Appendix A

Notation

This study frequently uses matrices and vectors. This appendix gives an overview of the notation that is used:

- matrices are indicated with capitals: A, B, C, etc.; the element in row i and column j of matrix A is indicated with $A_{ij}$.
- vectors are indicated with small letters: a, b, c, etc.; element i of vector b is indicated with $b_i$.
- scalars are indicated with greek letters: $\alpha$, $\beta$, $\gamma$, etc.

A special matrix is the unit matrix I. This is a diagonal matrix with all its diagonal elements equal to one. A diagonal matrix is a square matrix with zero elements everywhere except in the leading diagonal.

A special vector is the sum vector i. All elements of the sum vector equal unity. E.g., if $n=3$, the unit matrix and the sum vector are:

$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad i = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

Some special matrices and vectors are indicated as follows:

- the transposed matrix of matrix X with $X^T$; the transposed matrix is a matrix of which the rows and columns are interchanged.
- the transposed vector of vector x with $x^T$; the transpose of a row vector is a column vector and conversely.
- diagonal matrix of vector x with $x^D$; the leading diagonal of the matrix contains the elements of x.
The following matrices, vectors and scalars are used in the input-output methodology (chapter 3, and appendices 4.A and 7.A):

A  technological matrix
B  Leontief inverse matrix
C  matrix of direct energy consumption per fuel
D  matrix of direct energy intensities per fuel
E  matrix of (total) energy intensities per fuel
F  matrix of change in one element of the technological matrix
P  diagonal matrix with the diagonal elements of the energy sectors equal to the energy prices and the other diagonal elements equal to unity
Q  diagonal matrix with the diagonal elements of the energy sectors equal to the ERE values and the other diagonal elements equal to unity
R  matrix of maximal change per element of the technical matrix so that the energy intensities do not change more than a fixed percentage
V  matrix of primary inputs of final demand
W  matrix of primary inputs
Y  matrix of final demand
Z  matrix of intermediate deliveries

c  vector of direct energy use
d  vector of direct energy intensities
e  vector of (total) energy intensities
f  vector of change in one direct energy intensity
h  vector of changes in (total) energy intensities
k  vector of total direct emission
l  vector of direct emission intensities
m  vector of (total) emission intensities
p  vector of direct emission coefficients (emission per unit energy)
t  vector of total final spendings
u  vector of total primary inputs
v  vector of depreciation
w  vector of investments
x  vector of total production
y  vector of total final demand

Δ  change in total energy required for final demand
ε  total energy requirements of final demand
φ  change of element of technological matrix or direct energy intensity vector
ρ  percentage change in (total) energy intensities
Appendix B

Data

Both the input-output model and the hybrid model require large amounts of data. This appendix specifies the origin of some of the data used in the calculations. Most data originate from the Netherlands Central Bureau of Statistics (CBS). The input-output model uses input-output tables and energy use data. Furthermore, ERE values and CO₂ emission factors are used. In case of the historic analysis, price indices are used.

B.1 INPUT-OUTPUT TABLES

Annually, CBS publishes input-output tables for the Dutch economy (CBS-NR; CBS-PS). These tables are compiled within the framework of the National Accounts. The National Accounts, which are published annually in September, contain the annual figures of the preceding year and the input-output tables of three years before. So, it takes three years before input-output tables are made available. The input-output tables have been published since 1948. From time to time, the composition of the input-output tables is revised as for the sectoral division or data collection. The latest revision took place in the National Accounts 1991 which concerns the year 1989. Because of the revisions in the composition of the input-output tables, at irregular times, these input-output tables are not compatible for the full period since 1948. The longest range of tables that are constructed in the same way, is available for the period 1969-1988. Since 1987, the CBS also compiled so-called ‘make’ and ‘use’ tables as part of the System of National Accounts1. These tables, which describe the relations between economic sectors and commodities, are very detailed; they contain about 200 branches of industries and 800 commodities. Nowadays, the CBS compiles input-output tables on the basis of the make and use tables.

CBS publishes two input-output tables for the Dutch economy. The first is composed on the basis of producers’ prices, the second is based on basic prices. The tables in basic prices are the most appropriate for input-output analysis (Konijn, 1994). A separate table in the National Accounts contains the imports of goods and services according to competitive sectors. This table also

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1 Another development in the System of National Accounts concerns the integration of environmental aspects (Haan et al., 1993; Haan, 1995).
contains the non-competitive imports. The depreciation of the sectors is part of the value added. Since 1989, the depreciation has not been published separately anymore. The investments are part of final demand.

The input-output tables for the Netherlands contain 59 economic sectors. Sector 58 is the sector housekeeping services, which has no intermediate inputs. Therefore, the energy intensity of this sector is considered to be zero and this sector is not included in the presentation of the results. Sector 59 functions as a remaining sector. Row 59 contains the deliveries of goods and services of which the origin is unknown. Similar, column 59 contains goods and services for which the destination is not known. The energy intensity of sector 59 has no meaning, since the deliveries in row 59 are not related to the deliveries in column 59.

A basic assumption in input-output analysis concerns homogeneous production. This means that each sector produces only one commodity and each commodity is produced by only one sector. For the sectors in the input-output tables published by CBS this assumption is certainly not true, since most sectors produce secondary products, which are not characteristic for the sector. Therefore, in input-output analysis it is preferable to use a homogeneous table which is based on commodities. Konijn and De Boer (1993) compiled such a table for the Netherlands for the year 1990.

B.2 PRICE INDICES

The input-output tables for the years 1969-1988 are corrected for price changes to exclude differences in the time series of energy intensities resulting from these changes. All prices are expressed in prices of 1980. For this purpose, price index data are derived from data of the Central Planning Bureau (CPB, annually). The CBS also publishes input-output tables in prices of the previous year, but this is done only since the input-output table of 1981 (CBS-P, several issues).

The CPB publishes several series of data in current prices and in prices of the preceding year. For the years 1950-1981, the data were derived from CPB research. Since 1981, they have been directly derived from the deflated CBS input-output tables. This study uses two series of data, namely the value of the domestic deliveries and the value of the exports. Both series - in prices of the preceding year - are converted to series with all data in prices of the year 1980. The series concern 25 branches of industry. The indices for the 25 branches are assigned to the 57 economic sectors from the input-output tables.
B.3 ENERGY CONSUMPTION DATA

The energy data used originate from the Netherlands Central Bureau of Statistics (CBS). The CBS publishes data of the energy-supply in the Netherlands in the Nederlandse Energiehuishouding (CBS-NEH). The annual publication gives an overview of energy consumption per energy carrier. The annual issue is based on the quarterly issue with the same title.

Table B.1 shows the energy consumption data of the production sectors and the households per energy carrier for 1990. This appendix reports on the compilation of the 1990 energy use data of the economic sectors used in the input-output model. The energy use data required by the alternative methods (section 5.1.2) are available, on request, from the author. This study distinguishes the energy carriers coal products, oil products, natural gas, and electricity. The energy statistics also report on the energy carrier other fuels. In this study, this carrier is included in the carrier oil. The energy statistics discern four groups of energy consumers: industry, households, transport and other final consumers. The category transport contains both industrial transport and household transport. This study divides the energy used for transport over the production sectors and the households. For the period 1969-1988, the division is based on monetary values in the input-output tables. For the base year 1990, all energy for passenger cars is assigned to the households.

The data of natural gas are corrected for temperature fluctuations by using so-called degree days. For all days, the number of degree days is defined as the difference between the twenty-four hours average temperature and 18 °C. The year 1990 was a rather warm year. Taking the average number of degree days over the period 1961-1990 as reference, all temperature dependent energy use has to be multiplied by the factor 1.2. This study assumes that only the consumption of natural gas is temperature dependent. Table B.2 shows for the economic sectors the temperature dependent share of natural gas consumption.
### Table B.1: Energy consumption of economic sectors per energy carrier (coal, oil, gas, gas corrected, and electricity) and total primary in 1990.

<table>
<thead>
<tr>
<th>Sector</th>
<th>coal (PJ)</th>
<th>oil (PJ)</th>
<th>gas (PJ)</th>
<th>gas-c (PJ)</th>
<th>elec (PJ)</th>
<th>total (PJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>agriculture, horticulture and forestry</td>
<td>.0</td>
<td>20.7</td>
<td>126.9</td>
<td>149.0</td>
<td>6.6</td>
<td>191.7</td>
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<td>fishing</td>
<td>.0</td>
<td>14.1</td>
<td>.0</td>
<td>.0</td>
<td>.0</td>
<td>15.7</td>
</tr>
<tr>
<td>crude oil and natural gas production</td>
<td>.0</td>
<td>.0</td>
<td>.0</td>
<td>.0</td>
<td>.0</td>
<td>.0</td>
</tr>
<tr>
<td>other mining and quarrying</td>
<td>.0</td>
<td>.7</td>
<td>.2</td>
<td>.2</td>
<td>.4</td>
<td>2.1</td>
</tr>
<tr>
<td>slaughtering and meat-processing ind.</td>
<td>.0</td>
<td>.2</td>
<td>2.4</td>
<td>2.6</td>
<td>1.3</td>
<td>6.4</td>
</tr>
<tr>
<td>manufacture of dairy products</td>
<td>.0</td>
<td>.3</td>
<td>13.8</td>
<td>14.7</td>
<td>1.8</td>
<td>20.1</td>
</tr>
<tr>
<td>processing of fish, fruit and vegetables</td>
<td>.0</td>
<td>.0</td>
<td>2.3</td>
<td>2.5</td>
<td>.7</td>
<td>4.4</td>
</tr>
<tr>
<td>grain-processing industry</td>
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<td>.2</td>
<td>3.2</td>
<td>3.4</td>
<td>2.6</td>
<td>11.8</td>
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<td>.1</td>
<td>10.4</td>
<td>11.2</td>
<td>.7</td>
<td>14.1</td>
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<td>flour-processing industry</td>
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<td>.0</td>
<td>2.4</td>
<td>2.6</td>
<td>.6</td>
<td>4.1</td>
</tr>
<tr>
<td>manufacture of cocoa and chocolate</td>
<td>.0</td>
<td>.0</td>
<td>1.9</td>
<td>2.0</td>
<td>.7</td>
<td>3.9</td>
</tr>
<tr>
<td>manufacture of margarine, starch, etc.</td>
<td>.0</td>
<td>.8</td>
<td>18.4</td>
<td>19.7</td>
<td>2.0</td>
<td>26.2</td>
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<tr>
<td>beverage industry</td>
<td>.0</td>
<td>.0</td>
<td>4.1</td>
<td>4.4</td>
<td>1.0</td>
<td>7.1</td>
</tr>
<tr>
<td>tobacco-processing industry</td>
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<td>.0</td>
<td>.7</td>
<td>.8</td>
<td>.4</td>
<td>1.8</td>
</tr>
<tr>
<td>wool industry</td>
<td>.0</td>
<td>.0</td>
<td>.2</td>
<td>.2</td>
<td>.1</td>
<td>.5</td>
</tr>
<tr>
<td>cotton industry</td>
<td>.0</td>
<td>.0</td>
<td>1.2</td>
<td>1.3</td>
<td>.5</td>
<td>2.6</td>
</tr>
<tr>
<td>knitting and hosiery industry</td>
<td>.0</td>
<td>.0</td>
<td>.3</td>
<td>.3</td>
<td>.1</td>
<td>.6</td>
</tr>
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<td>textiles industry</td>
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<td>.0</td>
<td>3.1</td>
<td>3.4</td>
<td>.7</td>
<td>5.3</td>
</tr>
<tr>
<td>clothing industry</td>
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<td>.0</td>
<td>.2</td>
<td>.3</td>
<td>.1</td>
<td>.6</td>
</tr>
<tr>
<td>leather, footwear and other leatherware</td>
<td>.0</td>
<td>.0</td>
<td>.3</td>
<td>.3</td>
<td>.2</td>
<td>.7</td>
</tr>
<tr>
<td>wood and furniture industry</td>
<td>.0</td>
<td>.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.1</td>
<td>4.0</td>
</tr>
<tr>
<td>paper and cardboard industry</td>
<td>.0</td>
<td>.0</td>
<td>29.1</td>
<td>29.7</td>
<td>2.6</td>
<td>37.1</td>
</tr>
<tr>
<td>paperware and corrugated cardboard ind.</td>
<td>.0</td>
<td>.0</td>
<td>1.8</td>
<td>1.8</td>
<td>1.0</td>
<td>4.7</td>
</tr>
<tr>
<td>printing, publishing and related ind.</td>
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<td>.0</td>
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<td>2.4</td>
<td>2.2</td>
<td>8.4</td>
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<td>.0</td>
<td>.0</td>
<td>.0</td>
<td>.0</td>
<td>.0</td>
</tr>
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<td>chemical basic products industry</td>
<td>16.6</td>
<td>318.6</td>
<td>255.7</td>
<td>261.1</td>
<td>17.3</td>
<td>685.8</td>
</tr>
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<td>6.7</td>
<td>2.7</td>
<td>15.9</td>
</tr>
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<td>rubber and plastic-processing industry</td>
<td>.5</td>
<td>.0</td>
<td>4.2</td>
<td>4.7</td>
<td>4.0</td>
<td>16.4</td>
</tr>
<tr>
<td>manufacture of building materials, etc.</td>
<td>3.3</td>
<td>6.3</td>
<td>22.5</td>
<td>23.0</td>
<td>4.4</td>
<td>46.4</td>
</tr>
<tr>
<td>basic metal industry</td>
<td>73.0</td>
<td>4.5</td>
<td>15.5</td>
<td>15.8</td>
<td>26.8</td>
<td>185.9</td>
</tr>
<tr>
<td>manufacture of metal products</td>
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<td>.0</td>
<td>5.9</td>
<td>6.6</td>
<td>3.5</td>
<td>16.3</td>
</tr>
<tr>
<td>machinery</td>
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<td>.0</td>
<td>3.2</td>
<td>3.6</td>
<td>2.0</td>
<td>9.2</td>
</tr>
<tr>
<td>electrotechnical industry</td>
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<td>.0</td>
<td>7.0</td>
<td>7.7</td>
<td>4.4</td>
<td>19.9</td>
</tr>
<tr>
<td>automobile industry</td>
<td>.0</td>
<td>.0</td>
<td>2.1</td>
<td>2.4</td>
<td>1.1</td>
<td>5.4</td>
</tr>
<tr>
<td>manufacture of transport equipment</td>
<td>.0</td>
<td>.0</td>
<td>1.1</td>
<td>1.2</td>
<td>.7</td>
<td>3.1</td>
</tr>
<tr>
<td>manufacture of instr. and optical goods</td>
<td>.0</td>
<td>.0</td>
<td>.5</td>
<td>.6</td>
<td>.5</td>
<td>1.8</td>
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<td>.0</td>
<td>.0</td>
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<td>gas distribution</td>
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<td>.0</td>
<td>.0</td>
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<td>water supply</td>
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<td>.3</td>
<td>.3</td>
<td>2.0</td>
<td>6.1</td>
</tr>
<tr>
<td>construction and installation</td>
<td>.0</td>
<td>26.0</td>
<td>3.9</td>
<td>4.6</td>
<td>1.6</td>
<td>38.0</td>
</tr>
<tr>
<td>wholesale trade and retail trade</td>
<td>.0</td>
<td>3.4</td>
<td>25.3</td>
<td>29.7</td>
<td>16.3</td>
<td>78.6</td>
</tr>
<tr>
<td>hotels, restaurants, cafes etc.</td>
<td>.0</td>
<td>2.5</td>
<td>13.0</td>
<td>15.3</td>
<td>4.9</td>
<td>31.7</td>
</tr>
<tr>
<td>repair of consumer goods</td>
<td>.0</td>
<td>.6</td>
<td>3.9</td>
<td>4.6</td>
<td>1.9</td>
<td>10.5</td>
</tr>
<tr>
<td>sea and air transport</td>
<td>.0</td>
<td>40.9</td>
<td>1.8</td>
<td>2.1</td>
<td>1.5</td>
<td>51.7</td>
</tr>
<tr>
<td>other transport storage</td>
<td>.0</td>
<td>115.3</td>
<td>4.6</td>
<td>5.4</td>
<td>7.3</td>
<td>153.4</td>
</tr>
<tr>
<td>communication</td>
<td>.0</td>
<td>3.5</td>
<td>1.4</td>
<td>1.6</td>
<td>.9</td>
<td>7.9</td>
</tr>
</tbody>
</table>
For the time series 1969-1988, the level of detail in the statistics is not the same for all years. In the 70s, the energy use of a small number of industry sectors, the households and the total domestic energy use are published. In the 80s, the statistics consist of energy use data of a large number of sectors.

In calculating the historical series of energy intensities, the energy use of the input-output sectors is determined similarly for all years. This is done by using the degree of detail of the energy use data in the beginning of the 70s complemented with financial data of energy deliveries from the input-output tables. So, the energy data used for the 80s may differ slightly from the energy data published by the CBS. In determining the energy use of sectors, the net available energy is often used. The net available energy is the sum of the final energy use and the energy used by the sectors for the own conversion of secondary energy carriers. Since the older volumes of the NEH only contain the

<table>
<thead>
<tr>
<th>sector</th>
<th>share (%)</th>
<th>remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>households</td>
<td>85.0</td>
<td></td>
</tr>
<tr>
<td>services</td>
<td>82.5</td>
<td></td>
</tr>
<tr>
<td>agriculture</td>
<td>82.5</td>
<td></td>
</tr>
<tr>
<td>industries, small</td>
<td>50.0</td>
<td>other metal, textiles, other industries</td>
</tr>
<tr>
<td>industries, mixed</td>
<td>33.0</td>
<td>food and drugs</td>
</tr>
<tr>
<td>industries, large</td>
<td>10.0</td>
<td>all other industries</td>
</tr>
<tr>
<td>energy sector</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>
final energy use (and not the conversion energy), the final energy use was starting-point in the compilation of the energy use data. In this approach, the conversion energy is included in the ERE values (see B.4). This may introduce some small errors, since the ERE values used are based on energy conversion in energy sectors and not on conversion in non-energy sectors.

The energy use of the industrial sectors in the input-output table is determined from the final energy use of the following industrial branches:
- food industry (sectors 5-14)
- textiles industry (15-18)
- paper and paperware industry (22-23)
- chemical industry (26-27)
- building materials industry (29)
- basic metal industry (30)
- metal processing industry (31-35)
- other industry (19-21, 24, 28, 36).

The partition of the energy use over the sectors within an industrial branch is based on the energy deliveries in financial units in the input-output tables. The following changes are applied on the data published:
- Concerning the years 1969-1971, naphtha is added to the energy use of the chemical industry (NEH, 1973).
- Since the publication NEH 1983 the industrial energy consumption of liquid energy carriers has contained a part 'not specified', which concerns lubricants and some other oil products. This energy consumption is assigned to the chemical industry.

The energy use of the non-industrial sectors - with the exception of agriculture and horticulture - is determined with input-output data mainly. This is carried out by assuming the same energy price for all sectors. For the sector agriculture and horticulture, a separate series of energy use data is determined. The share of this sector in the energy use of the Netherlands is about 5%. Besides, especially horticulture pays strong deviating energy prices. The series for agriculture and horticulture is determined from existing data (Cuelenaere, 1990) and extrapolations.

For the years 1969-1974, only the final electricity and gas consumption of households and other non-industrial sectors (excluding agriculture and horticulture) was published, and not the consumption of coal and oil products. For the solid fuels, an estimation is made of the consumption in these sectors for these years. This estimation is based on the consumption in 1975, the monetary deliveries of the coal sector in the years concerned and the development of the industrial coal price for these years. The consumption of liquid fuels is determined on the basis of the estimation of the solid fuel consumption mentioned. On the basis of the input-output table deliveries, this
liquid fuel consumption is assigned to non-industrial sectors and households under the assumption of the same energy price for the sectors considered.

B.4 ERE VALUES

Depending upon the calculation method, the energy use of the energy sectors is assigned directly to the non-energy sectors. Therefore, the energy use of the energy sectors is set to zero. For the non-energy sectors, the total primary energy use is calculated by using ERE values (see table B.3). The ERE value of an energy carrier gives the total amount of primary energy required for the production of the energy carrier. The ERE values used in the calculations consider the whole production chain of the energy carriers. The ERE values contain both the energy required for extraction and transport of the primary energy carriers required and the energy needed for production and distribution of the secondary energy carrier. The ERE values are calculated by using an input-output energy analysis of the energy sectors (Nieuwlaar, 1992). These ERE values do not contain energy requirements of materials, capital goods, etc. used in the energy sectors. The indirect energy requirements calculated with the input-output tables include these energy requirements. The Nieuwlaar study concerns the year 1987. It is assumed that the ERE values for coal products, oil products and natural gas have the same value during the period 1969-1990. For electricity, an ERE value is calculated for this period based on fuel mix and efficiency of the power plants.

The ERE of coal products is based on the conversion in coke factories, since a main part of the category coal products consists of coke. The input-output ratio of coal conversion to coke is about 1.14 in the years 1969-1990 (CBS-NEH). This value multiplied with the ERE of coal extraction, which is 1.10 (Nieuwlaar, 1992), gives the ERE of coal products, 1.25 MJ/MJ. The energy input-output ratio of oil refineries fluctuates during the whole period around 1.07 MJ/MJ (CBS-NEH). By using an ERE value of 1.04 MJ/MJ for oil extraction (Nieuwlaar, 1992), this gives an ERE value of 1.11 MJ/MJ for oil products.

The ERE value of natural gas extraction is 1.01 according to (Nieuwlaar, 1992). Since the losses at gas distribution are minimal, the overall ERE value of gas is also 1.01. The ERE value of electricity depends on the fuel mix and the efficiencies in power stations (Sep, several issues). For the period 1969-1990, the ERE values are calculated on the basis of the fuel mix and

This method implies that the energy use of transport is also assigned to the households and non-industrial sectors. More recent CBS-publications list this energy use separately.
efficiency. It is assumed that all electricity is derived from fossil fuels, although part of electricity is produced by nuclear plants. The share of nuclear electricity in total electricity consumption is low (according to Sep (1991) about 5% in 1990). Table B.3 shows the ERE values of electricity for the period 1969-1988. The distribution of electricity has an ERE value of 1.06 MJ/MJ (Rossum, 1990).

**Table B.3** ERE values of electricity (MJ/MJ) excluding and including distribution for the period 1969-1990 (calculations based on Sep).

<table>
<thead>
<tr>
<th>year</th>
<th>excl.</th>
<th>incl.</th>
<th>year</th>
<th>excl.</th>
<th>incl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>3.09</td>
<td>3.27</td>
<td>1980</td>
<td>2.75</td>
<td>2.91</td>
</tr>
<tr>
<td>1970</td>
<td>2.99</td>
<td>3.16</td>
<td>1981</td>
<td>2.77</td>
<td>2.92</td>
</tr>
<tr>
<td>1971</td>
<td>2.92</td>
<td>3.08</td>
<td>1982</td>
<td>2.74</td>
<td>2.90</td>
</tr>
<tr>
<td>1972</td>
<td>2.88</td>
<td>3.04</td>
<td>1983</td>
<td>2.66</td>
<td>2.81</td>
</tr>
<tr>
<td>1973</td>
<td>2.81</td>
<td>2.97</td>
<td>1984</td>
<td>2.64</td>
<td>2.79</td>
</tr>
<tr>
<td>1974</td>
<td>2.75</td>
<td>2.91</td>
<td>1985</td>
<td>2.64</td>
<td>2.79</td>
</tr>
<tr>
<td>1975</td>
<td>2.74</td>
<td>2.89</td>
<td>1986</td>
<td>2.65</td>
<td>2.80</td>
</tr>
<tr>
<td>1976</td>
<td>2.72</td>
<td>2.87</td>
<td>1987</td>
<td>2.64</td>
<td>2.80</td>
</tr>
<tr>
<td>1977</td>
<td>2.70</td>
<td>2.85</td>
<td>1988</td>
<td>2.64</td>
<td>2.79</td>
</tr>
<tr>
<td>1978</td>
<td>2.70</td>
<td>2.86</td>
<td>1989</td>
<td>2.59</td>
<td>2.73</td>
</tr>
<tr>
<td>1979</td>
<td>2.73</td>
<td>2.89</td>
<td>1990</td>
<td>2.60</td>
<td>2.75</td>
</tr>
</tbody>
</table>

Method 3 (section 5.2.1) uses ERE values which only concern the energy requirements for extraction and transport abroad. These ERE values are 1.10 for coal and 1.04 for crude oil (Nieuwlaar, 1992). The ERE values of natural gas and electricity are set to 1. The energy use data of the energy sectors contain the energy requirements for extraction, production and transport in the Netherlands.

### B.5 CO₂ EMISSION COEFFICIENTS

In a similar way, by using CO₂ emission coefficients, CO₂ emission intensities are calculated. A CO₂ emission coefficient gives the cumulative CO₂ emission per unit of energy (in this study expressed in kg CO₂/GJ). The emission coefficient contains both the emission at extraction and production of the energy carrier and at consumption of the energy carrier. Table 5.A.3 shows these emission coefficients for the energy carriers distinguished in this study, viz. coal
products, oil products, natural gas and electricity.

Just as at the ERE values, the CO₂ emission coefficient of coal products is based on coke. The cumulative CO₂ emission of coke factories is 29.9 kg CO₂ per GJ. At combustion of coke another 103 kg CO₂ per GJ is emitted. So, the CO₂ emission coefficient of coke becomes 132.9 kg/GJ. (Nieuwlaar, 1992). Although this value is for 1987, it is supposed to be the same for the whole period 1969-1990. The coefficient for oil products is based on the cumulative CO₂ emission of refineries, which is 9.1 kg/GJ (Nieuwlaar, 1992). The CO₂ emission at end-use varies from 66 to 73 kg/GJ. This study assumes an average of 69.5 kg/GJ, so the coefficient for oil products becomes 78.6 kg/GJ. The cumulative CO₂ emission of natural gas exploitation is 0.5 kg/GJ (Nieuwlaar, 1992). This value is used for natural gas, because the losses at the distribution of gas are insignificant. The CO₂ emission at the combustion of natural gas is 56 kg/GJ. This results in a CO₂ emission factor of 56.5 kg/GJ.

The CO₂ emission coefficient of electricity is based on the fuel mix and efficiency in the power plants. Since these factors changed in the period 1969-1988, the CO₂ emission coefficient of electricity is calculated for the whole period by using data of efficiency and fuel mix in the power plants (Sep, annually). Table B.4 shows the CO₂ coefficients calculated. The values also contains a factor 1.06 for electricity distribution (Rossum, 1990).

<table>
<thead>
<tr>
<th>year</th>
<th>CO₂ coefficient (kg/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969</td>
<td>247.7</td>
</tr>
<tr>
<td>1970</td>
<td>217.6</td>
</tr>
<tr>
<td>1971</td>
<td>199.4</td>
</tr>
<tr>
<td>1972</td>
<td>187.8</td>
</tr>
<tr>
<td>1973</td>
<td>177.3</td>
</tr>
<tr>
<td>1974</td>
<td>167.9</td>
</tr>
<tr>
<td>1975</td>
<td>166.5</td>
</tr>
<tr>
<td>1976</td>
<td>174.4</td>
</tr>
<tr>
<td>1977</td>
<td>172.5</td>
</tr>
<tr>
<td>1978</td>
<td>181.3</td>
</tr>
<tr>
<td>1979</td>
<td>189.4</td>
</tr>
<tr>
<td>1980</td>
<td>201.9</td>
</tr>
<tr>
<td>1981</td>
<td>206.6</td>
</tr>
<tr>
<td>1982</td>
<td>206.5</td>
</tr>
<tr>
<td>1983</td>
<td>193.5</td>
</tr>
<tr>
<td>1984</td>
<td>191.9</td>
</tr>
<tr>
<td>1985</td>
<td>191.4</td>
</tr>
<tr>
<td>1986</td>
<td>193.3</td>
</tr>
<tr>
<td>1987</td>
<td>196.5</td>
</tr>
<tr>
<td>1988</td>
<td>207.0</td>
</tr>
<tr>
<td>1989</td>
<td>199.9</td>
</tr>
<tr>
<td>1990</td>
<td>209.7</td>
</tr>
</tbody>
</table>
Figure B.1 depicts the CO₂ emission coefficients in table B.4 graphically. The changes in fuel mix at electricity production are evident. In the period between 1969 and 1975, the share of coal decreases in favor of the share of gas. The CO₂ emission coefficient declines by about 33%. After 1975, gas is partly substituted by oil and the share of coal rises again. After 1981, oil gradually disappears as fuel in electricity production and the shares of gas and coal rise. The CO₂ emission coefficient in 1990 is at the same level as in the early 70s.

B.6 TECHNICAL ENERGY CONSERVATION POTENTIALS

Several studies report data concerning the technical energy conservation potentials of production and consumption sectors. This study uses two studies in the calculations (Melman et al., 1993; Beer et al., 1994). The technical energy conservation potential of a sector is the reduction of the energy use in that sector that can be achieved at a certain moment by implementation of the most efficient technology available. The technical conservation potentials only concern energy use for processes. Feedstock energy is not considered. Technical energy conservation potentials take into account the expected improvements in technology. The potentials are based on the level of activities in the base year, so volume changes in production or consumption are not taken into account. The TNO-study and ICARUS-study present conservation potentials for both fuel consumption and electricity consumption. Table B.5 shows the potentials for the input-output production sectors and the households.

3 In this thesis the first study is referred to as the TNO-study and the second one as the ICARUS-study.
Table B.5  Technical energy conservation potentials on fuel (Q) and electricity (E) for the year 2015 in percentages (TNO data derived from Melman et al., 1993; ICARUS data derived from Beer et al., 1994).

<table>
<thead>
<tr>
<th></th>
<th>TNO</th>
<th></th>
<th>ICARUS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>agriculture, horticulture and forestry</td>
<td>83</td>
<td>-12</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>fishing</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>crude oil and natural gas production</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>other mining and quarrying</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>slaughtering and meat-processing ind.</td>
<td>63</td>
<td>-7</td>
<td>55</td>
</tr>
<tr>
<td>6</td>
<td>manufacture of dairy products</td>
<td>53</td>
<td>9</td>
<td>81</td>
</tr>
<tr>
<td>7</td>
<td>processing of fish, fruit and vegetables</td>
<td>53</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>8</td>
<td>grain-processing industry</td>
<td>28</td>
<td>29</td>
<td>57</td>
</tr>
<tr>
<td>9</td>
<td>sugar industry</td>
<td>66</td>
<td>-48</td>
<td>74</td>
</tr>
<tr>
<td>10</td>
<td>flour-processing industry</td>
<td>53</td>
<td>56</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>manufacture of cocoa and chocolate</td>
<td>53</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>12</td>
<td>manufacture of margarine, starch, etc.</td>
<td>34</td>
<td>6</td>
<td>63</td>
</tr>
<tr>
<td>13</td>
<td>beverage industry</td>
<td>60</td>
<td>15</td>
<td>79</td>
</tr>
<tr>
<td>14</td>
<td>tobacco-processing industry</td>
<td>53</td>
<td>9</td>
<td>53</td>
</tr>
<tr>
<td>15</td>
<td>wool industry</td>
<td>36</td>
<td>25</td>
<td>73</td>
</tr>
<tr>
<td>16</td>
<td>cotton industry</td>
<td>36</td>
<td>25</td>
<td>73</td>
</tr>
<tr>
<td>17</td>
<td>knitting and hosiery industry</td>
<td>36</td>
<td>25</td>
<td>73</td>
</tr>
<tr>
<td>18</td>
<td>textiles industry</td>
<td>59</td>
<td>25</td>
<td>73</td>
</tr>
<tr>
<td>19</td>
<td>clothing industry</td>
<td>33</td>
<td>8</td>
<td>73</td>
</tr>
<tr>
<td>20</td>
<td>leather, footwear and other leatherware</td>
<td>33</td>
<td>8</td>
<td>73</td>
</tr>
<tr>
<td>21</td>
<td>wood and furniture industry</td>
<td>33</td>
<td>8</td>
<td>64</td>
</tr>
<tr>
<td>22</td>
<td>paper and cardboard industry</td>
<td>50</td>
<td>15</td>
<td>69</td>
</tr>
<tr>
<td>23</td>
<td>paperware and corrugated cardboard ind.</td>
<td>33</td>
<td>8</td>
<td>44</td>
</tr>
<tr>
<td>24</td>
<td>printing, publishing and related ind.</td>
<td>33</td>
<td>8</td>
<td>40</td>
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<tr>
<td>25</td>
<td>petroleum industry</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>26</td>
<td>chemical basic products industry</td>
<td>29</td>
<td>7</td>
<td>32</td>
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<tr>
<td>27</td>
<td>chemical final products industry</td>
<td>29</td>
<td>7</td>
<td>32</td>
</tr>
<tr>
<td>28</td>
<td>rubber and plastic-processing industry</td>
<td>33</td>
<td>8</td>
<td>43</td>
</tr>
<tr>
<td>29</td>
<td>manufacture of building materials, etc.</td>
<td>45</td>
<td>7</td>
<td>50</td>
</tr>
<tr>
<td>30</td>
<td>basic metal industry</td>
<td>16</td>
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<td>30</td>
</tr>
<tr>
<td>31</td>
<td>manufacture of metal products</td>
<td>58</td>
<td>5</td>
<td>77</td>
</tr>
<tr>
<td>32</td>
<td>machinery</td>
<td>58</td>
<td>5</td>
<td>77</td>
</tr>
<tr>
<td>33</td>
<td>electrotechnical industry</td>
<td>58</td>
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<td>77</td>
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<tr>
<td>34</td>
<td>automobile industry</td>
<td>58</td>
<td>5</td>
<td>77</td>
</tr>
<tr>
<td>35</td>
<td>manufacture of transport equipment</td>
<td>58</td>
<td>5</td>
<td>77</td>
</tr>
<tr>
<td>36</td>
<td>manufacture of instr. and optical goods</td>
<td>33</td>
<td>8</td>
<td>43</td>
</tr>
<tr>
<td>37</td>
<td>electricity generation</td>
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<td>0</td>
<td>0</td>
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<td>39</td>
<td>water supply</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>construction and installation</td>
<td>0</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>41</td>
<td>wholesale trade and retail trade</td>
<td>45</td>
<td>26</td>
<td>55</td>
</tr>
<tr>
<td>42</td>
<td>hotels, restaurants, cafes etc.</td>
<td>69</td>
<td>39</td>
<td>50</td>
</tr>
<tr>
<td>43</td>
<td>repair of consumer goods</td>
<td>58</td>
<td>36</td>
<td>55</td>
</tr>
<tr>
<td>44</td>
<td>sea and air transport</td>
<td>25</td>
<td>0</td>
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<tr>
<td>45</td>
<td>other transport storage</td>
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<td>10</td>
<td>40</td>
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<tr>
<td>46</td>
<td>communication</td>
<td>78</td>
<td>53</td>
<td>84</td>
</tr>
</tbody>
</table>
The conservation potentials in the TNO-study concern the so-called net energy use of several sectors in 2015 in relation to 1986. The net energy use takes into account additional electricity consumption for environmental measures. Although our base year is 1990, the given potentials are used here under the assumption that in the period 1986-1990 only few of the savings indicated have been realized. The base year of the ICARUS-study is 1990. In the ICARUS-study the data for both studies have been compared (Beer et al., 1994). The energy potentials show that the data of the ICARUS-study are more optimistic than the TNO data.

Thus far, the determination of the energy and CO₂ savings in the households did not take into account the savings potentials that can be realised in the energy supply system. The TNO-study does not pay attention to the energy supply system; the ICARUS-study does so. Considerable savings can be achieved at the extraction of primary energy and at the production of electricity (e.g. more efficient plants and a different mix of fossil fuels). In the calculations a 10% improvement in the conversion of coal, mineral oil and natural gas is assumed. The ICARUS-study indicates for the refineries a technical energy conservation potential of 14%. This has been implemented here as improvement in the ERE-values of the energy carriers. ICARUS gives for electricity production an efficiency of 49.7% in 2015 with a fuel mix of 60% natural gas, 30% coal and 10% nuclear and imports. In the calculations presented here, a fossil fuel mix of 67% natural gas and 33% coal is used.