A Guide to the AIM/ENDUSE Model - Technology Selection Program with Linear Programming -

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Contents

1 The AIM/ENDUSE model

The AIM/ENDUSE model was developed as a tool for estimating enduse energy consumption so as to evaluate the available countermeasures and select appropriate energy conservation technologies.

This manual explains the technology selection program (**engd**) with linear programming and its data files. The first memo on the program **engd** based on linear programming was opened as of August 22, 1993. The program has been modified since then and was revised largely at the late of 1995. This technical/user manual consists of

- Economic criteria of technology selection
- Model formulation with LP
- Implementation of the Enduse model
- Description of input data files
- A simple example - example1 -
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2 Economic criteria of technology selection

The AIM/ENDUSE model accounts for final consumption of energy based on actual energy use and the way energy services are performed by energy devices. Energy consumption is not an objective in itself. Rather energy is used to provide energy services such as heating, cooking, lighting, and passenger and goods transport. This program provides the combination of energy devices to be used in the total system so as to minimize the total cost for supplying energy services. Energy consumption used in this system is then calculated for estimating CO_2 emissions. The total cost consists of purchase costs, running costs, emission dues and other related costs and is expressed in an annual term as follows:

$$\text{Total cost} = \sum_{\text{energy devices in the system}} \{\text{energy device cost (including gas emission cost)} + \text{related costs}\} \quad (1)$$

The total cost is expressed in two ways; ALC (Annualized Life-cycle Cost) and PTC (Payback Time Cost). ALC converts a purchase price to an annual cost by considering repayment period and a discount rate. PTC compares initial costs of energy devices based on payback time. The annual cost by ALC is estimated as follows:

$$ALC = P \cdot [P \rightarrow M]_L^\theta + \sum_{\text{energy types}}^{N} E_k \cdot p_k \quad (2)$$

where, P is a present value of the technology including every cost except for energy costs. $[P \rightarrow M]_L^\theta$ is a capital recovery factor that converts a purchase price to an annual price. E_k is energy consumption of the k-th energy type and p_k is its energy price. A capital recovery factor is calculated as follows:

$$[P \rightarrow M]_L^\theta = \frac{\theta(1+\theta)^L}{(1+\theta)^L - 1} \quad (3)$$

where, θ is an interest rate and L is recovery time of the technology.

The cost based on PTC is calculated as follows:

$$PTC = \frac{P}{T} + \sum_{\text{energy type}}^{N} E_k \cdot p_k \quad (4)$$

where, T is a standard payback time.

The system consists of energy devices that provides energy services by consuming energy supplied from outside of the system. Energy services should be provided more than required. Energy devices are grouped by their introduced year and the group is called a cohort. The service devices of the same cohort have the same characteristics; the device type, the technological level and the remaining lifetime. Each cohort is an element of the system and its amount is a system variable. If the old device has reached its scheduled replacement time, its cohort is removed from the system. The energy device technologies are selected at each time period based on several conditions such as old stocks of devices, reformable devices and available new devices so as to supply energy service demands. Several assumptions are made in this program on available energy technologies, reformable technologies and so on.

Each energy device produces more than one energy service using more than one type of energy. Each energy device has its technological level, labeled 1, 2, 3, $\cdots$. The amount of an energy device is expressed in terms of the service amount by the device. The technological level of the same device type introduced in the same year is identical. The number is labeled according to its introduced year, that is, the newly introduced technology has larger number of technological level than that of the old ones. The service efficiency, energy efficiency and purchase price are the same if the devices with the same technological level are introduced in the same year. Cohorts may be replaced when service demands are changed, life time is over and/or new technology is introduced. The following three types of selecting processes are checked. The first is to replace the old device by a new device, because the remaining life time of the old one is over. When a service demand is increased, a new device will be also introduced. The second one is to reform the old device. The third is to introduce an energy conservative device, although the old device can still be operative. When checking the introduction of a new device, the cost equation (2) or (4) is calculated. In case of reforming the old device, the difference of the purchase price of the old device and the reformed device is considered. The cost in the third case is the same as in the first case. In this case, the purchase cost of the existing device is considered to be the dead weight cost and is not summed to the total cost.

3 Model formulation with LP

3.1 Model elements

3.1.1 Final energy services (SV)

A final energy service is one that is produced by a set of energy devices and supplied to outside of the system. The unit of energy service depends on the kind of service. The amount of energy service demands are given exogenously by the service demand table (`scenario.srv`). The measurement unit is specified independently. For example, an unit of cooling is cooking kwh/year and an unit of lighting is average energy consumption per household per year in 1985.

3.1.2 External energy types (ENG)

Service devices use different types of energy such as electricity, coal, oil and gas to produce energy services. There are two types of energy; external and internal energy types. In the case of external energy type, the total amount of energy used in the system is supplied from outside. Energy that is partly or totally generated in the system is called internal energy type. Internal energy type is explained in section 3.1.4. A unit of energy should be consistent in the sytem. That is, the unit of energy given in a technology basic table (`scenario.tec`) should be identical with that given in the table of energy price and CO_2 emission factor (`scenario.peg`). Sometimes external energy types include goods that are not used as energy. A measurement unit of such goods is not necessarily coincide with energy unit.

3.1.3 Service devices (SD)

A service device supplies more than one energy service by consuming more than one type of energy. A main service of a service device is called the standard service. A stock of a service device is defined so that it supplies a unit of its standard service. The result does not depend on which service is assumed to be its standard service. A service device is characterized by its type (SD), its engineering level (ENGNG), its life time (LIFE, year), its initial cost (PFIX), energy consumption per unit stock (ENGDSD), energy services supplied by unit stock (SDPSD). The total number of service devices is *NSD*.

A unit stock of a service device that does not consume energy is defined by its reduction rate. The effects of heat insulating material in the household sector can be measured by the amount of saved energy. For example, suppose that by using house insulation, the amount of energy used for space heating is reduced by 60% and that for cooling is reduced by 80%. Assume the standard service by house insulation is space heating, and the energy consumed by space heating and cooling is measured by the amount of energy used by the average household with a private house in a base year, say 1985. Then a unit stock of house insulation for an average house per year performs 0.4 heating service and 0.2 cooling service.

In case of handling a complicated system, it is sometimes easier to have a virtual device that hypothetically converts energy to services for handling system constraints. This will be explained in detail in section 7.

3.1.4 Internal energy/service types

Some or total amount of internal energy/service type is generated and used in the system. Electricity generated by a co-generation device in the system is an example of the internal energy/service type. Energy imported or exported as the internal energy/service types is not treated in the model. Its energy use and related carbon exchange should be counted elsewhere.

3.2 Characteristics of service devices

A service device is characterized by its type, its technological level and its introduced year. A group of service devices that have same characteristics is called a cohort.

3.2.1 Technological factors

$A_{j,i}$: The amount of the j-th service performed by a unit of the i-th cohort.
$E_{i,k}$: The amount of the k-th energy used by a unit of the i-th cohort.
L_i: The remaining life time (usable years) of the i-th cohort.

3.2.2 Cost coefficients

P_i: The initial cost of a unit of the service device of the i-th cohort.

3.3 System variables

The controllable system variables when considering the introduction of service devices are explained in this section. The total number of the system variables is *LP_VAR*. The range of its reference number is displayed in [ ]. *LP_VAR* equals *N4V*. The total number of cohorts is *ISD* and equals *N3V*.

3.3.1 Stocks of service devices

The service devices that have already been introduced and are used without reform in the current stage. The range of old stocks is [*1, N1V*].

3.3.2 Reformed devices

The service devices that have already been introduced and are reformed in the current stage. The range of reform stocks is [*N1V+1, N2V*].

3.3.3 Purchased devices

The service devices that are purchased in the current stage. The range of recruit stocks is [*N2V+1, N3V*].

3.3.4 Internal energy purchased from outside

Internal energy is defined as an energy type that is generated in the system. Sometimes the total amount of internal energy used in the system can not be generated in the system and some part should be purchased. The difference of the internal energy demand and generated energy is called internal energy purchased. The range of internal energy purchased is [*N3V+1, N4V*].

3.4 Constraints

In addition to each system variable being non-negative, there are several constraints on the stocks of service devices, the amount of energy services, the amount of external energy and the amount of internal energy/services. The range of constraint equations is displayed in [ ].

3.4.1 Constraints on old stocks (previously introduced devices)

The stock of the previous stage, x_{0i}, is equal to or greater than the sum of the unreformed stock, x_i, and reformed stock, $x_{i'}$, of the corresponding cohorts in the current stage.

$$x_i + x_{i'} \leq x_{0i}, \qquad i = 1, N1V \qquad [1, N1C] \tag{5}$$

If some of the service devices of the i-th cohort are reformed, a new cohort, the i'-th cohort, is generated whose components are the reformed service devices of the i-th cohort.

3.4.2 Constraints on reformable devices

Suppose $X_{rf,s}$ be the reformable units of the service device type s in the current stage, then the following constraint is applied.

$$\sum_{i=N1V}^{N2V} \delta_{sd,s,i} \cdot x_i \leq X_{rf,s}, \qquad [N1C + 1, N2C] \tag{6}$$

where, $\delta_{sd,s,i}$ equals 1 when the service devices type of the i-th cohort is s, and 0 if it is otherwise. NSD is the number of the service device types and s is between 1 and NSD.

3.4.3 Constraints on newly introducible devices

Suppose $X_{rc,i}$ be the maximum amount of service devices of the i-th cohort that can be introduced, then the newly introduced devices of the i-th cohort should be below that.

$$x_i \leq X_{rc,i}, \qquad i = N2V + 1, N3V \tag{7}$$

In case that the total amount of introducible devices of the device type s is limited, the following constraint is applied:

$$\sum_{i=1}^{N3V} \delta_{sd,s,i} \cdot x_i \leq X_{rc,s}, \tag{8}$$

where $X_{rc,s}$ is the maximum amount of introducible devices of the device type s.

When the service of the service device type s to the j-th service is limited by its rate, constraints are given as follows:

$$\sum_{i=1}^{N3V} \delta_{sd,s,i} \cdot A_{j,i} \cdot x_i \leq U_{s,j} \sum_{i=1}^{N3V} A_{j,i} \cdot x_i \tag{9}$$

where, $U_{s,j}$ is the maximum rate of the j-th service supplied by the service device type s. s is between 1 and NSD. The range of equations (7) $\sim$ (9) is $[N2C + 1, N3C]$.

3.4.4 Constraints on meeting energy service demands

The energy service performed by the energy device should satisfy the enduse service demand.

$$\sum_{i=1}^{N3V} A_{j,i} \cdot x_i \geq S_j, \qquad j = 1, NSV \qquad [N3C + 1, N4C] \tag{10}$$

where, S_j is the enduse demand of the j-th energy service. NSV is the sum of final and internal energy services. When j represents a final energy service, S_j is the amount of the final service. In the case of an internal energy service, S_j is the amount of the internal service subtracted by internal energy purchased.

$$S_j = -x_l + \sum_{i=1}^{N3V} x_i \cdot E_{i,l}, \qquad l = N3V + 1, N4V \tag{11}$$

where, l is the number of the internal energy that corresponds to the j-th internal service.

3.4.5 Constraints on energy supply

When the supply of the k-th external energy is limited, the following constraint is applied:

$$\sum_{i=1}^{N3V} x_i \cdot E_{i,k} \leq Q_{k'}, \qquad k' = 1, NENGCST \tag{12}$$

where, $Q_{k'}$ is the maximum energy supply potential of the k'-th energy. Energy types are numbered sequentially. k' is the sequential number excluding unlimited energy, while k is the sequential number including both limited and unlimited energy. In case of internal energy, the following constraint is applied:

$$x_k \leq Q_{k'}, \qquad k' = 1, NENGCST \tag{13}$$

where $NENGCST$ is the number of energy constraints. The range of equations (12) ~ (13) is $[N4C+1, N5C]$.

3.5 Objective function

The final objective is to find shares of energy devices that minimize the following costs.

$$\sum_{i=1}^{N3V} C_i \cdot x_i \rightarrow minimum \tag{14}$$

where, in case of ALC method, cost coefficient, C_i is expressed as follows:

$$C_i = \begin{cases} (1-\varepsilon \cdot L_i) \cdot \sum_{k=1}^{NENERGY} E_{i,k} \cdot p_k & \text{if} \quad i = 1, N1V \\ (1-\varepsilon \cdot L_i) \cdot \left\{ (P_i - P_i^{old}) \cdot [P \rightarrow M]_{L_i}^{\theta} + \sum_{k=1}^{NENERGY} E_{i,k} \cdot p_k \right\} & \\ & \text{if} \quad i = N1V+1, N2V \\ (1-\varepsilon \cdot L_i) \cdot \left\{ P_i \cdot [P \rightarrow M]_{L_i}^{\theta} + \sum_{k=1}^{NENERGY} E_{i,k} \cdot p_k \right\} & \\ & \text{if} \quad i = N2V+1, N3V \\ p_{k'} & \text{if} \quad i = N3V+1, N4V \end{cases} \tag{15}$$

where, ε is a small positive number and is used to select the older energy devices to be replaced when there are more than two cohorts with the same cost. $NENERGY$ is the total number of energy types. p_k is the energy price of the k-th energy. P_i is the purchase price of the i-th cohort. P_i^{old} is the purchase price of the old device with the lower technological level that will be reformed to be the member of the i-th cohort. This equation shows that the reform cost is the difference of the cost of the reformed device and that of unreformed one. The cost of the k'-th internal energy, $p_{k'}$, that will be purchased from outside is the energy price corresponding to the i-th energy type.

In case of PTC, $[P \to M]^{\theta}_{L_i}$ is replaceed with $1/\min\{T, L_i\}$, where T is a standard payback time.

Table 1: program and data files for example1

File name	Contents
programs	
pcaim.exe	main program
input data files	
example1.ctl	parameter control file for example1
example1.tec	technology basic table for example1
example1.shr	technology share bound table for example1
example1.imp	technology improvement table for example1
example1.peg	table of energy price and CO_2 emission factor for example1
example1.srv	service demand table for example1
output data files	
example1.log	log file of LP processes for example1
example1.ot1	output file of service demand, energy consumption, etc. for example1

4 Implementation of the ENDUSE model

The model is coded with fortran programming language.

4.1 The flow diagram of the program

Figure 1 shows the model flow of the program.

Table 1 shows the list of the program and data files that are necessary to run a simple example - example1-.

4.2 Compilation and run

The enduse program is now running under unix and MS-dos.

To run the pcaim.exe, use explorer and double click pcaim icon. Input scenario name of 8 characters. After the program was run, scenario.ot1 will be created. Use this file to analyze the result.

For checking input data and LP coefficients, set `DEBUG` parameter to be `ON` in the parameter control file (*scenario*`.ctl`). The outputs are printed in the LP log file (*scenario*`.log`).

4.3 Error messages

Errors are listed for input data and LP processes. When solution of LP is infeasible or infinite, the message of `infeasible solution` or `infinite solution` is printed.

The LP program is infeasible when there are theoretical errors in input data, especially in the technology share bound table (*scenario*`.shr`), and the service demand table (*scenario*.`srv`), and/or there are great difference in the order of variables. In the latter case, it may possible to clear errors by modifying their orders. Some of shares should be greater than 1.

5 Description of input data files

This chapter shows how to make input data files.

5.1 Necessary input data files and basic rules

There are seven types of input data files as shown in Table 2. The files with (∗) are requisite and others are made upon request. Data files are written in a text format. A file name of eight characters expresses scenario name (`scenario`), its extension of three characters expresses a type of data files. (`ctl, tec,shr, imp, srv, peg` and `seg`).

Table 2: Input data files necessary for Enduse model (seven types)

File name	Contents
scenario.`ctl`	lists of control parameters (∗)
scenario.`tec`	basic characteristics of energy devices (∗)
scenario.`shr`	bounds of shares of devices
scenario.`imp`	possible improvement of technology
scenario.`srv`	service demand (∗)
scenario.`peg`	energy price and CO_2 emission factor (∗)
scenario.`seg`	maximum potential of energy supply

A line starting with '#' is a comment line. A set of data is written in a line, and each item is divided by more than one blank. It should be noted that when information on service share and/or energy prices is given, data before the first produced year and after last produced year should be given. This is because missing data are interpolated by using such information.

5.2 Parameter control file (*scenario*.`ctl`)

Parameters used in computation are written in the parameter control file. One parameter is written in a line in the following format. Blanks should not be inserted before and after '='.

'keyword of parameter' = 'value of parameter'

The list of keywords of parameters are given in Table 3. If *INTEREST* does not equal 0, an annualized life-cycle cost with a capital revulsion rate is adopted. Otherwise, a payback time cost with a payback time *YEAR_CR* is applied.

5.3 Technology basic table (*scenario*.`tec`)

Eleven items of data are listed in a technology basic table. They are a device number (No.), a device code (CODE_SD), a service code (K_SV), an energy code (KENG), a

Table 3: List of keywords of parameters

Keyword	Contents	Example
INTEREST	interest rate	0.03
YEAR_S	start year of calculation	1955
YEAR_E	end year of calculation	2010
YEAR_TAX	introduced year of carbon tax	1995
CARBONTAX	rate of carbon tax	3×10^{-6} (1,000 yen/gC)
YEAR_CR	standard capital revulsion year	10 (years)
DEBUG	flug for debug	ON or OFF

Table 4: An example of a technology basic table (a part)

```
#----------------------------------------------------------------------------
#NO.  CODE_SD K_SV KENG IENGNG PRICE LIFE Y_STRT Y_END SV_SD ENG_SD  notes
#----------------------------------------------------------------------------
# Coke making processes
 IST01 STCKF1  ZC1  COL   1   5000   30   1930   2010  36.74  51.80
 IST01 STCKF1  ZC1  ZUT   1   5000   30   1930   2010  36.74   3.06
 IST01 STCKF1  ZC1  ZEL   1   5000   30   1930   2010  36.74   0.43
 IST01 STCKF1  ZCG  COL   1   5000   30   1930   2010   9.66  51.80
 IST02 STCKF2  ZC1  COL   1    450   30   1930   2010  36.74  51.80
 IST02 STCKF2  ZC1  ZUT   1    450   30   1930   2010  36.74   3.02
 IST02 STCKF2  ZC1  ZEL   1    450   30   1930   2010  36.74   0.43
 IST02 STCKF2  ZCG  COL   1    450   30   1930   2010   9.66  51.80
```

technological level (IENGNG), an initial price (PRICE), life time (LIFE), first produced year (Y_START), last produced year (Y_END), amount of service (SV_SD) and energy consumption (ENG_SD). An example of a technology basic table is shown in Table 4.

11 fields are used for specifying basic information. An additional item (notes) can be written in the 12th field.

5.3.1 Device number (No.)

A device number has 5 characters. The first three characters represent a sector and the other two characters represent a reference number in the sector. This device number has no meaning in calculation.

5.3.2 Device code (CODE_SD)

A device code has 6 characters. The same device has the same device code.

5.3.3 Service code (K_SV)

A service code has three characters. A service code of an internal service starts with `Z` and that of related goods starts with `Y`.

5.3.4 Energy code (KENG)

An energy code has three characters. An energy code of internal energy starts with `Z`, and that of related goods starts with `Y`. If internal energy exists, internal service of the same code should be given.

5.3.5 Technological level (IENGNG)

Technological levels are numbered sequentially $1, 2, \ldots$ from old technologies. If a service device has only one technology, its technologial level is 1.

5.3.6 Initial price (PRICE)

A unit of a service device is identical with that of energy price (*scenario*.**peg**).

5.3.7 Amount of service (SV_SD)

An amount of energy service supplied by an energy device. A unit of service depends on service itself and be identical with that given in the service demand table (*scenario*.`srv`). It is better to set the unit of energy service so that the amount of energy service can be written in a few orders.

5.3.8 Energy consumption (ENG_SD)

Energy consumption per unit of energy device.

5.3.9 Miscellaneous

If a device uses multiple energy types and supplies multiple energy services, such information is given in multiple lines. In that case, the amount of device is assumed to be the same, and corresponding initial cost, amount of service and energy consumption are listed.

5.4 Technology share bound table (*scenario*.shr)

A technology share bound table is one that presents maximum potential share of energy service that a device can supply. For the past share, actual share should be given. This file is necessary only for the device whose share is limited. An example of a technology share bound table is shown in Table 5.

Table 5: An example of a technology share bound table (a part)

```
#----------------------------------------------------------------------
#  No. CODE_SD K_SV MAXIMP TYPE YEAR1 SHARE1 YEAR2 SHARE2 YEAR3 SHARE3
#----------------------------------------------------------------------
 IST01  STCKF1  ZC1  MAX%  LIN  1950   1.01  1990  0.951  2010  1.01
 IST02  STCKF2  ZC1  MAX%  LIN  1950   0.00  1990  0.05   2010  1.01
```

5.4.1 Device number (No.)

The device reference number is identical with that given in a technology basic table.

5.4.2 Device code (CODE_SD)

The device code is identical with that given in a technology basic table.

5.4.3 Service code (K_SV)

A service type whose share is limited.

5.4.4 MAXIMP

`MAX%` shows that share is limited by its maximum ratio.

5.4.5 Interpolation method (TYPE)

An interpolation method is specified. 'LIN' corresponds to linear interpolation, and 'RAT' interpolates data with geometric interpolation.

5.4.6 YEAR1,SHARE1,YEAR2,SHARE2,...

A data is given by pairs of year and share. The total share should be greater than 1 when shares of the all device types are specified.

5.5 Technology improvement table (*scenario*.imp)

Technology efficiency and its cost are given when technology is improved. An example of a technology improvement table is given in Table 6.

5.5.1 Device number (No.)

The device number is identical with that corresponding to the technology basic table.

Table 6: An example of a technology improvement table (a part)

```
#----------------------------------------------------------------------------------
#No  CODE_SD K_SV KENG IENGNG IMP_KIND TYPE YEAR1 IMP1 YEAR2 IMP2 YEAR3 IMP3
#----------------------------------------------------------------------------------
RES01 DCOOL1 DAC ELR 1 ENG LIN 0 213.1 1980 213.1 1985 199.2 1990 192.4 2010 175.0
RES02 DCOOL2 DAC ELR 1 ENG LIN 0 567.2 1980 567.2 1985 530.3 1990 512.2 2010 465.7
RES03 DCOOL3 DAC ELR 1 ENG LIN 0 649.8 1980 649.8 1985 607.6 1990 586.8 2010 533.5
RES04 DCOOL4 DAC ELR 1 ENG LIN 0 633.3 1980 633.3 1985 592.1 1990 571.9 2010 520.0
```

5.5.2 Device code (CODE_SD)

The device code is identical with that given in the technology basic table.

5.5.3 Service code (K_SV)

A service type whose service efficiency is improved, is specified if an improvement type (IMP_KIND) is 'SRV'. Otherwise, any service type supplied by that device is given.

5.5.4 Energy code (KENG)

An energy type whose energy efficiency is improved, is specified if an improvement type (IMP_KIND) is 'ENG'. Otherwise, any energy type used by that device is given.

5.5.5 Technological level (IENGNG)

Technological level corresponding to that given in the technology basic table.

5.5.6 Improvement type (IMP_KIND)

'ENG' means that efficiency of energy consumption is improved. 'SRV' means efficiency of energy service is improved, and 'PRC' means an initial cost is down.

5.5.7 Types of interpolation (TYPE)

The interpolation method is specified. 'LIN' means linear interpolation, and 'RAT' interpolates data with geometric interpolation.

5.5.8 YEAR1,IMP1,YEAR2,IMP2,...

A data set is given by pairs of year and improved data (IMP; energy consumption, service, or a purchase price). The total number of sets are less than ten.

5.6 Service demand table (*scenario*.srv)

For all service types, necessary demands should be listed. 0 of intermediate service means that it is not supplied to outside from the system. An example of a service demand table is shown in Table 7.

Table 7: An example of a service demand table (a part)

```
# ----------------------------------------------------------------------------------
#No  K_SV TYPE YEAR1 QSV1 YEAR2 QSV2    YEAR3  QSV3    YEAR4  QSV4    YEAR5  QSV5
# ----------------------------------------------------------------------------------
IST01 HSP LIN  1900   1  1973 32330000 1975 26395000 1980 25776000 1985 22853000
IST02 CSP LIN  1900   1  1973 25405000 1975 23607000 1980 32253000 1985 37384000
IST03 ZC1 LIN  1900   0  9999    0
IST04 ZCG LIN  1900   0  9999    0
```

5.6.1 Device number (No.)

A device number corresponds to that in the technology basic table.

5.6.2 Service code (K_SV)

It should be noted that data are given for all service types.

5.6.3 Interpolation methods (TYPE)

The service demand is interpolated with the given data. 'LIN' uses a linear function and 'RAT' uses a geometric function.

5.6.4 YEAR1,QSV1,YEAR2,QSV2,...

A data set is given by pairs of year (YEAR) and service demand (QSV). The total number of sets are less than 10.

5.7 Table of energy price and CO_2 emission factor (*scenario*.peg)

CO_2 emission factor and energy price for each energy type are given in Table 8.

5.7.1 Reference number (No.)

A reference number in this file.

Table 8: An example of a table of energy price and CO_2 emission factor (a part)

```
#-----------------------------------------------------------------
#No. KENG CO2_COEF CHGP_ENG YEAR1 PRICE1 YEAR2 PRICE2 YEAR3 PRICE3
#-----------------------------------------------------------------
 1  COL  10422     LIN      1900    116  1990    116  9999    116
 2  COK  10612     LIN      1900    337  1990    337  9999    337
 3  CKG  10612     LIN      1900    337  1990    337  9999    337
 4  OLG   7658     LIN      1900   1321  1990   1321  9999   1321
 5  OLK   7775     LIN      1900    481  1990    481  9999    481
```

5.7.2 Energy code (KENG)

Energy types given in the technology basic table should be listed in this file.

5.7.3 CO_2 emission factor (CO_2COEF)

CO_2 emission factor. Its standard unit is $gC/10^2$Mcal. In case of related goods, their units are coincident with the unit of the goods. The standard unit of limestone (CEK) is gC/ton.

5.7.4 Interpolation method (CHGP_ENG)

The interpolation method is specified for energy price. 'LIN' uses linear and 'RAT' uses geometric interpolation, respectively.

5.7.5 YEAR1,PRICE1,YEAR2,PRICE2,...

A data set is given by pairs of year (YEAR) and energy price (PRICE). Total sets are less than 10.

5.7.6 Miscellaneous

An example of energy code (KENG) and CO_2 emission factor (CO_2COEF) is shown in Table 9.

5.8 Maximum energy supply (*scenario*.seg)

Maximum energy suppy is given only for specifying the limited energy. A standard unit of energy is 10^2Mcal. In case of internal energy, the amount purchased from outside is written. An example of a maximum energy supply table is shown in Table 10.

Table 9: Standard values of CO_2 emission factors

CO_2COEF (gC/10^8cal)

energy type	KENG	this model	JEA	IPCC/OECD
COL	coal	10422	10422	10810
COK	coke (purchased)	10612	12300	12361
CKG	coke oven gas (purchased)	10612	-	-
OLG	gasoline	7658	7658	7919
OLK	kerosene	7775	7748	8212
OLL	diesel oil	7839	7839	8464
OLH	heavy oil (C)	8180	8180	-
OLO	other petroleum products	7737	-	8380
LPG	LPG	6883	6883	7207
GAS	gas	5639	5693	6411
SOR	solar power	0	-	-
ELR	electricity for household	12128	-	-
ELC	electricity for service sector	12128	-	-
ELI	electricity for industry	12128	-	-
VAP	steam	0	-	-
JET	jet fuel	7665	7665	8171
OLC	oil coke	10612	10612	11523
OLN	naphtha	7605	7605	8380
BLK	kraft black liquid	10751	10751	-
BRK	bark	10751	-	-
OIL	crude oil	7811	7811	8380
CEK	limestone	120000 gC/ton	-	-
WHT	waste heat	0	-	-
YSR	scraped (purchased) iron	0	-	-
YIR	iron ore	0	-	-
ZC1	electricity by co-generation	0	-	-
ZCG	coke oven gas	0	-	-
ZCK	coke (internal)	0	-	-
ZSI	sinter	0	-	-
ZMT	hot metal	0	-	-
ZBG	blast furnace gas	0	-	-
ZUT	UTILITY	0	-	-
ZST	molten steel	0	-	-
ZFG	basic oxygen furnace gas	0	-	-
ZSP	slabs, blooms, billets	0	-	-
ZHS	hot rolled steel products	0	-	-
ZSR	scraped (internal) iron	0	-	-

Table 10: An example of a maximum energy supply table (a part)

```
#---------------------------------------
#No  KENG  TYPE   YEAR1 SSV1  YEAR2  SSV2
#---------------------------------------
 1   SOR   LIN   1950  0.0   9999   0.0
 2   ZEL   LIN   1950  0.0   9999   0.0
 3   ZUT   LIN   1950  0.0   9999   0.0
```

5.8.1 Reference number (No.)

A reference number in this file. It is an independent number and is not used in the calculation.

5.8.2 Energy type (KENG)

An energy type whose energy supply is limited.

5.8.3 Interpolation method (TYPE)

Maximum energy supply is interpolated with given data. 'LIN' uses a linear function and 'RAT' uses a geometric function.

5.8.4 YEAR1,SSV1,YEAR2,SSV2,...

A data set is given by pairs of year (YEAR) and maximum energy supply (SSV). The total sets are less than ten.

6 A simple example - example1 -

6.1 Model of example1

This chapter explains how to use enduse model by a simple example. Figure 2 shows an energy flow of this model. There are two service devices; independent power generation devices (OCODE1,2) and a cooling device (OCOOL1). The independent power generation devices (OCODE1,2) use heavy oil (OLH) and supply electricity (ZEL) and hot water (OHW). The cooling device (OCOOL1) uses gas (GAS) and generated electricity (ZEL) for supplying cooling service (OAC).

6.2 Input data file

Six input files shown in Table 11 are used. The maximum energy supply table (`example1.seg`) is not used here.

Table 11: Input files for example1

file name	contents
example1.ctl	parameter control file
example1.tec	technology basic table
example1.shr	technology share bound table
example1.imp	technology improvement table
example1.peg	table of energy price and CO_2 emission factor
example1.srv	service demand table

6.2.1 Parameter control file

Table 12 illustrates the contents of the parameter control file for example1. As *YEAR_TAX* > *YEAR_E*, carbon tax is not introduced here. As *INTEREST = 0.0*, a payback time method is used.

Table 12: Parameter control file (`example1.ctl`)

```
INTEREST=0.0
YEAR_S=1955
YEAR_E=2010
YEAR_TAX=2020
CARBONTAX=3.0E-6
YEAR_CR=35.0
DEBUG=ON
```

6.2.2 Technology basic table

Table 13 shows the technology basic table. It is assumed as a technology scenario that a new type of an individual power generation device (OCODE2) will be introduced from 1980. This new type generation device supplies twice service, consumes 2/3 energy compared to the old type. The initial cost of the new device is twice compared with that of the old one.

Table 13: Technology basic table (`example1.tec`)

# No.	CODE_SD	K_SV	KENG	IENGNG	PRICE	LIFE	Y_START	Y_END	SV_SD	ENG_SD	notes
EXP01	OCODE1	OHW	OLH	1	100	20	1950	9999	10	300	power generation
EXP01	OCODE1	ZEL	OLH	1	100	20	1950	9999	50	300	
EXP02	OCODE2	OHW	OLH	1	200	20	1980	9999	20	200	
EXP02	OCODE2	ZEL	OLH	1	200	20	1980	9999	100	200	
EXP03	OCOOL1	OAC	GAS	1	50	10	1950	9999	50	50	cooling
EXP03	OCOOL1	OAC	ZEL	1	50	10	1950	9999	50	10	

6.2.3 Technology share bound table

Table 14 shows the bounds of technology share. The old type generation device (OCODE1) has 100% share till 1980 when a new type device is introduced for supplying electricity (ZEL). In 1990, the new type is allowed to be less than 20% share. After 2010, there is no bound for introducing a new type device.

Table 14: Technology share bound table (`example1.shr`)

#No.	CODE_SD	K_SV	MAXIMP	TYPE	YEAR1	SHARE1	YEAR2	SHARE2	YEAR3	SHARE3	YEAR4	SHARE4
EXP01	OCODE1	ZEL	MAX%	LIN	1950	1.01	1980	1.01	1990	0.81	2010	1.01
EXP02	OCODE2	ZEL	MAX%	LIN	1950	0.00	1980	0.00	1990	0.20	2010	1.01

note: When the total number is less than 1, the model is infeasible. Sometimes 1 is expressed as 0.99999 in the computer, it is recommened that the total number is greater than 1.

6.2.4 Technology improvement table

Table 15 shows information on technology improvement. Only cooling device (OCOOL1) is improved. The improved type is energy (ENG). The energy efficiency is constant from 1950 to 1980, improved linearly from 1980 to 2000, and constant after that.

Table 15: Technology improvement table (`example1.imp`)

```
#------------------------------------------------------------------------------
# No. CODE_SD K_SV KENG IENGNG IMP_KIND TYPE  YEAR1 IMP1 YEAR2 IMP2 YEAR3 IMP3
#------------------------------------------------------------------------------
 EXP03 OCOOL1  OAC  ZEL  1  ENG  LIN   1950 50 1980 50 1990 45 2000 40 2010 40
#------------------------------------------------------------------------------
```

Table 16: Service demand table (`example1.srv`)

```
#-----------------------------------------------------------------------------
# No.  K_SV TYPE  YEAR1 QSV1  YEAR2 QSV2  YEAR3 QSV3  YEAR4 QSV4  YEAR5 QSV5
#-----------------------------------------------------------------------------
 EXP01  OHW  LIN  1950  100   1985  120   1995  130   2000  150   2010   150
 EXP02  OAC  LIN  1950  500   1985  600   1995  800   2000  950   2010  1000
 EXP03  ZEL  LIN  1950  0.0   9999  0.0
#-----------------------------------------------------------------------------
```

6.2.5 Service demand

Table 16 shows energy service demand. Electricity from independent power generation device (ZEL) is not supplied to outside.

6.2.6 Table of energy price and CO_2 emission factor

Energy prices and CO_2 emission factors taken in this model are shown in Table 17. Energy prices are assumed to be constant.

Table 17: Table of energy price and CO_2 emission factor (`example1.peg`)

```
#-----------------------------------------------------------------------
# No. CODE_ENG CO2_COEF CHGP_ENG YEAR1 PRICE1 YEAR2 PRICE2 YEAR3 PRICE3
#-----------------------------------------------------------------------
 1    OLH      8180      LIN      1900   259   1990   259   2010   259
 2    GAS      5639      LIN      1900  1071   1990  1071   2010  1071
 3    ZEL      0.0       LIN      1900  0.00   9999  0.00
#-----------------------------------------------------------------------
```

Table 18: An example of outputs, a part of `example1.ot1`

```
SHSV__SD OHW 1995 0.13000E+03 0.13000E+03 OCODE1  59.7 OCODE2  40.3
SHSV__SD ZEL 1995 0.00000E+00 0.65000E+03 OCODE1  59.8 OCODE2  40.3
SHSV__SD OAC 1995 0.80000E+03 0.80000E+03 OCOOL1 100.0
SHENG_SD OLH 1995 0.28535E+04 0.28535E+04 OCODE1  81.7 OCODE2  18.3
SHENG_SD GAS 1995 0.80000E+03 0.80000E+03 OCOOL1 100.0
SHENG_SD ZEL 1995 0.69286E+03 0.69286E+03 OCOOL1 100.0
ETENG_SD ENG 1995 0.36535E+04 OCODE1  63.8 OCODE2  14.3 OCOOL1  21.9
ETENG_EG ENG 1995 0.36535E+04 OLH  78.1 GAS  21.9
SHCO2_SD OLH 1995 0.23342E+08 0.23342E+08 OCODE1  81.7 OCODE2  18.3
SHCO2_SD GAS 1995 0.45112E+07 0.45112E+07 OCOOL1 100.0
SHCO2_SD ZEL 1995 0.00000E+00 0.00000E+00 : This energy is closed.
CTENG_SD CO2 1995 0.27853E+08 OCODE1  68.4 OCODE2  15.4 OCOOL1  16.2
CTENG_EG CO2 1995 0.27853E+04 OLH  83.8 GAS  16.2
```

6.3 Results

The program outputs `example1.log` and `example1.ot1`. In this section, the results when **lpsolve** is selected as a LP solver is given. `example1.log` is an output file for logging the results of LP calculation processes. `example1.ot1` is an output file for printing energy consumption, supplied services and CO_2 emissions in the format shown in the next section. The explanation of `example1.log` is skipped here, because it needs a large amount of spaces. A part of its result in 1995 is given in Annex A.

6.4 `example1.ot1`

Table 18 shows data of `example1.ot1` in 1995. The first field shows what kind of data is given in that line. It has 8 characters composed of two characters, three characters, an underline and two characters. Table 19 shows the meaning of these codes.

6.4.1 SHSV__SD

An amount of service supplied to outside of the system (external service), total amount of service including internal and external services, and service share of each service devices are shown in the line starting `SHSC__SD`. In Table 18, these data are listed for services, OHW, ZEL and OAC. For example, the total amount of the service `OHW` is 0.13×10^3. Its 59.7% is supplied by the device `OCODE1`, giving $0.13\times10^3\times0.597$ service. In case of intermediate service (ZEL), as it does not supply the energy to outside of the system, the number of the 4-th field is zero.

Table 19: The meaning of codes used in `example1.ot1`

Code	Meaning
First two characters	
SH	The *4*-th field is data for each service type or energy type
ET	The *4*-th field is total energy consumption
CT	The *4*-th field is total CO_2 emission
The *3*-rd to it 5-th characters	
SV_	The *4*-th field is service amount
ENG	The *4*-th field is energy consumption
CO2	The *4*-th field is CO_2 emission
The *7*-th to *8*-th characters	
SD	After the *5*-th or *6*-th filed, share data for service devices
EG	After the *5*-th or *6*-th filed, energy share data

6.4.2 SHENG_SD

An amount of energy supplied to the system from outside (external energy), total amount of energy including internal and external energy, and energy share of each energy type are shown in the line starting `SHENG_SD`. In Table 18, these data are listed for energy types, OLH, GAS and ZEL. For example, the total amount of energy `OLH` used in the system is 0.285×10^4. Its 81.7% is supplied by the device `OCODE1`, giving $0.285\times10^4\times0.817$ energy.

6.4.3 ETENG_SD

Total external energy consumption and external energy consumption for each device are shown in the line starting `ETENG_SD`. For example, total external energy consumption is 0.36535×10^4 and the device OCODE1 is supplied its 63.8%, that is $0.36535\times10^4\times0.638$ energy.

6.4.4 ETENG_EG

Total external energy consumption and external energy consumption for each energy type are shown in the line starting `ETENG_EG`. For example, total external energy consumption is 0.36535×10^4 and the energy OLH supplies its 78.1%, that is $0.36535\times10^4\times0.781$ energy.

6.4.5 SHCO2_SD

Total CO_2 emission for each energy type and CO_2 emission from each device are shown in the line starting `SHCO2_SD`. Energy type is given in the second field. In Table 18, these data are listed for energy type, OLH, GAS and ZEL. For example, the total amount of CO_2 emission from energy type `OLH` is 0.23342×10^8 and its 81.7% is from the device `OCODE1`, giving $0.23342 \times 10^8 \times 0.817$ emission.

6.4.6 CTENG_SD

Total CO_2 emission and CO_2 emission from each device are shown in the line starting `CTENG_SD`. For example, the total amount of CO_2 emission from all energy type 0.27853×10^8 and its 68.4% is from the device `OCODE1`, giving $0.27853 \times 10^8 \times 0.684$ emisson.

6.4.7 CTENG_EG

Total CO_2 emission and CO_2 emission from each energy type are shown in the line starting `CTENG_SD`. For example, the total amount of CO_2 emission from all energy type 0.27853×10^8 and its 83.8% is from the energy type `OLH`, giving $0.27853 \times 10^8 \times 0.838$ CO_2 emisson.

6.5 Technology selection

Table `example1.ot1` gives some information on technology selection. Technology selection for individual power generation device is considered here. This example assumes that a new type of power device (OCODE2) is first introduced in 1980, giving 20% service in 1990. Its share will be increased and it may possible to give 100% service in 2010. This model uses linear programming for selecting service devices with information on initial costs, energy consumption and service efficiency. Figure 3 shows the shares of electricity generated by independent power generation device (old and new types). This figure shows that after 2010 when there is no limitation for introducing new type devices, the old type devices are completely replaced by new type devices. 3 shows the result for hot water supply (OHW). A similar result is also obtained in the case for electricity (ZEL).

6.6 CO_2 emissions

The output file `example1.ot1` gives also information on CO_2 emission. For examples, Figure 4 shows total CO_2 emissions. Figure 5 shows CO_2 emission by energy type. Figure 6 shows CO_2 emission by energy device.

7 An example - an iron and steel industry -

7.1 Model of the example - an iron and steel industry -

This chapter explains the end-use model with a relatively complicated model of an iron and steel industry. The CO_2 emission from the iron and steel industry in Japan is 45.0MtonC in 1985 and 48.0MtonC in 1990. They share 37.0%(1985) and 35.1%(1990) of CO_2 emissions from the industrial sector, taking the largest share. Coal is the major source of CO_2 emissions. This model takes the following three types of steel making processes.

- Hot metal from the blast furnace is transformed to the basic furnace, which refines it into steel (hereafter, called the blast furnace process).
- The electric arc furnace plant produces steel using ferrous scrap as a raw material (hereafter, called the electric arc furnace process).
- The smelting reduction furnace produces hot metal with iron ore and coal (hereafter, called the smelting reduction process).

An open-hearth furnace is not treated here, because it is not used in Japan. Figure 7 shows the production processes by each method.

The blast furnace and the electric arc furnace are operating now. The smelting reduction method is a revolutionary iron making process and is now under development. It can reduce iron ore with coal that is cheaper than coke. Figure 8 shows the model of the iron and steel industry that is explained in detail in the next section.

7.2 Model description

7.2.1 External energy and related goods

There are four types of external energy shown in Figure 8. They are coal (COL), limestone (CHK), purchased coke (CEK) and purchased electricity (ELI). Iron ore (YOR) and scrap (YSR) are treated as related goods. Each external energy and related goods are explained below.

Coal(CEL) Main energy as well as related goods. Its CO_2 emission factor is high, that is, 10422 gC/10^8cal. Energy price is assumed to be 116 yen/10^8cal. This is used as energy and related goods in a coke oven, a sintering machine and a blast furnace. It is also used in the smelting reduction process.

Limestone (CHK) Limestone is treated as related goods in the sintering process. This model does not account CO_2 emission from limestone.

Purchased coke (COK) In the blast furnace process, in addition to coke generated from coke ovens (ZCK), coke is purchased from outside of the system. It is also treated as external energy to UTILITY device for producing internal energy (ZUT). CO_2 emission factor of purchased coke is 10612gC/10^8cal. Its price is 337 yen/10^8cal. The price of internal energy (ZCK) is 0 yen. If the amount of internal energy is not sufficient for the demand, purchased coke (COK) is given as external energy.

Purchased electricity (ELI) Purchased energy is not directly used in the production process. It is summed to electricity generated by the power device and then used in the processes. Its CO_2 emission factor is assumed to be 12128gC/10^8cal for accounting CO_2 emission from the energy conversion sector. Its price is 1538 yen/10^8cal.

Iron ore (YIR) Iron ore is related goods used in the sintering and smelting reduction processes.

Scrap (YSR) Scrap is related goods used in an electric arc furnace.

7.2.2 Final service

The final services in the iron and steel industry are hot rolled steel products (HSP) and cold rolled steel products (CSP). Their service demands are given exogenously in the service demand table (`indsteel.srv`). For example, the demand of HSP is 2.054×10^7(ton) and that of CSP is 4.206×10^7(ton) in 1990.

7.2.3 Internal energy/service

Energy and/or service produced in the system that is not final service (HSP or CSP) is internal energy/service. Furnace gases and waste heat are examples of internal energy/services. Hot coke generated from a coke oven is internal service as well as internal energy supplied to a coke quenching machine as shown in Figure 8.

Furnace gases (such as cove oven gas, blast furnace gas and basic oxygen furnace gas) and purchased coke (COK) are input to control terminals (used as energy devices in this model) called STUTL and then treated as internal energy/service called utility (ZUT). This utility energy (ZUT) is used by the individual power generating device as well as by other devices.

Waste heat from a coke quenching machine (ZEC) and a blast furnace (ZEF) is converted to internal electricity (ZEL) by the power generating devices (STELE3,STELE4).

7.2.4 Independent power generating device

An independent power generating device generates internal electricity (ZEL) by consuming utility energy (ZUT). Its energy efficiency is assumed to be 40%. The total amount of energy used in the system is supplied by internal electricity (ZEL). Purchased electricity (ELI) is input to internal electricity (ZEL).

7.2.5 Control terminal of the system flow

A parallelogram in Figure 8 shows a terminal called a control terminal of the system flow. It is a virtual device added for convenience. STELE1, STEEEE and STUTL1 $\sim$ 4 in Figure 8 are such terminals.

STUTL1 $\sim$ 4 convert furnace gas (coke oven gas (ZCG), blast furnace gas (ZBG) and basic oxygen furnace gas (ZFG)) and purchased coke (COK) into internal energy (ZUT).

STEEEE is used for the following reason. Assume that the future share bound of coarse steel products by electricity arc furnaces is given totally and not given by each device. A flow control terminal (STEEEE) is allocated at the down stream from an electric arc furnace and controls the share of coarse steel from electric arc furnace. The purchase price of the device is 0 yen and an unit of service is supplied by unit energy.

Figure 9 shows the electric and utility flows of the system.

7.3 Input data files

Seven input data files are used in the model as shown in Table 20. The lists of these files are given in Annex B.

Table 20: Input data files in the steel industry

File name	Contents
`indsteel.ctl`	paremeter control file
`indsteel.tec`	technology basic table
`indsteel.shr`	technology share bound table (including a standard and an energy saving scenarios)
`indsteel.imp`	technology improvement table
`indsteel.srv`	service demand table
`indsteel.peg`	table of energy price and CO_2 emission factor
`indsteel.seg`	maximum energy supply table

7.3.1 Energy consumption by service devices

In the technology basic table (`indsteel.tec`), the amount of energy corresponding to produce one ton coarse steel is given. In the computer simulation process, as it is better to use a value close to one, the unit is assumed to be 10^8cal/ton-coarse steel. Table 21 shows energy consumption of coal (COL), purchased coke (COK), internal electricity (ZEL) and utility (ZUT) by the major service devices for blast furnace processes.

7.3.2 Service by service devices

The amount of energy service is given in a unit corresponding to produce one ton coarse steel. That is 10^8cal/ton-coarse steel like the unit of energy consumption.

Table 22 shows the amounts of services supplied by the major service devices in the blast furnace processes. The unit service of that tables is the amount of the annual service divided by the annual coarse steel production of 76,374kton.

7.3.3 Introduction price

An introduction price is given in terms of investigating devices for producing one ton of coarse steel.

7.4 Technology selection

In the iron and steel industry, the three types of processes of making steel (the blast furnace, electric arc furnace and smelting reduction processes) are treated in one energy

Table 21: Energy consumption of the major devices in blast furnace processes

upper row: annual energy consumption
lower row: energy consumption per unit service
(10^8cal/ton-coarse steel)

Process (Device code)	Coal (COL)	Purchased coke (COK)	Electricity (ZEL)	Utility (ZUT)
Coke oven (STCKF1)	41157000	0	83.5	600.4
	(Gton)		(Mcal/ton-Coal)	(Mcal/ton-Coal)
	0	0	0.726	5.22
Sintering machine (STCKD1)	0	0	35.7	0
			(kWh/ton-sinter)	
	0	0	0.407	0
Blast furnace (BISTBF1)	441	462.5	28.8	39
	(Mcal/ton-coal)	(Mcal/ton-coke)	(kWh/ton-hot metal)	(Mcal/ton-coal)
	4	4.89	0.262	0.412
basic oxygen furnace (STSNT1)	0	0	79.9	17.7
			(Mcal/ton-coarse steel)	(Mcal/ton-coarse steel)
	0	0	0.799	0.177
Continuous caster (CISTAF1)	0	0	458	67.6
			(kWh/ton-coarse steel)	(Mcal/ton-coarse steel)
	0	0	0.726	5.22
Reheating furnace (RISTRH1)	0	0	234	380
			(Mcal/ton-hot rolled products)	(Mcal/ton-hot rolled products)
	0	0	2.23	3.62
Annealing furnace (ISTRH1)	0	0	507	442.3
			(Mcal/ton-cold rolled products)	(Mcal/ton-cold rolled products)
	0	0	2.94	2.57

Table 22: Energy service by the major devices by the blast furnace processes

service unit: 10^8cal/ton-coarse steel

Process	Service type	Annual service	Unit Service
coke oven (STCKF1)	hot coke (ZC1)	27845(10^{10}kcal)	36.46
	coke furnace gas (ZCG)	-	9
sintering machine (STCKD1)	sinter(ZSI)	101187(kton)	1.324
blast furnace (ISTBF1)	hot metal (ZMT)	80730(kton)	1.057
	blast furnace gas (ZBG)	1534Nm^3	32.43
Basic oxygen furnace (STSNT1)	coarse steel(ZST)	76374(kton)	1
	basic oxygen furnace gas (ZFG)	-	2.074
continuous caster (ISTAF1)	slabs (ZSP)	111709(kton)	1
reheating furnace (ISTRH1)	hot rolled products (HSP)	106740(kton)	0.955
annealing furnace (ISTRH1)	cold rolled products (CSP)	64586(kton)	0.58

flow system. It is possible to calculate the effects of different energy saving system at the same time in this model. For example, introduction of a smelting reduction furnace or an electric arc furnace, and selection of energy saving devices in the blast furnace and the electric arc furnace processes can be checked totally. The service devices enclosed by boxes, and flows of electricity and utility shown in Figure 8 are candidates for selecting devices except the sintering machine in the blast furnace process. As no alternative devices for sintering processes is listed. It is possible to control the introduction of technology for coarse steel production by the share bound table (`indsteel.shr`). For electric arc furnace processes, as there are alternatives in the arc furnaces, a system control terminal (STEEEE) is allocated to control the whole production of coarse steel and to select the more economic arc furnace. The technology basic table (`indsteel.tec`) in Annex B shows alternative devices in detail.

7.5 Scenario setting

7.5.1 Service demand

Scenario data on hot and cold rolled steel products are shown in Table 23. The data from 1970 to 1990 shows the past records and data from 1991 are given by scenarios. The value between the given data are interpolated with linear functions.

Table 23: Service scenario in the iron and steel industry

service unit: 10^7ton

year	1985	1990	2000	2010
hot rolled products (HSP)	4.139197	4.215558	3.509452	3.509452
cold rolled products (CSP)	5.694222	6.458508	5.376708	5.376708

Table 24: Share bound scenario in the iron and steel industry

Scenario name	Standard scenario				Energy saving scenario			
year	**1985**	**1990**	**2000**	**2010**	**1985**	**1990**	**2000**	**2010**
basic oxygen furnace (ISTOF1)	70%	68%	65%	60%	70%	68%	65%	65%
electric arc furnace (STEEEE)	30%	32%	35%	35%	30%	32%	35%	35%
smelting reduction furnace (STDIOS)	0%	0%	0%	5%	0%	0%	0%	65%

7.5.2 Technology share bound in the iron and steel industry

The shares of the basic oxygen, the electric arc and the smelting reduction furnaces are given by actual past record from 1970 to 1990. These data are given by scenarios from 1991. There are two scenarios. The standard scenario limits the share of the smelting reduction furnace to 5% in 2010. The upper share by the saving scenario in 2010 is 65%. This is shown in Table 24.

7.6 Simulation results

The simulation outputs several items of information to output file (`indsteel.ot1`) from the start year of simulation. It is better to split the file for arranging the output data as shown in Table 25.

For arranging the data, several softwares or commands can be used such as Excel and **grep** (UNIX command). For making `shsv__.hsp`, the following command is typed.

```
> grep "SHSV__SD HSP" indsteel.ot1 > shsv__sd.hsp
```

Table 25: An example of splitting outputs of `indsteel.ot1`

File name	Contents
`cteng_eg.co2`	total CO_2 emission and its share by energy types
`cteng_sd.co2`	total CO_2 emission and its share by devices
`eteng_eg.eng`	total energy consumption and its share by energy types
`eteng_sd.eng`	total energy consumption and its share by devices
`shsv__sd.`*sd*	amount of service and share of devices by service types (*sd*)
`sheng_sd.`*eng*	energy consumption and share of devices by energy types (*eng*)
`shco2_sd.`*eng*	CO_2 emission and share of device by energy types (*eng*)

7.6.1 Comparison of CO_2 emissions

Figure 10 shows the CO_2 emission with the standard and energy saving scenarios.