.83	0.33	1.91	0.53	1.32
Chemicals and fertilizers	0.79	1.98	12.79	1.14	3.30
Textile	0.65	0.62	3.67	0.48	1.06
Pulp, paper and printing	0.64	0.99	4.95	0.59	0.99
Rubber and plastics	0.46	0.70	4.11	0.59	1.28
Other services	0.34	0.33	3.63	0.26	0.26
Mechanical engineering	0.28	0.29	6.67	0.48	0.70
Overall	1.09	0.99	6.60	0.66	1.10

* Source: Tiwaree and Imura (1994).

From the Table 4-44, it is notable that the energy intensities have differed largely when compared among the same sectors of different countries. The energy intensity of a sector in a county depends on its own industrial structure, efficiency of the sector's energy related production technology, and also the industrial structure as well as production technology of other sectors from which it receives goods and services required for producing its output.

Among the five countries, Thailand stands for the second place from the bottom in the rank of overall total energy intensity while Japan has the lowest value and China has the highest value with extremely high total energy intensities in many economic sectors.

Table 4-45 shows the total CO_2 intensities of the five countries for the same economic sectors as in the comparison of total energy intensities. The total CO_2

intensities of most of the inter-industry sectors in each country has nearly followed the patterns of their respective energy intensities. The reason for the same is that the fossil fuel based energy has large share in primary energy consumption in each of these countries. Among the five countries, Thailand is in the middle for the overall total CO_2 intensity rank with high values in energy and land transport sectors. Here too, Japan obtains the lowest value while China has the highest one.

4.7.2. Overall Embodied CO_2 to Embodied Energy Ratio

Table 4-46 represents the comparative ratio of embodied CO_2 to embodied energy (final demand) between Thailand in the year 1995 and some other countries in the year 1992 (as the data for 1995 is not available). The ratios for other countries, which are China, India, Japan, and USA refer to the study of Tiwaree and Imura (1995).

Table 4-46. Comparison of embodied CO_2 to embodied energy (final demand) ratio between different countries.

Unit : TCO_2/TOE

Countries	Ratio
Thailand	3.09
China	3.56
India	3.26
Japan	2.57
USA	2.60

Based on the data presented in Table 4-46, Thailand has a medium level of embodied CO_2 to embodied energy (final demand) ratio compared to the other four countries. Japan and USA are in the lower side while China and India are in the upper side. It is interesting to note the importance of increasing the share of non-fossil or renewable energy sources in Asian countries such as Thailand, China, India and

others to improve their embodied CO_2 embodied energy ratio which will lead to reduction of embodied CO_2.

4.8 Notable Economic Sectors

As described in the sub-sections above, besides energy sectors such as gas distribution, oil products, and electricity generation & distribution, economic sectors with substantial high total energy or CO_2 intensities and/or embodied energy or corresponding CO2 (final demand) for the year 1995 were cement, construction, land transport, drink & tobacco, and food & allied. These sectors were energy intensive sectors.

4.8.1 Gas Distribution Sector

Natural gas is a major domestic energy source of the country. The average production in 1998 was 1,704 million cubic feet/day, an increase of 8.9 % from the previous year, with total production of 15.3 MTOE, or 38.6 % of the total indigenous energy production (Department of Energy Development and Promotion, 1999). In the context of energy consumption and respective environmental deterioration, this economic sector in 1995 had the highest total and direct energy intensities as well as total and direct CO_2 intensities (i.e., 2.28 TOE/฿ 10,000, 2.00 TOE/฿ 10,000, 6.55 TCO_2/฿ 10,000, and 5.76 TCO_2/฿ 10,000, respectively). This sector's embodied energy (final demand) was 1.66 MTOE in the year 1995. This is 2.31 % of total primary energy supply for the whole economy. The sector's direct embodied energy, in the form of natural gas and crude oil, accounted for 88.01 % embodied energy (final demand), while indirect embodied energy included coal, natural gas, crude oil, and electricity used in the intermediate input. The amount of corresponding embodied CO_2 (final demand) from this sector in 1995 was 4.79 $MTCO_2$. The share of direct embodied CO_2 to total embodied CO_2 was 31.24 %, similar to that of energy. So, it is worthwhile to minimize the direct energy and corresponding CO_2 intensities

in order to reduce the embodied energy and corresponding CO_2 in final demand of this sector.

4.8.2 Oil Products Sector

There are six petroleum oil refinery plants in Thailand with total refining capacity of 810 thousand barrels per day in 1998 (National Energy Policy Office, 1999). This sector's direct embodied energy, in the form of crude oil, natural gas and some oil products, accounted for 95.51 % of embodied energy (final demand). Indirect energy included coal, natural gas, crude oil, and oil products. The energy and CO_2 intensities as well as embodied energy (final demand) and corresponding embodied CO_2 in 1995 were very high compared to other economic sectors. The total and direct energy intensities were equal to 1.00 and 0.95 TOE/฿ 10,000, respectively, while total and direct CO_2 intensities were 2.87 and 2.74 TCO_2/฿ 10,000, respectively. While the embodied energy (final demand) and corresponding CO_2 of this sector were 6.56 MTOE and 18.89 $MTCO_2$, that accounted for 9.11 % and 8.04 % of overall embodied energy and corresponding CO_2 (final demand) including residential sector.

As reported by the Department of Energy Development and Promotion (1996), the energy loss in transformation process in 1995 was 10.7 % that increased from 7.02 % in the previous year. According to Thailand Energy Development Plans, annual energy consumption demand will increase in the rate of 4.7 % during the year 2002 to 2006, and 5.3 % during the year 2007 to 2011. In these circumstances, the amount of loss in energy transformation will be significantly increased. Hence, reduction of this loss by any methods such as the use of modern technologies with less wastes and loss, application of waste recycling system would be important not only in loss reduction but also in energy conservation and corresponding CO_2 reduction.

As in case of gas distribution sector, the majority of energy and CO_2 intensities as well as outputs, were on direct sides, hence improvement of these properties should aim to direct rather than indirect sides to achieve a significant result.

4.8.3 Electricity Generation and Distribution Sector

In Thailand there are several types of electricity generation systems, namely, hydro power, thermal energy, co-generation, gas turbine, diesel turbine, wind power turbine, geo-thermal energy, and solar cell. In 1998, total electricity generation was 91,241 Gw-h, and natural gas was the major energy source (50.8 %) followed by fuel oil (19.2 %), lignite (18.1 %), hydropower, (5.6 %) and other energies (6.4 %) (National Energy Policy Office, 1999). In 1995, 2.88 MTOE of oil was used in electricity generation. At the same time, total CO_2 intensity of this sector was high (i.e., 2.65 TCO_2/฿ 10,000) compared to other economic sectors that induced embodied CO_2 (final demand) of 9.71 $MTCO_2$ in that year. Direct embodied energy (final demand) that accounted for 44.95 % of embodied energy (final demand) of the sector was in the form of coal, natural gas, crude oil, and oil products.

For energy transformation in power plants, the loss was up to 62 % of the energy input (Department of Energy Development and Promotion, 1996), mostly in the form of heat. This problem has been partly solved by using the co-generation system, but still not sufficient to minimize such loss effectively. An urgent increase in the share of co-generation system by government power plants as well as private, such as Independent Power Producers (IPP), and Small Power Producers (SPP) will directly lead to loss reduction, while the increased use of cleaner energies in these systems such as natural gas, hydro power, wind power and solar energy will help reduce CO_2 emission in the electricity generation processes as well.

Regarding efficient use of energy, special electrical equipment and machines such as electronic ballast, high-intensity discharge lamp power reduction equipment, voltage regulator, fluorescent lighting control, demand controller, variable speed motor, motor load controller, high efficiency motor, and high efficiency welding machine are already in use. Use of these equipment and machines in various economic sectors, more widely, contributes a substantial reduction in electrical power consumption.

4.8.4 Cement Sector

There are about 350 cement factories of various sizes in Thailand with total production capacity of about 265 million tonnes/year (Department of Industrial Works, 2000). From this study, it is notable that cement sector had high total and direct energy intensities as well as total and direct CO_2 intensities in 1995, which were 0.55 TOE/฿ 10,000, 0.37 TOE/฿ 10,000, 2.05 TCO_2/฿ 10,000 and 1.48 TCO_2/฿ 10,000, respectively. The sector's direct embodied energy (final demand), in the form of coal, oil products, and electricity, accounted for 67.14 %. Indirect embodied energy took a share of 32.86 % included coal, natural gas, crude oil, oil products, electricity, and baggase. Embodied energy (final demand) in the year 1995 was 0.17 MTOE which induced corresponding embodied CO_2 of 0.64 $MTCO_2$. In this circumstance, energy-efficient technologies are needed to decrease energy intensity, such as exhausted hot air recycling system, material pre-heat system, use of high performance material such as ceramics fiber for kiln wall, to replace conventional fire-brick wall. At the same time, mitigation of embodied CO_2 may be considered in field of fuel mix ratio, for instance, increase share of natural gas in total energy consumption, and introduce practical use of cleaner energy such as solar energy. The activities should be conducted in both sides, cement production factories themselves, and all of their input suppliers.

4.8.5 Construction Sector

This sector consists of private house construction, building and infrastructure including the construction of electrical power plants and communication systems. Although the total energy and total CO_2 intensities of this sector were fairly low in the year 1995, the embodied energy (final demand) throughout the year was highest among all economic sectors as there were a lot of construction activities all over the country. Embodied energy (final demand) in 1995 in this sector was 8.02 MTOE that accounted for 11.13 % of the overall embodied energy in the final demand, and induced corresponding embodied CO_2 in the amount of 26.15 $MTCO_2$, which was also the highest. Oil products were direct energy input for this sector and took a share of only 2.24 % of the total input, while indirect energy input with 97.76 % share included coal, natural gas, crude oil, oil products, electricity, and fuel wood. As the sector was responsible for much more embodied energy (final demand) and corresponding embodied CO_2 indirectly than directly, energy efficient production technologies and energy saving practices should be employed in economic sectors whose products was supplied to the construction sector. Those sectors were timber & its product, cement, building material & glass, iron & steal, and land transport.

4.8.6 Land Transport Sector

This sector comprises passenger and cargo transportation of all types on land including trains. In 1995, the sector's embodied energy (final demand) was 6.76 MTOE that accounted for 9.39 % of overall embodied energy (final demand). Direct embodied energy had a share of 27.96 % comprised of oil products for the majority and a small amount of electricity. While the indirect embodied energy in a share of 72.04 % included coal, natural gas, crude oil, oil products, electricity, and bagasse embodied in the intermediate input from oil products, rubber & plastics, automobiles & bicycle, and other services sectors. As the total CO_2 intensities was high (0.99 TCO_2/฿ 10,000), the embodied CO_2 (final demand) was up to 19.77 $MTCO_2$ or 8.42 % of overall embodied CO_2 (final demand) of the economy. In this regard, promotion of energy efficient use such as use of proper octane number gasoline oil, energy conservation program such as "Car Free Day" campaigns, and environment protection

such as use of catalytic converters in cars, use of natural gas to replace gasoline oil for some types of cars, and etc., would be of great importance in reducing embodied energy and corresponding embodied CO_2 in this sector.

4.8.7 Drink & Tobacco Sector

This sector includes liquor, beer, soft drink and drinking water production, tobacco maturing and tobacco products. With reference to data of the year 1995, this sector had a very high ratio of embodied CO_2 to embodied energy (final demand) which was 3.51 TCO_2/TOE. The embodied energy (final demand) of 1.71 MTOE induced the corresponding embodied CO_2 of 5.99 $MTCO_2$ which accounted for 2.55 % of the overall embodied CO_2. The majority of the embodied energy (final demand) in this sector was direct energy in the form of coal, oil products, fuel woods, and bagasse, and accounted for 66.85 % of the embodied energy. Indirect embodied energy included coal, natural gas, crude oil, oil products, electricity, fuel wood, and baggase. To decrease the corresponding embodied CO_2 in this sector, the emphasis should be given on reducing the direct embodied energy (final demand) as well as minimizing the use of bio-mass fuels, which are carbon-intensive, and increasing the use of cleaner energy such as natural gas, bio-gas, and solar energy.

4.8.8 Food and Allied Sector

This sector consists of all kinds of food, ingredients, and animal feed. In 1995, this sector had high embodied energy (final demand) and high corresponding embodied CO_2 which were 4.76 MTOE and 15.36 $MTCO_2$, that accounted for 6.61 % and 6.54 % of the overall quantities, respectively. Direct embodied energy (final demand) in a share of 34.74 % included coal, oil products, electricity, fuel wood, paddy husk, and bagasse. Indirect embodied energy (final demand) that shared 65.26 % included coal, natural gas, crude oil, oil products, electricity, fuel wood, paddy husk, and bagasse. In this regard, reduction of indirect embodied energy (final

demand) by application of energy efficient methods and energy saving practices would be of great importance. At the same time, using less bio-mass fuels and consuming more cleaner energies will help to achieve more corresponding embodied CO_2 reduction in the sector.

4.9 Effects of Change in Production Technology and Fuel Mix

4.9.1 Change in Production Technologies

In an input-output table, the technical coefficients related to economic sectors describe the existing production technology. If A_c is the technology that might be replaced by A_n, then the new technical coefficient A_{cn}, reflecting the incorporation of new technology would be

$$A_{cn} = A_c r + A_n (1-r) \qquad (4\text{-}1)$$

Where A_n is the technical coefficients related to new production technology, r is the percentage of old production technology to be used by production sectors (i.e., (1-r) is the percentage of new production technology that will replace the old production technology). Then calculation of A_n can be done by using the equation,

$$A_n = (e_c/e_n)A_c \qquad (4\text{-}2)$$

Where,

e_c and e_n, respectively are the average production efficiencies of existing and new technologies (Tiwaree and Imura, 1994).

For an example, if 50 % of the existing production technology is upgraded in term of energy efficiency (e.g., from 75 to 90 %), then

$$A_n = 0.83A_c$$

$$A_{cn} = 0.5A_c + 0.5A_n$$
$$= 0.92A_c$$

In this case, the incorporation of new technology change the technical coefficients by 8.00 %.

At the same time, if the production technologies (matrix A in section 2) employed in some economic sectors are upgraded, reductions in embodied energy (final demand) and corresponding CO_2 of all economic sectors will be higher than those affected by decrease in direct embodied energy (final demand). For example, if matrix A for the 8 notable economic sectors discussed in subsection 4.7 above are upgraded by 20 %, reductions in embodied energy (final demand) and corresponding CO_2 of all economic sectors can be achieved by 8.52 % and 8.78 %, respectively. While a reduction by 20 % of direct embodied energy (final demand) in the same 8 economic sectors will reduce only 5.23 % of embodied energy (final demand) as well as corresponding CO_2.

4.9.2 Fuel Mix Ratios

Carbon-dioxide emissions depend on fuel mix ratios. Increased consumption of carbon-intensive fuels such as fossil fuels and bio-mass fuels in economic sectors will raise the ratios of embodied CO_2 to embodied energy (final demand).

The situation can be explained by changing fuel mix ratio of the total primary energy input for 8 selected economic sectors in the year 1995. These sectors are gas distribution, oil products, electricity generation & distribution, cement construction, land transport, drink & tobacco, and food & allied sectors. The total primary energy input of the 8 economic sectors mentioned above was 47,292.18 thousand TOE (that accounted for 88.01 % of the overall total primary energy input for all economic sectors), of which

Coal	= 6,382.25	KTOE
Natural gas	= 8,542.94	KTOE
Crude oil	= 23,981.04	KTOE

Oil products	=	4,805.47	KTOE
Electricity	=	136.31	KTOE
Fuel wood	=	218.69	KTOE
Paddy husk	=	560.28	KTOE
Bagasse	=	2,665.20	KTOE

Multiplying energy consumption by CO_2 emission factors for each type of energies, the corresponding embodied CO_2 (final demand) from these sectors would be 150,061 thousand tonnes. Replacing coal and oil products by electricity with the same amount of energy input, the corresponding direct embodied CO_2 from these sectors would be 108,531 thousand tonnes, a decrease by 27.68 % from the original value or a reduction of 24.46 % of the overall embodied CO_2 (final demand) from the whole economy.

4.10 Model Sensitivity Analysis

The sectoral aggregation of an input-output table may influence the sensitivity of the model. Therefore, it is appropriate to perform the input-output analysis without making any change in the original classification of the economic sectors. In view of this, in this study the input-output analysis of all 179 economic sectors (without any aggregation or disaggregation) was carried out. However, interpretation of results of the analysis of all those 179 economic sectors in a clear and concise manner is not possible. Therefore, it is necessary to aggregate the different economic sectors into appropriate groups either before the application of input-output model or after the application of the model. In this study, aggregation of all the 179 economics sectors into appropriate 35 economic sectors has been done after the analysis. In this way the results of the non-aggregated sectors as well as the aggregated sectors after analysis were the actual results. On the other hand, if the sectoral aggregation is made prior to the input-output analysis, the result of the individual sector would be different. Table 4-47 illustrates the situation for all of the 35 economic sectors. It is notable that in case of sectoral aggregation before the application of the input-output model, the

results of all sectors have at least some changes from their individual values although the overall result is the same.

Table 4-47. Model sensitivity on sectoral aggregation.

Sectors	Total energy intensities in 1995 (TOE/฿ 10,000)			
	Sectoral aggregation		Differences	
	After analysis (Actual)	Before analysis	Intensities	%
Agricultural, forestry, fishing	0.083	0.087	-0.004	-4.95
Air and water transport	0.234	0.210	0.024	10.22
Automobiles, bicycles	0.030	0.030	0.000	-0.50
Bricks and tiles	0.285	0.284	0.001	0.35
Building materials, glasses	0.161	0.158	0.003	1.85
Cement	0.548	0.542	0.006	1.09
Ceramics	0.209	0.208	0.001	0.48
Charcoal and fuel wood	0.009	0.014	-0.005	-55.56
Chemicals and fertilizers	0.045	0.036	0.009	20.02
Coal mining	0.129	0.112	0.017	13.18
Construction	0.098	0.098	0.000	0.16
Drink and tobacco	0.117	0.042	0.075	64.15
Electrical engineering	0.018	0.018	0.000	-1.06
Electricity generation	0.783	0.759	0.024	3.07
Food and allied	0.108	0.101	0.007	6.79
Gas distribution	2.276	2.273	0.003	0.13
Hotel and restaurant	0.102	0.113	-0.011	-10.40
Iron and steel	0.039	0.042	-0.003	-7.27
Land transport	0.339	0.348	-0.009	-2.58
Leather, etc.	0.038	0.047	-0.009	-23.15
Mechanical engineering	0.020	0.021	-0.001	-6.25
Metallic mineral	0.047	0.046	0.001	2.96
Non ferrous metal	0.014	0.014	0.000	0.00
Non-metallic mineral	0.091	0.100	-0.009	-9.83
Oil and natural gas	0.075	0.073	0.002	2.67
Oil products	0.997	1.055	-0.058	-5.77
Other manufacturing	0.024	0.028	-0.004	-16.27
Other services	0.027	0.027	0.000	-1.05
Pulp, paper and printing	0.065	0.060	0.005	7.19
Rubber and plastics	0.070	0.100	-0.030	-42.86

Ship, train, aircraft	0.008	0.011	-0.003	-39.59
Textile	0.068	0.070	-0.002	-2.48
Timber and its product	0.044	0.036	0.008	17.77
Water supply and sanitation	0.083	0.085	-0.002	-2.23
Wholesale and retail	0.029	0.028	0.001	3.18
Overall	0.082	0.082	0.000	0.00

4.11 Trends of Energy Consumption and Corresponding CO_2 Emission in Thailand

4.11.1 Energy Consumption

With reference to the analytical results expressed earlier in this chapter, overall energy intensity for the whole economy has been decreased in the year 1995 (0.08 TOE/฿ 10,000) compared to the year 1985 (0.13 TOE/฿ 10,000). This indicates a downward trend of the overall total energy intensity in future. In particular, shifts from non-commercial energy sources (such as renewable energy) to commercial

energy sources (such as fossil fuels and electricity) in the process of economic development, and more efficient production technologies to increase the efficiency of commercial energy use have led to decreasing energy intensity. Base on the data of total primary energy supply as shown in annex II, the amount of non-commercial energy sources accounted for 13.29 % of the total primary energy supply in 1985 where that in 1995 accounted for 8.30 % only. However, there is an increase in total energy intensities for some economic sectors such as gas distribution, bricks & tiles, and air & water transport which is mainly due to the increase in their direct energy intensities.

The trend of energy consumption expressed in terms of embodied energy (final demand) is clearly noticeable to be upward resulting from the rising energy demand of the economy (from 17.65 MTOE in 1985 to 53.53 MTOE in 1995). At present, the demand for energy continues to increase rapidly. If there is no effective management plan for energy resources management, energy shortage will become a serious problem in the near future.

4.11.2 Carbon-dioxide Emission

Based on the results presented in this chapter, the overall total CO_2 intensity was decreased from 0.40 TCO_2/฿ 10,000 in the year 1985 to 0.25 TCO_2/฿ 10,000 in the year 1995 with a downward trend. Despite decrease in overall total CO_2 intensity, increase of this intensity in some economic sectors is noticeable. This is especially true for gas distribution, cement, and bricks & tiles sectors. So, it is worthwhile to minimize the CO_2 intensities in these economic sectors especially in the direct side in order to reduce the amount of CO_2 emissions.

On the other hand, the ratio of overall CO_2 emission to energy consumption showed an upward trend as it was increased from 3.07 TCO_2/TOE in the year 1985 to 3.09 TCO_2/TOE in the year 1995. Although the difference was just nominal, increase in the amount of CO_2 emission would be significant with respect to the rising energy demand at present as well as in future. Change in fuel mix ratio, such as increase in the share of natural gas or bio-gas or hydro-power, solar energy etc. in total energy

consumption, will reduce the above mentioned ratio and, consequently, lead to reduction of overall CO_2 emission. At the same time, enhancement of energy conservation practices and introduction of energy efficient production technology will play further important role in the reduction of corresponding CO_2 emission.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Energy is an important input (direct and indirect) in an economy since there is hardly any production or consumption activity which requires no energy input. In Thailand, energy requirement is being largely met by fossil and bio-mass fuels, the major cause of large emission of CO_2.

In this study, a model based on the input-output analysis was used to account for embodied energy as well as corresponding CO_2 in final demand of various economic sectors in Thailand for the years 1985 and 1995. It can be observed that in addition to energy sectors (such as gas distribution, oil products, and electricity), economic sectors such as cement, construction, land transport, drink & tobacco, and food & allied had very high total (direct plus indirect) energy or total CO_2 intensities in both years. It has been observed that the share of carbon-intensive fuels in the fuel mix was increased in 1995 compared to 1985. It is also noteworthy that even though the share of the overall direct embodied energy (final demand) and corresponding CO_2 emission increased in 1995 as compared to 1985, overall indirect embodied energy (final demand) and corresponding CO_2 emission of Thai economy had still large shares in 1995 (68.76 %). This is an indication of strong economic and environmental interdependence among different economic sectors of Thai economy. Although some of the economic sectors were fairly able to reduce their total (direct plus indirect) energy or total CO_2 intensities in 1995, some other sectors clearly increased the same compared to 1985. Accounting for total energy used in and corresponding CO_2 emission from different economic sectors of Thai economy for the production of goods and services would provide essential information for energy-environment policy makers. This study clearly shows the importance of energy saving practices, use of energy efficient production technologies, and consumption of cleaner energies for the reduction of energy consumption as well as CO_2 emission in Thailand.

5.2 Recommendations

Although both overall energy and corresponding CO_2 intensities during the period of 1985 to 1995 have been found in downward trend, much more improvement is imperative. In this regard, introduction of further energy efficient production technologies and energy conservation strategies in different economic sectors with major consideration to those economic sectors with high total energy and corresponding CO_2 intensities (such as gas distribution, oil products, electricity

generation and distribution, cement, and land transport) should be done to achieve sustainable economic development in Thailand.

Despite some reduction in overall energy and corresponding CO_2 intensities, overall ratio of CO_2 emission to energy consumption has been found in increasing trend. Therefore, increase in the share of non-carbon or low-carbon intensive energy in every economic sector of Thai economy is very important.

The present study has few deficiencies occurring from the limited data availability. First, Thailand has been treated as a closed economy. Calculations of energy and corresponding CO_2 embodied in the imported goods and services is neglected and export of embodied energy or CO_2 has been considered as part of the final demand within the country. Thus, any embodied energy or CO_2 in the imported goods & services has been assumed to be equal to the embodied energy or CO_2 in the exported goods & services. In reality, it could differ. In order to get better result, the future study should include the calculation of the embodied energy or CO_2 in the imported goods and services. Data of input-output table of major trading partners of Thailand is necessary for such study.

In the currently available input-output tables of Thailand, all the inter-industry transactions are in monetary units. Moreover, the primary energy data available does not show its detail transaction between different inter-industry or economic sectors. Therefore, the row of the concerned energy sectors were converted into equivalent physical units assuming that the price of the primary energy is uniform throughout the economy. In practice, price may differ from sector to sector. For improvement, at least row of the energy sectors should be available in physical units. Any future study should consider this matter.

ANNEXURES

ANNEX I

National Energy-Environmental Policy

According to the Eighth National Economic and Social Development Plan (1997-2001), The National Energy Policy Office (NEPO), being a national policy making mechanism for energy, is responsible for the follow-up on the implementation of the Plan, and has established targets of the energy development as follow:

1. Increase commercial primary energy production at an annual growth rate of 3.0 % during the Eighth National Plan period.

2. Maintain the growth rate of the domestic primary commercial energy consumption at the same level as the growth rate of the gross domestic product during the plan period.

3. Maintain the level of energy import dependence at below 64 % by the year 2001.

4. Set targets for domestic production of natural gas, crude oil, condensate and coal/lignite.

5. Set targets for energy import.

6. In crease the electricity generation capacity by power plants of the Electricity Generating Authority of Thailand and purchase from independent power producer (IPP) as well as from small power producers (SPP) using non-conventional energy or co-generation system.

7. Reduction of power consumption through demand side management.

8. Establish the reliability standard of the power system.

9. Limit emission of sulfur dioxide from commercial energy consumption of economic sectors to suitable levels.

In order to achieve the targets, the strategies for energy development have been established as follow:

1. Provide an adequate amount of energy to satisfy demand at reasonable prices while ensuring quality and security of supply.

2. Promote efficient and economical use of energy.

3. Promote competition in energy supply industry and increase private sector role.

4. Prevent and solve environmental problems resulting from energy. development and utilization, as well as improve safety of energy related activities.

5. Develop legislation related to energy and energy administration mechanism.

ANNEX II

Total Primary Energy Supply (Excluding Residential Sector)

Primary Energy Type	Total Primary Energy Supply (KTOE)	
	1985	1995
Coal	1,653.04	6,896.11
Natural Gas	2,874.07	8,695.97
Crude Oil	8,243.76	24,410.62
Oil Products	2,253.58	8,643.61
Electricity	377.89	630.64
Fuel Wood	80.62	705.00

Paddy Husk	1061.00	620.00
Bagasse	1,219.00	3,135.00
Sum	17,762.96	53,736.95

Source : Department of Energy Development and Promotion (1986; 1996); International Energy Agency (1997a).

ANNEX III

Energy Consumption and CO_2 Emission in Residential Sector

Primary Energy Type	Energy Consumption (KTOE)		CO_2 Emission (1,000 tonnes)	
	1985	1995	1985	1995
Coal	0	0	0	0
Oil Products	436.52	1,276.45	1,351.47	3,951.89
Natural Gas	0	0	0	0
Electricity	444.19	1,257.49	0	0
Fuel Wood	8,295.24	15,779.64	34,309.12	65,264.57
Total	9,175.95	18,313.58	35,660.59	69,216.46

Source : Department of Energy Development and Promotion (1986; 1996); International Energy Agency (1997a).

ANNEX IV

Consumer Price Index (CPI) for Thailand

Year	Index
1985	67.5
1986	68.8
1987	70.5
1988	75.0

1989	79.0
1990	83.7
1991	88.5
1992	92.1
1993	95.1
1994	100.0
1995	105.8
1996	112.0
1997	118.2
1998	127.8
1999	128.2
2000[(1)]	131.4

[(1)] Estimation

Source: Bank of Thailand (2000).

ANNEX V

Exchange Rate

Year	Baht/US$
1985	27.21
1995	24.94

Source: Bank of Thailand (1996).

ANNEX VI

Economic Sectors Aggregation

Sector No.	Sector Description	Sub-sectors
1	Agricultural, forestry, fishing	Rice plantation
		Corn plantation
		Sorghum and cereal plantation
		Tapioca plantation
		Other corps plantation

		Legumes plantation
		Vegetables plantation
		Fruit plantation
		Sugarcane plantation
		Coconut plantation
		Palm tree plantation
		Jute plantation
		Fibred plants farming
		Tobacco Plantation
		Coffee, tea and cocoa production
		Rubber tree plantation
		Other agricultural products
		Cattle farming
		Pig farming
		Livestock farming
		Poultry farming
		Poultry products
		Silk worm breeding
		Agricultural services
		Forest products & hunting
		Sea and coastal fishery
		Fresh water fishery
2	Charcoal and fuel wood	Charcoal & firewood production
3	Coal mining	Coal mining
4	Oil and natural gas	Oil and natural gas
5	Metallic mineral	Iron mining
		Tin mining
		Tungsten mining
		Other ore mining

6	Non-metallic mineral	Fluorite mining
		Ore mining for chemicals and fertilizers
		Limestone mining
		Stone mining
		Special ores mining
7	Food and allied	Salt production
		Slaughter houses
		Canned meat & other meat products
		Milk products
		Canned fruit and vegetable production
		Canned fish and seafood production
		Coconut and palm oil production
		Lard and vegetable oils production
		Rice mill
		Tapioca products
		Corn grinding
		Starch production
		Bread production
		Noodle production
		Sugar production
		Sweets, candy production
		Ice production
		Seasoning powder production
		Refreshments production
		Cooking ingredients production

		Animal feed production
8	Drink and tobacco	Liquor production
		Beer production
		Soft drinks production
		Tobacco leaves maturing
		Tobacco product
9	Textile	Natural and synthetic threads production
		Weaving
		Bleaching, dye and cloth printing
		Cloth excluding garment production
		Knitting
		Garment production
		Carpet & cover materials production
		Jute products
10	Leather, etc.	Leather preparation
		Leather products
		Shoes production
11	Timber and its product	Timber production
		Miller
		Wood products
		Wood furniture production
12	Pulp, paper and printing	Pulp and paper production
		Paper products
		Paper printing
13	Chemicals and fertilizers	Primary industrial chemicals production
		Fertilizer & pesticide

		production
		Paint, wax and lacquer production
		Medicine production
		Soup and detergent production
		Cosmetics production
		Match production
		Chemicals consumer products
14	Oil products	Petroleum oil refinery
		Other petroleum products
15	Rubber and plastics	Plastic, resin & synthetic rubber production
		Raw rubber production
		Vehicle tires production
		Rubber products
		Plastic products
16	Ceramics	Ceramics and pottery production
17	Bricks and tiles	Bricks and tiles production
18	Cement	Cement production
19	Building materials, glass	Glass products
		Concrete products
		Non-metallic materials production
20	Iron and steel	Iron and steel industry
		Steel products
21	Non ferrous metal	Metal product excluding iron
22	Mechanical engineering	Iron and steel equipment manufacturing
		Metal furniture and fixing materials production

		Metal products for construction
		Other metal products
		Engine & turbine manufacturing
		Agricultural machine & equipment manufacturing
		Machine for woodwork and metalworking manufacturing
		Special machine and equipment manufacturing
		Office and home equipment and tool manufacturing
23	Electrical engineering	Industrial electrical M/C & equipment manufacturing
		Communication equipment manufacturing
		Electrical household products
		Metal wire and shielded cable production
		Batteries production
		Electrical appliances production
24	Ship, train, aircraft	Ship repairing and manufacturing
		Train manufacturing and maintenance
		Aircraft manufacturing
25	Automobiles, bicycle	Automobiles manufacturing
		Motorcycle & bicycle manufacturing
		Vehicle maintenance
26	Other manufacturing	Scientific and medical

		equipment manufacturing
		Photo and optic equipment manufacturing
		Watch production
		Ornament production
		Musical instrument and sport equipment production
		Other industrial products
27	Electricity generation, distribution	Electricity generation
28	Gas distribution	Gas refinery and distribution
29	Water supply and sanitation	Water supply business
		Sanitary services
30	Construction	Private house construction
		Building construction excluding residence
		Infrastructure construction for agriculture and forestry
		Other infra-structure construction
		Electricity Plant construction
		Building & communication system construction
		Other construction
31	Wholesale and retail	Wholesale
		Retail
32	Hotel and restaurant	Food and drink services
		Hotel and accommodation services
33	Land transport	Train transportation
		Land transportation
		Truck transportation

		Additional service to land transportation
34	Air and water transport	Sea transportation
		Coastal and inland water transportation
		Additional service to water transportation
		Air transportation
		Transportation related service
35	Other services	Warehouse and silo
		Post and telecommunication
		Finance
		Life insurance
		Disaster insurance
		Real estate business
		Business services
		Government affair
		Educational services
		Research institutes
		Medical and health services
		Private professional institutes
		Community services
		Movie production and distribution
		Movie theatre
		Radio and television broadcasting
		Library and museum
		Entertainment services
		Maintenance and repair services
		Personal services

Miscellaneous activities

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