MULTILEVEL COMPUTER MODEL OF WORLD DEVELOPMENT SYSTEM

User Oriented Descriptions

A SERIES: PART III. THE ENERGY SUPPLY MODEL

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THE ENERGY SUPPLY MODEL

ABSTRACT

The Energy Supply Model is a simulation model for detailed planning of a regional energy system from the primary energy inputs to secondary energy distribution to the final user. The model structure consists of a network of elementary allocation, collection and conversion processes. Thirteen different primary and seven secondary energy forms are considered. The model incorporates some twenty-five conversion processes. All presently conceivable energy forms and conversion processes are included. Exports, imports, as well as concentrated and distributed waste energies are accounted for. Primary and secondary energy costs, capital investment in conversion plants and the number of plants are computed. The flexibility of the model allows the simulation of a wide variety of possible energy supply systems.

I. MATHEMATICS OF THE MODEL

The mathematics of the model--although of some complexity--are rather simple.

At first the annual values of energy inputs, allocation fractions, etc. are calculated by means of linear interpolation using the time-series given on the data deck.

Energy flows are then computed by multiplying the input energy flow by the respective parameter, e.g. the flow of solar energy allocated to central electric power generation is:

$$ESOEL = ESOL \cdot FSOEL$$

Converting ESOEL into electrical energy generates a flow to waste energy:

$$WSOL = ESOEL \cdot (1-CESOL)$$

where CESOL denotes the respective conversion efficiency. From these flows total waste energy, total useful energy and energy flows going to end-user sectors are calculated by summing up analogous flows, e.g. total energy going to industry is:

$$EIN = EELIN + EHTIN + ESFIN + EGSIN + ELFIN + ESOIN$$

The right side denoting the respective flows of electrical energy (EELIN), central heat (EHTIN), solid fuel (ESFIN), gaseous fuel (EGFIN), liquid fuel (ELFIN), and decentralized solar energy (ESOIN) to the industrial sector.

Energy costs are computed by multiplying amounts of energy by the corresponding energy price specified in the scenario.

Thus the mathematics of the model consist only of multiplications and additions. Nevertheless, the model is a complex one because of the many energy types and conversion processes considered.

II. TERMINAL INPUT AND DATA BASE

A. Request from the Model

Due to the complexity of scenario data required for running the ESP-Model an interactive mode seemed neither desireable nor advantageous for users. Thus the only request during the run-time of the model will be:

"ENTER NDRU (13) FOR OUTPUT CONTROL"

The array NDRU is used to control the output that is actually produced on the lineprinter. One has to specify NDRU(I) = 1 to get the I-th page of the printout and NDRU(I) = 0 to supress it.

As for the batch-version of the ESP-MODEL which may be run on the CYBER 74 at Technische Hochschule in Vienna, NDRU is the last record to be read just after the scenario data that are dealt with below. In this case the data deck consists of 113 cards instead of 112.

B. Data

Since the ESP-Model does not contain any fixed parameters (allocation fractions, conversion efficiencies, user efficiencies, energy prices) running the simulation requires the careful preparation of a 'scenario' prescribing each of the parameters over the time period of interest (usually 1970 to 2025).

The input data deck consists of 112 cards specifying time-series for 100 parameters, 24 parameters which remain constant during the computation and some label specifications for the printing program. The time-series are limited to 12 datapoints per parameter corresponding to 5 or 10 year time increments for a computation period of 55 or 110 years respectively. Each time-series fits on one data card per format 12F6.2. Data cards are labelled in columns 73 - 80 to facilitate exchange of individual time-series. The input data are the following:

LABELR: Region label with up to 40 characters

LABELS: Scenario label with up to 40 characters

LABUDR: Label with energy units for tables to be printed (max. 60 characters)

LABCDR: Label with cost units for tables to be printed (max. 60 characters)

LABUCD: Label with energy units and cost units for tables to be printed (max. 60 characters)

LABUPL: Label with energy units for plots to be printed (max. 30 characters)

LABCPL: Label with cost units for plots to be printed (max. 30 characters)

NDATA : Number of data years (usually 12)

IEARS : Data years (usually 1970, 1975, ..., 2020, 2025)

Each of the following 99 time-series consist of as many values as indicated by NDATA.

ETOT : Total primary net energy input

EFUT : Hypothetical futuristic energy input

ESOL : Solar energy input

EGEO : Geothermal energy input

EFUS : Fusion energy input

ENUC : Nuclear energy input

EHYD : Hydro-power energy input

EIEL : Imported electricity

EBIO : Wood, wastes and bio-matter

ETSL : Tar sands and oil shale

EOL : Crude oil input

ECL : Energy input from coal and lignite

EILF : Imported liquid fuel

EGS : Energy input from gas

ENIMP : Total imported energy

EXBCV : Exports before conversion

EINU : Imported nuclear energy

EIGS : Imported gas

EIOL : Imported crude oil

EICL : Imported coal

ENUEX : Exported nuclear energy

EGSEX : Exported gas

EOLEX : Exported crude oil

ECLEX : Exported coal

EGSFD : Exported gas for field use

The following 33 time-series are the energy allocation fractions before conversion of:

FSOHT : Solar energy going to central heat plants

FSOEL : Solar energy to central electric power generation

FGEHT : Captured geothermal energy to central heat plants

FBIGL : Wood, wastes and bio-matter to gasification and liquefaction

FBIHP : Wood, wastes and bio-matter to central heat and electric power plants

FBIW : Bio-energy going to gasification and liquefaction that is lost in gasification and liquefaction processes

FBILF : Bio-energy going to gasification and liquefaction that is converted to liquid fuels

FTSW : Energy in oil shale and tar sands that is lost in gasification and liquefaction processes

FTSLF : Energy in oil shale and tar sands converted to liquid fuels

FOLW : Energy in oil going to refining that is lost in the refining process

FOLLF : Energy in oil going to refining that is converted to liquid fuels

FCLCH : Coal going to non-energy use (chemicals)

FCLGL : Coal going to gasification and liquefaction

FCLUS : Coal going to decentralized use

FCLW : Coal energy for gasification and liquefaction that is lost in the gasification and liquefaction processes

FCLLF : Coal energy for gasification and liquefaction that is converted to liquid fuels

FSYGX : Domestically produced synthetic gas energy going to export

FGSFC : Total gas energy going to large central fuel cell installations

FGSCH : Total gas energy going to non-energy uses (fertilizers, plastics, chemicals)

FGSHT : Total gas energy going to central heat plants

FGSPR : Total gas energy going to central electrical power generation by combustion

FSYFX : Domestically produced liquid fuel energy going to export

FLFPR : Total liquid fuel energy going to central electric power generation by combustion

FLFFC : Total liquid fuel energy going to large central fuel cell installations

FLFCH : Total liquid fuel energy going to non energy uses

FLFHT : Total liquid fuel energy going to central heat plants

FSFPR : Solid fuel energy to central heat and power plants going to central electric power generation by combustion

FCBS : Total fuel energy going to combustion in standard electric power plants (1970 efficiency)

FH2EX : Energy in total hydrogen generated centrally by heat or electrolysis going to export

FELEX : Total electric energy generated centrally going to export

FELH2 : Total electric energy generated centrally going to central generation of hydrogen by electrolysis

FHTH2 : Total useful heat energy generated centrally going to central generation of hydrogen

FNUHT : Nuclear energy going to central heat plants

Fractions of energy distribution to users:

FELRC : Total electrical energy going to residential/ commercial sector

FELIN : Total electrical energy going to industrial sector

FHTRC : Total central heat going to residential/commercial sector

FHTIN : Total central heat going to industrial sector

FSFRC : Total solid fuel energy going to residential/ commercial sector

FSFIN : Total solid fuel energy going to industrial sector

FGSRC : Total gaseous fuel energy going to residential/ commercial sector

FGSIN : Total gaseous fuel energy going to industrial sector

FLFRC : Total liquid fuel energy going to residential/ commercial sector

FLFIN : Total liquid fuel energy going to industrial sector

FSORC : Total decentralized solar energy going to residential/ commercial sector

FSOIN : Total decentralized solar energy going to industrial sector

Efficiencies of central conversion processes. If you want to have an efficiency of 50% for a certain conversion process you have to set the corresponding factor equal to 0.5. Since efficiency may vary in the future time-series are used.

CEFUT : Hypothetical future energy to electricity

CRFUT : Fraction of rejected heat recovered from process

CESOL : Solar energy to electricity

CEGEO : Geothermal energy to electricity

CRGEO : Fraction of rejected heat recovered from process

CEFUS : Fusion energy to electricity

CRFUS : Fraction of rejected heat recovered from process

CENUC : Nuclear energy to electricity

CRNUC : Fraction of rejected heat recovered from process

CEHYD : Hydropower to electricity

CETRA : Transmission of electricity over large distances

CECBS : Combustion heat to electricity by standard 1970 processes

CRCBS : Fraction of rejected heat recovered from process

CECBA : Combustion heat to electricity by advanced process

CRCBA : Fraction of rejected heat recovered from process

CEFCL : Fuel energy to electricity in fuel cells

CSOHT : Solar energy to central process heat

CGEHT : Geothermal energy to central heat

CHTCB : Fuel energy to heat of combustion in large plants

CHTRC : Heat recovered from electricity generating processes to central heat

CELH2 : Electrical energy to hydrogen energy by electrolysis

CHTH2 : Heat energy to hydrogen energy by heat process

CHTUT : Transmission of heat over intermediate distances

CNUHT : Nuclear energy to heat.

Efficiencies of user sector:

CERC : Average efficiency of energy use in residential/commercial

CEIN : Average efficiency of energy use in industrial sector

CELTR : Average efficiency of electrical energy use in transportation

CSFTR : Average efficiency of solid fuel energy use in transportation

CLFTR : Average efficiency of liquid and gaseous fuel energy use in transportation.

The last four cards, which are also read per format 12F6.2 contain the prices for primary and secondary energies as well as the capital investment per installed KW effective.

Primary energy prices:

PEFUT: Hypothetical futuristic

PESOL: Solar

PEGEO: Geothermal

PEFUS: Fusion

} Card No. 109

PENUC: Nuclear

PEHYD: Hydro

PEIEL: Exported electricity

PEBIO: Wood, wastes, biomatter } Card No. 109

PETSL: Tar sands and oil shale

PEOL: Crude oil

PECL: Coal and lignite

PEILF: Imported liquid fuel

PEGS: Gas Card No. 110

Secondary_energy_prices_to_user.

PREL: Electricity

PRHT: Heat

PRSF: Solid fuel } Card No. 111

PRGS: Gaseous fuel

PRLF: Liquid fuel

PRSO: Solar energy

Remark: Of course energy prices have to be chosen in accordance with the energy unit.

Capital_investment_per_installed_KW_effective.

PIEGL: Gasification and liquefaction plants, refineries, shale oil plants

PIEEL: Electric power plants } Card No. 112

PIEHT: Central heat plants

PIEH2: Central generation of hydrogen

Output Control

NDRU (I), I = 1,13 : Array used for controlling lineprinter output. Used only for batch-version of the model. } Card No. 113

UNITED STATES
ADVANCED TECHNOLOGY MIX WITHOUT NUCLEAR POWER (US3)
BILLIONS OF METRIC TONS OF COAL EQUIVALENT PER YEAR
BILLIONS OF UNINFLATED 1974 US DOLLARS PER YEAR
US DOLLARS PER METRIC TON OF COAL EQUIVALENT
10**9 MTCE PER YEAR
10**9 US DOLLARS PER YEAR
12

1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	IEARS
2.41	2.50	2.59	2.84	3.02	3.20	3.38	3.64	3.93	4.14	4.42	4.72	ETOT
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	EFUT
0.0	0.0	0.0	0.01	0.02	0.04	0.06	0.10	0.15	0.20	0.30	0.40	ESOL
0.0	0.0	0.01	0.03	0.04	0.06	0.08	0.10	0.12	0.15	0.18	0.20	EGEO
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	EFUS
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ENUC
0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.10	0.10	0.10	0.10	EHYD
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	EIEL
0.0	0.04	0.08	0.16	0.24	0.32	0.38	0.44	0.54	0.56	0.58	0.60	EBIO
0.0	0.0	0.03	0.06	0.08	0.11	0.15	0.21	0.25	0.25	0.25	0.25	ETSL
1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.07	1.04	1.0	0.95	0.9	EOL
0.45	0.51	0.61	0.77	0.87	0.99	1.12	1.27	1.43	1.62	1.83	2.07	ECL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	EILF
0.82	0.80	0.70	0.65	0.60	0.50	0.40	0.35	0.30	0.26	0.23	0.20	EGS
0.29	0.25	0.21	0.17	0.17	0.17	0.16	0.16	0.15	0.15	0.14	0.14	ENIMP
0.06	0.07	0.08	0.11	0.12	0.14	0.15	0.17	0.20	0.22	0.23	0.26	EXBCV
0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	EINU
0.04	0.05	0.06	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.04	EIGS
0.25	0.20	0.15	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	EIOL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	EICL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ENUEX
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	EGSEX
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	EOLEX
0.06	0.07	0.08	0.11	0.12	0.14	0.15	0.17	0.20	0.22	0.23	0.26	ECLEX
0.09	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.02	EGSFD
0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.05	0.05	0.05	0.05	0.05	FSOHT
0.0	0.0	0.0	0.0	0.0	0.05	0.07	0.10	0.15	0.20	0.25	0.30	FSOEL
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FGEHT
0.0	0.0	0.02	0.10	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.50	FBIGL
1.0	1.0	0.98	0.90	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.50	FBIHP

0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	FBIW
0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	FBILF
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	FTSW
0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	FTSLF
0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	FOLW
0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	FOLLF
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	FCLCH
0.0	0.0	0.02	0.07	0.1	0.2	0.3	0.35	0.40	0.45	0.50	0.50	FCLGL
0.41	0.39	0.37	0.35	0.33	0.31	0.30	0.28	0.26	0.24	0.22	0.20	FCLUS
0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	FCLW
0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	FCLLF
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FSYGX
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FGSFC
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	FGSCH
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FGSHT
0.18	0.15	0.12	0.10	0.09	0.07	0.05	0.05	0.05	0.05	0.05	0.05	FGSPR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FSYFX
0.1	0.09	0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	FLFPR
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FLFFC
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	FLFCH
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FLFHT
0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	FSFPR
1.0	1.0	1.0	0.95	0.93	0.90	0.85	0.83	0.81	0.80	0.78	0.75	FCBS
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FH2EX
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	FELEX
0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.02	0.02	0.02	0.02	0.02	FELH2
0.0	0.0	0.0	0.05	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.50	FHTH2
0.0	0.0	0.0	0.0	0.1	0.13	0.16	0.19	0.21	0.24	0.27	0.30	FNUHT
0.58	0.58	0.58	0.58	0.58	0.58	0.59	0.59	0.60	0.61	0.61	0.62	FELRC
0.42	0.42	0.41	0.41	0.39	0.38	0.37	0.36	0.35	0.34	0.32	0.30	FELIN
0.05	0.05	0.07	0.10	0.13	0.16	0.20	0.25	0.30	0.40	0.45	0.50	FHTRC
0.95	0.95	0.93	0.90	0.87	0.84	0.80	0.75	0.70	0.60	0.55	0.50	FHTIN
0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	FSFRC
0.92	0.93	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	FSFIN
0.42	0.43	0.44	0.45	0.47	0.48	0.49	0.50	0.51	0.53	0.54	0.55	FGSRC
0.55	0.53	0.51	0.50	0.48	0.46	0.45	0.43	0.42	0.40	0.38	0.35	FGSIN
0.22	0.22	0.21	0.21	0.20	0.20	0.19	0.18	0.17	0.16	0.15	0.15	FLFRC
0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	FLFIN
1.0	1.0	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	FSORC

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0.0    0.0    0.01   0.02   0.03   0.04   0.05   0.06   0.07   0.08   0.09   0.10   FSOIN
0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    CEFUT
0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    CRFUT
0.15   0.15   0.15   0.15   0.15   0.15   0.15   0.15   0.15   0.15   0.15   0.15   CESOL
0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   CEGEO
0.0    0.0    0.0    0.05   0.10   0.15   0.20   0.25   0.30   0.35   0.40   0.45   CRGEO
0.30   0.30   0.30   0.30   0.30   0.30   0.30   0.30   0.30   0.30   0.30   0.30   CEFUS
0.0    0.0    0.0    0.0    0.0    0.0    0.50   0.60   0.70   0.70   0.70   0.70   CRFUS
0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    0.3    CENUC
0.0    0.0    0.0    0.05   0.10   0.15   0.25   0.35   0.45   0.50   0.55   0.60   CRNUC
0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   CEHYD
0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   CETRA
0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   0.35   CECBS
0.0    0.0    0.0    0.0    0.05   0.10   0.15   0.20   0.20   0.25   0.25   0.25   CRCBS
0.55   0.55   0.55   0.55   0.55   0.55   0.55   0.55   0.55   0.55   0.55   0.55   CECBA
0.0    0.0    0.0    0.0    0.10   0.15   0.20   0.25   0.30   0.35   0.35   0.35   CRCBA
0.65   0.65   0.65   0.65   0.65   0.65   0.65   0.65   0.65   0.65   0.65   0.65   CEFCL
0.20   0.20   0.20   0.20   0.20   0.20   0.20   0.20   0.20   0.20   0.20   0.20   CSOHT
0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   CGEHT
0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   CHTCR
0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   CHTRC
0.70   0.70   0.70   0.70   0.70   0.70   0.70   0.70   0.70   0.70   0.70   0.70   CELH2
0.60   0.60   0.60   0.60   0.60   0.60   0.60   0.60   0.60   0.60   0.60   0.60   CHTH2
0.80   0.80   0.80   0.80   0.80   0.80   0.80   0.80   0.80   0.80   0.80   0.80   CHTUT
0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   CNUHT
0.75   0.75   0.75   0.80   0.80   0.80   0.85   0.85   0.85   0.85   0.85   0.85   CERC
0.75   0.75   0.75   0.80   0.80   0.80   0.85   0.85   0.85   0.90   0.90    .90   CEIN
0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   0.90   CELTR
0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   0.10   CSFTR
0.20   0.20   0.20   0.25   0.25   0.25   0.30   0.30   0.30   0.30   0.30   0.30   CLFTR
0.0    0.0    3.0    8.0    8.0    0.0    95.0   50.0   20.0   40.0   30.0   55.0   PRICES P
60.0                                                                                 PRICES P
80.0   350.0  70.0   80.0                                                           INV/KW
300.0  60.0   35.0   100.0  80.0   0.0                                             PRICES S
111111111111                                                                         NDRU
```

III. OUTPUT

The program provides quite a voluminous output in the form of tables and plots. In addition a file is written on unit number 4 that can be used as an input file for the Energy-Emission Register.

The actual output on the line printer can be controlled by the array NDRU(I) as already described.

Page 1 : The first page contains region, scenario and unit labels, and a reproduction of the input scenario concerning net primary inputs into region; imports, exports and field use contributing to net inputs.

Page 2 : Reproduction of the input scenario concerning energy allocation fractions before conversion.

Page 3 : Reproduction of the input scenario. Fractions for energy distribution to users, and conversion efficiencies are printed.

Page 4 : Reproduction of the input scenario. The factors for user efficiencies, primary and secondary energy prices, and capital investment per installed KW effective are printed.

These above mentioned pages cannot be suppressed by means of NDRU(I). The following 13 pages can be controlled by setting NDRU(I) = 0 to suppress, or NDRU(I) = 1 to get the I-th of these 13 pages.

Page 5 : Time-series for the net primary input energies with one year increments are printed (computed from the corresponding input time-series).

Page 6 : Time-series for primary energy inputs and costs by group:

COAL : Coal and lignite

GLFUEL : Gas and liquid energies

ECOEN : "Ecological energies": imported electricity, biomatter, hydropower, geothermal, solar

FISFUS : Fission and fusion energy.

Page 7 : Plot of energy input amounts for COAL, GLFUEL, ECOEN, FISFUS and TOTAL of Page 6.

Page 8 : Plot of energy input costs for the above mentioned energy groups.

Page 9 : Time-series for imports and exports of primary and secondary energies.

Page 10 : Gives time-series of the total amounts and total costs of energy import and export.

Page 11 : Plot of import and export total amounts, and total costs corresponding to time-series of page 10. Costs are scaled with a factor 50.

Page 12 : Number of 1000 MWe energy conversion plants, and corresponding cumulative capital investment assuming an operation at 75% utilization. Tables are given for the annual increments and the accumulative values.

Page 13 : Plot of number of 1000 MWe energy conversion plants and corresponding cumulative capital investment corresponding to columns 1 and 4 of page 12.

Page 14 : Table of secondary energies to user sector:

TOTEN : Total amount of secondary energy to user sectors

TOTCOST : Total costs to user sector.

Breakdown by energy kind:

EELUT : Electricity

EHTUT : Central heat

ESFUS : Solid fuel

EGSTU : Gaseous fuel

ELFUS : Liquid fuel

ESOUS : Decentralized solar heat.

Breakdown by end user sectors:

ERC : Energy to residential/commercial sector

EIN : Energy to industrial sector

ETR : Energy to transportation sector

ECHEM : Total energy to non-energy uses (e.g. chemicals)

Page 15 : Plot of secondary energies to user sector. The breakdown by energy kind represented in form of time-series in page 14 is plotted (electricity, central heat, solid fuel, gaseous fuel, liquid fuel).

Page 16 : Plot of secondary energies to user sector. On this page a breakdown by end user sectors is given (residential/commercial, industrial, transportation). In addition total amount, and total cost of secondary energies to user sector are plotted.

Page 17 : The last page provided by the ESP-programme gives time-series for the overall efficiency of energy conversion and distribution as well as for the total amount of concentrated waste heat.

```
      PROGRAM ESUP(INPUT,OUTPUT,EMDAT,TAPE1=INPUT,TAPE9=OUTPUT,
     1TAPE4=EMDAT)
C     ******************************
C     M.P. ENERGY - SUPPLY SUBMODEL
C     ******************************
C
      DIMENSION A(99,12),B(99)
      DIMENSION EPRIN1(14,56),EPRIN2(10,56),EPRIN3(14,56),
     1          EPRIN4(4,56),EPRIN5(6,56),EPRIN6(12,56),NDRU(17) ,
     2 EING(5,121)
      DIMENSION LABELR(35),LABELS(35),LABUDR(30),LABUCD(30),IEARS(12),
     1LABCDR(30),LABUPL(15),LABCPL(15)
      COMMON ETOT,EFUT,ESOL,EGEO,EFUS,ENUC,EHYD,EIEL,EBIO,ETSL,EOL,ECL,
     1EILF,EGS,ENIMP,EXBCV,EINU,EIGS,EIOL,EICL,ENUEX,EGSEX,EOLEX,ECLEX,
     2EGSFD,FSOHT,FSOEL,FGEHT,FBIGL,FBIHP,FBIW,FBILF,FTSW,FTSLF,FOLW,
     3FOLLF,FCLCH,FCLGL,FCLUS,FCLW,FCLLF,FSYGX,FGSFC,FGSCH,FGSHT,FGSPR,
     4FSYFX,FLFPR,FLFFC,FLFCH,FLFHT,FSFPR,FCRS,FH2EX,FELEX,FELH2,FHTH2,
     5FNUHT,FELRC,FELIN,FHTRC,FHTIN,FSFRC,FSFIN,FGSRC,FGSIN,FLFRC,FLFIN
      COMMON FSORC,FSOIN,CEFUT,CRFUT,CESOL,CEGEO,CRGEO,CEFUS,CRFUS,CENUC
     1,CRNUC,CEHYD,CETRA,CECBS,CRCBS,CECBA,CRCBA,CEFCL,CSOHT,CGEHT,
     2CHTCB,CHTRC,CELH2,CHTH2,CHTUT,CNUHT,CERC,CEIN,CELTR,CSFTR,CLFTR
      COMMON PEFUT,PESOL,PEGEO,PEFUS,PENUC,PEHYD,PEIEL,PEBIO,PETSL,PEOL,
     1PECL,PEILF,PEGS,PIEGL,PIEEL,PIEHT,PIEH2,PREL,PRHT,PRSF,PRGS,PRLF,
     2PRSP,ETR,ERC,EIN,ETA,PETT,PLNEW,CAPINV,CAPCUM,EWCON
      COMMON ECLCO,GLFUEL,GLFUCO,ECOEN,ECOCO,FISFUS,FISFCO,TOTCO,ENIMPC,
     1EXBCVC,USEREN,USERCO,EELUT,EHTUT,ESFUS,EGSTU,ELFUS,ESOUS,ECHEM,
     2ESFPR,ESFHT,ELFTR,ELFIN,ELFRC,EGSPR,EGSHT,EGSTR,EGSIN,EGSRC,
     3EUSE,EWAST,ESFTR,ESFIN,ESFRC,ELFPR,ELFHT,EH2EX,ESYGX,ESYFX,EELEX
      COMMON LLL
      EQUIVALENCE (B(1),ETOT)
      LLL = 0
      READ(1,1000) (LABELR(I),I=1,35)
      READ(1,1000) (LABELS(I),I=1,35)
      READ(1,1000) (LABUDR(I),I=1,30)
      READ(1,1000) (LABCDR(I),I=1,30)
      READ(1,1000) (LABUCD(I),I=1,30)
      READ(1,1000) (LABUPL(I),I=1,15)
      READ(1,1000) (LABCPL(I),I=1,15)
      READ(1,1010) NDATA
      READ(1,1020) (IEARS(I),I=1,NDATA)
      DO 5 I=1,99
      READ(1,1030) (A(I,J),J=1,NDATA)
5     CONTINUE
      READ(1,1030) PEFUT,PESOL,PEGEO,PEFUS,PENUC,PEHYD,PEIEL,PEBIO,PETSL
     1,PEOL,PECL,PEILF,PEGS
      READ(1,1030) PIEGL,PIEEL,PIEHT,PIEH2
      READ(1,1030) PREL,PRHT,PRSF,PRGS,PRLF,PRSP
      READ(1,1710) (NDRU(I),I=1,13)
      WRITE(4,1000) (LABELR(I),I=1,35)
      WRITE(4,1000) (LABELS(I),I=1,35)
      WRITE(9,1021)
      WRITE(9,1031) (LABELR(I),I=1,35)
      WRITE(9,1031) (LABELS(I),I=1,35)
      WRITE(9,1040) (LABUDR(I),I=1,30)
      WRITE(9,1050) (LABCDR(I),I=1,30)
      WRITE(9,1060)
      WRITE(9,1070)
      DO 9100 I = 1,NDATA
      WRITE(9,1090) IEARS(I),(A(L,I),L=1,14)
```

```
9100 CONTINUE
     WRITE(9,1100)
     WRITE(9,1110)
     DO 9110 I = 1,NDATA
     WRITE(9,1090) IEARS(I),(A(L,I),L=15,17),A(8,I),(A(L,I),L=18,19),
    1 A(13,I),(A(L,I),L=20,25)
9110 CONTINUE
     WRITE(9,1120)
     WRITE(9,1130)
     DO 9120 I = 1,NDATA
     WRITE(9,1140) IEARS(I),(A(L,I),L=26,41)
9120 CONTINUE
     WRITE(9,1150)
     DO 9130 I = 1,NDATA
     WRITE(9,1140) IEARS(I),(A(L,I),L=42,57)
9130 CONTINUE
     WRITE(9,1160)
     DO 9140 I = 1,NDATA
     WRITE(9,1140) IEARS(I),A(58,I)
9140 CONTINUE
     WRITE(9,1170)
     WRITE(9,1180)
     DO 9150 I = 1,NDATA
     WRITE(9,1090) IEARS(I),(A(L,I),L=59,70)
9150 CONTINUE
     WRITE(9,1190)
     WRITE(9,1200)
     DO 9160 I = 1,NDATA
     WRITE(9,1140) IEARS(I),(A(L,I),L=71,85)
9160 CONTINUE
     WRITE(9,1210)
     DO 9170 I = 1,NDATA
     WRITE(9,1140) IEARS(I),(A(L,I),L=86,94)
9170 CONTINUE
     WRITE(9,1220)
     WRITE(9,1230)
     DO 9180 I = 1,NDATA
     WRITE(9,1090) IEARS(I),(A(L,I),L=95,99)
9180 CONTINUE
     WRITE(9,1240)
     WRITE(9,1250) (LABUCD(J),J=1,30)
     WRITE(9,1310)
     WRITE(9,1320) PEFUT,PESOL,PEGEO,PEFUS,PENUC,PEHYD,PEIEL,PEBIO,
    1PETSL,PEOL,PECL,PEILF,PEGS
     WRITE(9,1270) (LABUCD(J),J=1,5)
     WRITE(9,1280)
     WRITE(9,1320) PIEGL,PIEEL,PIEHT,PIEH2
     WRITE(9,1290) (LABUCD(J),J=1,30)
     WRITE(9,1300)
     WRITE(9,1320) PREL,PRHT,PRSF,PRGS,PRLF,PRSP
     IYR = IEARS(1)
     DO 10 I = 1,NDATA
     L = I + 1
     IF (IYR .GE. IEARS(NDATA)) L = NDATA
     K = IEARS(L) - IEARS(I)
     IF(K .EQ. 0) K=1
     DO 10 J = 1,K
     DO 9 JJ=1,99
     B(JJ) = A(JJ,I) + (A(JJ,L)-A(JJ,I))*(J-1)/FLOAT(K)
```

```
9     CONTINUE
      CALL EEP
      LL = IYR - IEARS(1) + 1
      EPRIN1( 1,LL) = ETOT
      EPRIN1( 2,LL) = EFUT
      EPRIN1( 3,LL) = ESOL
      EPRIN1( 4,LL) = EGEO
      EPRIN1( 5,LL) = EFUS
      EPRIN1( 6,LL) = ENUC
      EPRIN1( 7,LL) = EHYD
      EPRIN1( 8,LL) = EIEL
      EPRIN1( 9,LL) = EBIO
      EPRIN1(10,LL) = ETSL
      EPRIN1(11,LL) = EOL
      EPRIN1(12,LL) = ECL
      EPRIN1(13,LL) = EILF
      EPRIN1(14,LL) = EGS
      EPRIN2( 1,LL) = ECL
      EPRIN2( 2,LL) = ECLCO
      EPRIN2( 3,LL) = GLFUEL
      EPRIN2( 4,LL) = GLFUCO
      EPRIN2( 5,LL) = ECOEN
      EPRIN2( 6,LL) = ECOCO
      EPRIN2( 7,LL) = FISFUS
      EPRIN2( 8,LL) = FISFCO
      EPRIN2( 9,LL) = ETOT
      EPRIN2(10,LL) = TOTCO
      EPRIN3( 1,LL) = EINU
      EPRIN3( 2,LL) = EIEL
      EPRIN3( 3,LL) = EIGS
      EPRIN3( 4,LL) = EIOL
      EPRIN3( 5,LL) = EILF
      EPRIN3( 6,LL) = EICL
      EPRIN3( 7,LL) = ENUEX
      EPRIN3( 8,LL) = EGSEX
      EPRIN3( 9,LL) = EOLEX
      EPRIN3(10,LL) = ECLEX
      EPRIN3(11,LL) = ESYGX
      EPRIN3(12,LL) = EH2EX
      EPRIN3(13,LL) = ESYFX
      EPRIN3(14,LL) = EELEX
      EPRIN4( 1,LL) = ENIMP
      EPRIN4( 2,LL) = ENIMPC
      EPRIN4( 3,LL) = EXBCV
      EPRIN4( 4,LL) = EXBCVC
      EPRIN5( 1,LL) = PETT
      EPRIN5( 2,LL) = PLNEW
      EPRIN5( 3,LL) = CAPINV
      EPRIN5( 4,LL) = CAPCUM
      EPRIN5( 5,LL) = ETA
      EPRIN5( 6,LL) = EWCON
      EPRIN6( 1,LL) = USEREN
      EPRIN6( 2,LL) = USERCO
      EPRIN6( 3,LL) = EELUT
      EPRIN6( 4,LL) = EHTUT
      EPRIN6( 5,LL) = ESFUS
      EPRIN6( 6,LL) = EGSTU
      EPRIN6( 7,LL) = ELFUS
      EPRIN6( 8,LL) = ESOUS
```

```
      DO 195 J=2,110,2
      EING(K,J) = (EING(K,J-1) + EING(K,J+1))/2.0
  195 CONTINUE
      CALL BILD(EING,2,112)
      WRITE(9,1450)
      GO TO 300
  200 WRITE(9,1600)
      WRITE(9,1610)
      WRITE(9,1615)
      DO 205 J=1,56
      IYR = 1970 + J - 1
      WRITE(9,1617) IYR,(EPRIN6(L,J),L 1,12)
  205 CONTINUE
      GO TO 300
  210 WRITE(9,1620) (LABUPL(L),L=1,10)
      WRITE(9,1630)
      DO 213 L=1,111,2
      K = (L-1)/2+1
      EING(1,L) = EPRIN6(3,K)
      EING(2,L) = EPRIN6(4,K)
      EING(3,L) = EPRIN6(5,K)
      EING(4,L) = EPRIN6(6,K)
      EING(5,L) = EPRIN6(7,K)
  213 CONTINUE
      DO 215 K=1,5
      DO 215 J=2,110,2
      EING(K,J) = (EING(K,J-1) + EING(K,J+1))/2.0
  215 CONTINUE
      CALL BILD(EING,5,112)
      WRITE(9,1450)
      GO TO 300
  220 DO 223 L=1,111,2
      K = (L-1)/2+1
      EING(1,L) = EPRIN6(9,K)
      EING(2,L) = EPRIN6(10,K)
      EING(3,L) = EPRIN6(11,K)
      EING(4,L) = EPRIN6(1 ,K)
      EING(5,L) = EPRIN6(2,K)/100.0
  223 CONTINUE
      WRITE(9,1640) (LABUPL(L),L=1,10),(LABCPL(L),L=1,15)
      WRITE(9,1650)
      DO 225 K=1,5
      DO 225 J=2,110,2
      EING(K,J) = (EING(K,J-1) + EING(K,J+1))/2.0
  225 CONTINUE
      CALL BILD(EING,5,112)
      WRITE(9,1450)
      GO TO 300
  230 WRITE(9,1660)
      WRITE(9,1670)
      WRITE(9,1680)
      DO 235 J=1,56
      IYR = 1970 + J - 1
      WRITE(9,1690) IYR,(EPRIN5(L,J),L=5,6)
  235 CONTINUE
  300 CONTINUE
 1040 FORMAT(1X,"ENERGY UNITS ARE ",30A2)
 1050 FORMAT(1X,"COST UNITS ARE ",30A2)
 1060 FORMAT(/,/," NET PRIMARY ENERGY INPUTS INTO REGION ",/)
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```
1070 FORMAT(1X,1X,"YEAR",4X,"ETOT",5X,"FFUT",5X,"ESOL",5X,"EGEO",5X,
     1"EFUS",5X,"ENUC",5X,"EHYD",5X,"EIEL",5X,"EBIO",5X,"ETSL",5X,
     2"EOL",6X,"ECL ",5X,"EILF",5X,"EGS")
1090 FORMAT(1X,1X,I4,14(1X,F8.3))
1100 FORMAT (/,/," IMPORTS,EXPORTS AND FIELD USE CONTRIBUTING TO NET IN
     1PUTS",/)
1110 FORMAT(1X,1X,"YEAR" ,4X,"ENIMP",4X,"EXBCV",4X,"EINU",5X,"EIEL",5X,
     1"EIGS",5X,"EIOL",5X,"EILF",5X,"EICL",5X,"ENUEX",4X,"EGSEX",4X,"EOL
     2EX",4X,"ECLEX",4X,"EGSFD")
1120 FORMAT(1H1,/," ENERGY ALLOCATION FRACTIONS BEFORE CONVERSION ",/)
1140 FORMAT(1X,I4,16F7.2)
1130 FORMAT(1X,"YEAR",3X,"FSOHT",2X,"FSOEL",2X,"FGEHT",2X,"FBIGL",2X,
     1"FBIHP",2X,"FBIW",3X,"FBILF",2X,"FTSW",3X,"FTSLF",2X,"FOLW",3X,
     2"FOLLF",2X,"FCLCH",2X,"FCLGL",2X,"FCLUS",2X,"FCLW",3X,"FCLLF")
1150 FORMAT(/,/," YEAR",3X,"FSYGX",2X,"FGSFC",2X,"FGSCH",2X,"FGSHT",
     12X,"FGSPR",2X,"FSYFX",2X,"FLFPR",2X,"FLFFC",2X,"FLFCH",2X,"FLFHT",
     22X,"FSFPR",2X,"FCBS",3X,"FH2EX",2X,"FELEX",2X,"FELH2"  ,2X,"FHTH2"
     3)
1160 FORMAT(/,/," YEAR",3X,"FNUHT")
1170 FORMAT(1H1,/," ENERGY DISTRIBUTION TO USERS",/)
1180 FORMAT(1X,1X,"YEAR",4X,"FELRC",4X,"FELIN",4X,"FHTRC",4X,"FHTIN",
     14X,"FSFRC",4X,"FSFIN",4X,"FGSRC",4X,"FGSIN",4X,"FLFRC",4X,"FLFIN",
     24X,"FSORC",4X,"FSOIN")
1190 FORMAT(/,/," CONVERSION EFFICIENCIES",/)
1200 FORMAT(1X,"YEAR",3X,"CEFUT",2X,"CRFUT",2X,"CESOL",2X,"CEGEO",2X,
     1"CRGEO",2X,"CEFUS",2X,"CRFUS",2X,"CENUC",2X,"CRNUC",2X,"CEHYD",
     22X,"CETRA",2X,"CECBS",2X,"CRCBS",2X,"CECBA",2X,"CRCBA")
1210 FORMAT(/,/," YEAR",3X,"CEFCL",2X,"CSOHT",2X,"CGEHT",2X,"CHTCB",
     12X,"CHTRC",2X,"CELH2",2X,"CHTH2",2X,"CHTUT",2X,"CNUHT")
1220 FORMAT(1H1,/,/," USER EFFICIENCIES",/)
1230 FORMAT(1X,1X,"YEAR",4X,"CERC",5X,"CEIN",5X,"CELTR",4X,"CSFTR",4X,
     1"CLFTR")

1240 FORMAT(/,/," ASSUMED FIXED PRICES AND COSTS",/)
1250 FORMAT(1X,"PRIMARY ENERGY PRICES IN ",30A2,/)
1310 FORMAT(1X,1X,"PEFUT",3X,"PESOL",3X,"PEGEO",3X,"PEFUS",3X,"PENUC",
     13X,"PEHYD",3X,"PEIEL",3X,"PEBIO",3X,"PETSL",3X,"PEOL",4X,"PECL",
     24X,"PEILF",3X,"PEGS")
1320 FORMAT(1X,14(F6.2,2X))
1270 FORMAT(/,/," CAPITAL INVESTMENT IN ",5A2," PER INSTALLED KW EFFECT
     1IVE ",/)
1280 FORMAT(1X,1X,"PIEGL",3X,"PIEEL",3X,"PIEHT",3X,"PIEH2")
1290 FORMAT(/,/," ENERGY COST TO USER IN ",30A2,/)
1300 FORMAT(1X,2X,"PREL",4X,"PRHT",4X,"PRSF",4X,"PRGS",4X,"PRLF",4X,
     1"PRSP",4X)
1360 FORMAT(1X,"NET PRIMARY INPUT ENERGIES")
1380 FORMAT(1X,"ENERGY FLOW AND COST BY GROUP",10X,
     1          "COAL=ECL, GLFUEL=EGS+EILF+EOL+ETSL, ECOEN=EBIO+EIEL+EHY
     1D+EGEO+ESOL, FISFUS=ENUC+EFUS+EFUT ")
1410 FORMAT(1X,1X,"YEAR",4X,"COAL",14X,"GLFUEL",12X,"ECOEN",13X,"FISFUS
     1",12X,"TOTAL")
1420 FORMAT(1X, 9X,"AMOUNT",3X,"COST",5X,"AMOUNT",3X,"COST",5X,"AMOUNT"
     1,3X,"COST",5X,"AMOUNT",3X,"COST",5X,"AMOUNT",3X,"COST")
1430 FORMAT(1X,"REGIONAL ENERGY INPUTS IN ",20A2)
1440 FORMAT(1X,"1=COAL AND LIGNITE, 2=OIL,SHALE,GAS,IMP.LIQ.FUELS, 3=WO
     1OD,WASTES,BIOMATTER;HYDRO;GEOTHERMAL;SOLAR;IMP.ELECT.ENERGY",/,
     2" 4=NUCLEAR AND FUSION ENERGY, 5=TOTAL ENERGY")
1450 FORMAT(12X,"1970",7X,"75",8X,"80",8X,"85",8X,"90",8X,"95",7X,"2000
     1",7X,"05",8X,"10",8X,"15",8X,"20",8X,"25")
```

```
1460 FORMAT(1X,"REGIONAL INPUT ENERGY COST IN ",20A2)
1470 FORMAT(1X,"IMPORTS AND EXPORTS OF PRIMARY AND SECONDARY ENERGIES")
1480 FORMAT(1X,10X,"IMPORTS",51X,"EXPORTS")
1490 FORMAT(1X,"YEAR",4X,"EINU",5X,"EIEL",5X,"EIGS",5X,"EIOL",5X,"EILF"
     1,5X,"EICL",5X,"ENUEX",4X,"EGSEX",4X,"EOLEX",4X,"ECLEX",4X,"ESYGX"
     2,4X,"EH2EX",4X,"ESYFX",4X,"EELEX")
1500 FORMAT(1X,I4,6(2X,F7.3),   8(2X,F7.3))
1510 FORMAT(1X,"IMPORT AND EXPORT TOTALS")
1520 FORMAT(1X,"YEAR",5X,"IMP AMT",3X,"IMP COST",2X,"EXP AMT",3X,"EXP C
     1OST")
1530 FORMAT(1X,I4,4X,4(F7.3,3X))
1540 FORMAT(1X,"ENERGY IMPORT AND EXPORT TOTALS IN ",10A2,"AND ",15A2)
1550 FORMAT(1X,"1=TOT.EN.IMPORTS, 2=TOT.EN.EXPORTS, 3=TOT.EN.IMPORT COS
     1TS, 4= TOTAL ENERGY EXPORT INCOME",/," IMPORT COSTS AND EXPORT INC
     2OME ARE SCALED; SCAL.FACT. = 50.0 ")
1560 FORMAT(1X,"NUMBER OF 1000 MWE EQUIV. PLANTS (OP. AT 75 PCT. UTILIS
     1ATION) AND CORR. CUM. CAPITAL INVESTMENT IN ",10A2)
1570 FORMAT(1X,"YEAR",5X,"NO.PLANTS",3X,"NEW PLANTS/YR",5X,"CAP.INV/YR"
     1,3X,"CUM. CAP. INVEST.")
1580 FORMAT(1X,I4,8X,2(F6.0,6X),3X,2(F8.2,9X))
1590 FORMAT(1X,"1=NUMBER OF 1000 MWE EQUIVALENT PLANTS AT 75 PCT. UTILI
     1SATION",/," 2=CUMULATIVE CAPITAL INVESTMENT IN CONVERSION PLANTS I
     2N ",8A2)
1600 FORMAT(1X,"SECONDARY ENERGIES TO USER SECTOR")
1610 FORMAT(1X,27X,"BREAKDOWN BY ENERGY KIND:",35X,"BREAKDOWN BY ENDUSE
     1R SECTORS:")
1615 FORMAT(1X,"YEAR",2X,"TOT.EN.",2X,"TOT.COST",4X,"EELUT",5X,
     1"EHTUT",5X,"ESFUS",5X,"EGSTU",5X,"ELFUS",5X,"ESOUS",5X,"ERC",7X,
     2"EIN",7X,"ETR",7X,"ECHEM")
1617 FORMAT(1X,I4,12(F8.3,2X))
1620 FORMAT(1X,"SECONDARY ENERGIES TO USER SECTOR IN ",10A2)
1630 FORMAT(1X,"1=ELECTR.ENERGY,2=CENTRAL HEAT, 3=SOLID FUELS, 4=GASEOU
     1S FUELS, 5=LIQUID FUELS")
1640 FORMAT(1X,"SECONDARY ENERGY DISTRIBUTION IN ",10A2," AND COST TO U
     1SER IN ",15A2)
1650 FORMAT(1X,"1=ENERGY TO RES./COM. SECTORS, 2=ENERGY TO IND. SECTOR,
     1 3=ENERGY TO TRANSP. SECTOR,",/," 4=TOTAL ENERGY TO USER SECTOR, 5
     2=TOTAL ENERGY COST TO USER SECTOR  (SCAL. FACT. = 100.0) ")
1660 FORMAT(1X,"CONCENTRATED WASTE HEAT AND OVERALL EFFICIENCY OF ENERG
     1Y CONVERSION AND DISTRIBUTION TO USER ")
1670 FORMAT(1X,"NOTE: ETA = (ETR+EIN+ERC)/(ETOT-ECHEM-EXACV)")
1680 FORMAT(1X,"YEAR",11X,"ETA",10X,"CONCENTRATED WASTE HEAT")
1690 FORMAT(1X,I4,10X,F6.3,18X,F6.3)
1700 FORMAT(" ENTER ENDRU(13) FOR OUTPUT CONTROL",/)
1710 FORMAT(14I1)
1720 FORMAT(1H1)
     STOP
     END
```

```
C      ENERGY SUPPLY MODEL
       SUBROUTINE EEP
       COMMON ETOT,EFUT,ESOL,EGEO,EFUS,ENUC,EHYD,EIEL,EBIO,ETSL,EOL,ECL,
      1EILF,EGS,ENIMP,EXBCV,EINU,EIGS,EIOL,EICL,ENUEX,EGSEX,EOLEX,ECLEX,
      2EGSFD,FSOHT,FSOEL,FGEHT,FBIGL,FBIHP,FBIW,FBILF,FTSW,FTSLF,FOLW,
      3FOLLF,FCLCH,FCLGL,FCLUS,FCLW,FCLLF,FSYGX,FGSFC,FGSCH,FGSHT,FGSPR,
      4FSYFX,FLFPR,FLFFC,FLFCH,FLFHT,FSFPR,FCBS,FH2EX,FELEX,FELH2,FHTH2,
      5FNUHT,FELRC,FELIN,FHTRC,FHTIN,FSFRC,FSFIN,FGSRC,FGSIN,FLFRC,FLFIN
       COMMON FSORC,FSOIN,CEFUT,CRFUT,CESOL,CEGEO,CRGEO,CEFUS,CRFUS,CENUC
      1,CRNUC,CEHYD,CETRA,CECBS,CRCBS,CECBA,CRCBA,CEFCL,CSOHT,CGEHT,
      2CHTCB,CHTRC,CELH2,CHTH2,CHTUT,CNUHT,CERC,CEIN,CELTR,CSFTR,CLFTR
       COMMON PEFUT,PESOL,PEGEO,PEFUS,PENUC,PEHYD,PEIEL,PEBIO,PETSL,PEOL,
      1PECL,PEILF,PEGS,PIEGL,PIEEL,PIEHT,PIEH2,PREL,PRHT,PRSF,PRGS,PRLF,
      2PRSP,ETR,ERC,EIN,ETA,PETT,PLNEW,CAPINV,CAPCUM,EWCON
       COMMON ECLCO,GLFUEL,GLFUCO,ECOEN,ECOCO,FISFUS,FISFCO,TOTCO,ENIMPC,
      1EXBCVC,USEREN,USERCO,EELUT,EHTUT,ESFUS,EGSTU,ELFUS,ESOUS,ECHEM,
      2ESFPR,ESFHT,ELFTR,ELFIN,ELFRC,EGSPR,EGSHT,EGSTR,EGSIN,EGSRC,
      3EUSE,EWAST,ESFTR,ESFIN,ESFRC,ELFPR,ELFHT,EH2EX,ESYGX,ESYFX,EELEX
       COMMON LLL
       FSOUS=1.-FSOHT-FSOEL
       FGEPR=1.-FGEHT
       FBIUS=1.-FBIGL-FBIHP
       FBIGS=1.-FBIW-FBILF
       FTSGS=1.-FTSW-FTSLF
       FOLGS=1.-FOLW-FOLLF
       FCLHP=1.-FCLCH-FCLGL-FCLUS
       FCLGS=1.-FCLW-FCLLF
       FSYGD=1.-FSYGX
       FGSUS=1.-FGSFC-FGSCH-FGSHT-FGSPR
       FSYFD=1.-FSYFX
       FLFUS=1.-FLFFC-FLFCH-FLFHT-FLFPR
       FSFHT=1.-FSFPR
       FCBA=1.-FCBS
       FELUS=1.-FELEX-FELH2
       FELTR=1.-FELRC-FELIN
       FHTTR=1.-FHTRC-FHTIN
       FSFTR=1.-FSFRC-FSFIN
       FGSTR=1.-FGSRC-FGSIN
       FLFTR=1.-FLFRC-FLFIN
       FSOTR=1.-FSORC-FSOIN
       FNUPR=1.-FNUHT
       ETOT=EFUT+ESOL+EGEO+EFUS+ENUC+EHYD+EIEL+EBIO+ETSL+EOL+ECL+EILF+
      1EGS
C
C      PRIMARY ENERGY ALLOCATION REFORE CONVERSION
C
C      SOLAR ENERGY:
       ESOHT=ESOL*FSOHT
       ESOEL=ESOL*FSOEL
       ESOUS=ESOL*FSOUS
C
C      GEOTHERMAL ENERGY:
       EGEHT=EGEO*FGEHT
       EGEPR=EGEO*FGEPR
C
C
C      NUCLEAR ENERGY:
       ENUPR=ENUC*FNUPR
       ENUHT=ENUC*FNUHT
```

```
C       WOOD, WASTES, BIOMATTER:
        EBIW=EBIO*FBIGL*FBIW
        EBILF=EBIO*FBIGL*FBILF
        EBIGS=EBIO*FBIGL*FBIGS
        EBIHP=EBIO*FBIHP
        EBIUS=EBIO*FBIUS
C
C       TAR SANDS AND OIL SHALE:
        ETSW=ETSL*FTSW
        ETSGS=ETSL*FTSGS
C
        ETSLF=ETSL*FTSLF
C       OIL:
        EOLW=EOL*FOLW
        EOLLF=EOL*FOLLF
        EOLGS=EOL*FOLGS
C
C       COAL:
        ECLCH=ECL*FCLCH
        ECLW=ECL*FCLGL*FCLW
        ECLLF=ECL*FCLGL*FCLLF
        ECLGS=ECL*FCLGL*FCLGS
        ECLUS=ECL*FCLUS
        ECLHP=ECL*FCLHP
C
C       WASTES FROM GASIFICATION AND LIQUEFACTION:
        EW=EBIW+ETSW+EOLW+ECLW
C
C       SYNTHETIC AND REFINED LIQUID FUELS:
        ESYLF=EBILF+ETSLF+EOLLF+ECLLF
        ESYFX=ESYLF*FSYFX
        ESYFD=ESYLF*FSYFD
        ETLF=EILF+ESYFD
        ELFFC=ETLF*FLFFC
        ELFCH=ETLF*FLFCH
        ELFHT=ETLF*FLFHT
        ELFPR=ETLF*FLFPR
        ELFUS=ETLF*FLFUS
C
C       NATURAL AND SYNTHETIC GAS:
        ESYGS=EBIGS+ETSGS+EOLGS+ECLGS
        ESYGX=ESYGS*FSYGX
        ESYGD=ESYGS*FSYGD
        ETGS=ESYGD+EGS
        EGSFC=ETGS*FGSFC
        EGSCH=ETGS*FGSCH
        EGSPR=ETGS*FGSPR
        EGSHT=ETGS*FGSHT
        EGSUS=ETGS*FGSUS
C
C       NONENERGY USE:
        ECH=ECLCH+EGSCH+ELFCH
C
C       SOLID FUELS:
        EFHP=EBIHP+ECLHP
C
C
C
C       CONVERSION PROCESSES
```

```
C       CONVERSION TO ELECTRICAL ENERGY
C
C       HYPOTHETICAL FUTURISTIC ENERGY:
        ELFUT=EFUT*CEFUT
        HTFUT=(1.-CEFUT)*CRFUT*EFUT
        WFUT=EFUT*(1.-CRFUT)*(1.-CRFUT)
C
C       SOLAR ENERGY:
        ELSOL=ESOEL*CESOL
        WSOL=ESOEL*(1.-CESOL)
C
C       GETHERMAL ENERGY:
        ELGEO=EGEPR*CEGEO
        HTGEO=(1.-CEGEO)*CRGEO*FGEPR
        WGEO=EGEPR*(1.-CEGEO)*(1.-CRGEO)
C
C       FUSION ENERGY
        ELFSN=EFUS*CEFUS
        HTFUS=EFUS*(1.-CEFUS)*CRFUS
        WFUS=EFUS*(1.-CEFUS)*(1.-CRFUS)
C
C       NUCLEAR ENERGY:
        ELNUC=ENUPR*CENUC
        HTNUC=ENUPR*(1.-CENUC)*CRNUC
        WNUC=ENUPR*(1.-CENUC)*(1.-CRNUC)
C
C       HYDROPOWER:
        ELHYD=EHYD*CEHYD
        WHYD=EHYD*(1.-CEHYD)
C
C       IMPORTED ELECTRICITY:
        ELIMP=EIEL*CETRA
        WEIMP=EIEL*(1.-CETRA)
C
C       COMBUSTION:
        ESFPR=EFHP*FSFPR
        ECBPR=ELFPR+EGSPR+ESFPR
        ECBS=ECBPR*FCBS
        ELCBS=ECBS*CECBS
        HTCBS=ECBS*(1.-CECBS)*CRCBS
        WCBS=ECBS*(1.-CRCBS)*(1.-CECBS)
        ECBA = ECBPR*FCBA
        ELCBA=ECBA*CECBA
        HTCBA=ECBA*(1.-CECBA)*CRCBA
        WCBA=ECBA*(1.-CECBA)*(1.-CRCBA)
C
C       SOLID FUFL ENERGY TO HEAT PLANTS:
        ESFHT=EFHP*FSFHT
C
C       CENTRAL FUEL CELLS:
        EGLFC=EGSFC+ELFFC
        ELFCL=EGLFC*CEFCL
        WFCL=EGLFC*(1.-CEFCL)
C
C       TOTAL ELECTRICAL ENERGY BEFORE HYDROGEN GENERATION:
        ELECE=ELFUT+ELSOL+ELGEO+ELFSN+ELNUC+ELHYD+ELIMP+ELCBS+ELCBA+ELFCL
C
C       TOTAL HEAT ENERGY RECOVERED FROM ELECTRICITY GENERATING PROCESSES:
        EHREC=HTFUT+HTGEO+HTFUS+HTNUC+HTCBS+HTCBA
```

```
C
C       TOTAL ENERGY LOST IN ELECTRICITY GENERATING PROCESSES:
        EWHTE=WFUT+WSOL+WGEO+WFUS+WNUC+WHYD+WEIMP+WCBS+WCBA+WFCL
C
C       CONVERSION TO HEAT
C
C       SOLAR ENERGY:
        EHSO=ESOHT*CSOHT
        WHSO=ESOHT*(1.-CSOHT)
C
C       GEOTHERMAL ENERGY:
        EHGE=EGEHT*CGEHT
        WHGE=EGEHT*(1.-CGEHT)
C
C       NUCLEAR ENERGY:
        EHNU=ENUHT*CNUHT
        WHNU=ENUHT*(1.-CNUHT)
C
C       COMBUSTION:
        EHTCB=EGSHT+ELFHT+ESFHT
        EHCB=EHTCB*CHTCB
        WHCB=EHTCB*(1.-CHTCB)
C
C       HEAT RECOVERED FROM PRODUCTION OF ELECTRICITY:
        EHRC=EHREC*CHTRC
        WHRC=EHREC*(1.-CHTRC)
C
C       TOTAL CENTRAL HEAT ENERGY BEFORE HYDROGEN GENERATION:
        EHEAT=EHSO+EHGE+EHCB+EHRC+EHNU
C
C       TOTAL ENERGY LOST IN CENTRAL HEAT PROCESSES:
        EWHTH=WHSO+WHGE+      WHCB+WHRC+WHNU
C
C       TOTAL NONENERGY:
        ECHUS=EGSCH+ELFCH+ECLCH
C
C       TOTAL SOLID FUEL:
        ESFUS=ECLUS+EBIUS
C
C       TOTAL ELECRICAL ENERGY BEFORE TRANSMISSION TO USERS:
        EELUS=ELECE*FELUS
C
C       HYDROGEN BY ELECTROLYSIS
        EH2EL=ELECE*FELH2*CELH2
        EWEH2=ELECE*FELH2*(1.-CELH2)
C
C       EXPORTED ELECTRICAL ENERGY:
        EELEX=ELECE*FELEX
C
C       TOTAL CENTRAL HEAT BEFORE TRANSMISSION TO USERS:
        EHTUS=EHEAT*(1.-FHTH2)
C
C       HYDROGEN BY HEAT PROCESS:
        EH2HT=EHEAT*FHTH2*CHTH2
        EWHH2=EHEAT*FHTH2*(1.-CHTH2)
        EH2T=EH2EL+ EH2HT
        EH2EX=EH2T*FH2EX
C
C       TOTAL GAS TO USERS:
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```
      EGSTU=EGSUS+EH2T*(1.-FH2EX)
C
C     TOTAL UNRECOVERED WASTE ENERGY:
      EWCON=EW+EWHTE+EWHTH+EWEH2+EWHH2
C
C     EXPORT BEFORE CONVERSION:
      EXBCV=ENUEX+EGSEX+EOLEX+ECLEX
C
C     EXPORT AFTER CONVERSION:
      EXACV=ESYGX+EH2EX+ESYFX+EELEX
C
C     TOTAL EXPORT:
      EXENT=EXBCV+EXACV
C
C     ELECTRICAL ENERGY TRANSMISSION TO USER:
      EELUT=EELUS*CETRA
      EWELT=EELUS*(1.-CETRA)
C
C     HEAT ENERGY TRANSMISSION TO USERS:
      EHTUT=EHTUS*CHTUT
      EWHTT=EHTUS*(1.-CHTUT)
C
C      TOTAL WASTED ENERGY AFTER TRANSMISSION TO USERS:
      EWTOT=EWCON+EWELT+EWHTT
C
C      ENERGY TRANSMITTED TO REGIONAL USERS:
      EINUS=EELUT+EHTUT+ESFUS+EGSTU+ELFUS+ESOUS
C
C     USEFUL ENERGY, NONENERGY, AND EXPORTS FROM CONVERION SECTOR:
      EOUTC=EINUS+ECHUS+EXACV
C
C     TOTAL ENREGY THROUGHPUT OF CONVERSION SECTOR:
      ETOTC=EOUTC+EWTOT
C
C
C     USER SECTOR
C
C     ALLOCATION OF ENERGY
C
C     ELECTRICAL ENERGY:
      EELRC=EELUT*FELRC
      EELIN=EELUT*FELIN
      EELTR=EELUT*FELTR
C
C     HEAT ENERGY:
      EHTRC=EHTUT*FHTRC
      EHTIN=EHTUT*FHTIN
      EHTTR=EHTUT*FHTTR
C
C     SOLID FUELS:
      ESFRC=ESFUS*FSFRC
      ESFIN=ESFUS*FSFIN
      ESFTR=ESFUS*FSFTR
C
C     GASEOUS FUELS:
      EGSRC=EGSTU*FGSRC
      EGSIN=EGSTU*FGSIN
      EGSTR=EGSTU*FGSTR
C
```

```
C       LIQUID FUELS:
        ELFRC=ELFUS*FLFRC
        ELFIN=ELFUS*FLFIN
        ELFTR=ELFUS*FLFTR
C
C        DECENTRALIZED SOLAR ENERGY:
        ESORC=ESOUS*FSORC
        ESOIN=ESOUS*FSOIN
        ESOTR=ESOUS*FSOTR
C
C        TOTAL ENERGY INTO RESIDENTIAL/COMMERCIAL SECTOR
        ERC=EELRC+EHTRC+ESFRC+EGSRC+ELFRC+ESORC
C
C       TOTAL ENERGY INTO INDUSTRIAL SECTOR
        EIN=EELIN+EHTIN+ESFIN+EGSIN+ELFIN+ESOIN
C
C       TOTAL ENERGY INTO TRANSPORTATION SECTOR
        ETR=EELTR+EHTTR+ESFTR+EGSTR+ELFTR+ESOTR
C
        ECHEM=ECHUS
        ETA = (ERC+EIN+ETR)/(ETOT-ECHEM-EXACV)
C
C        EFFICIENCIES
C
C        RESIDENTIAL/COMMERCIAL:
        EURC=ERC*CERC
        EWRC = ERC*(1.-CERC)
C
C       INDUSTRIAL:
        EUIN=EIN*CEIN
        EWIN=EIN*(1.-CEIN)
C
C       TRANSPORTATION:
        CETR=(EELTR*CELTR+ESFTR*CSFTR+(EGSTR+ELFTR)*CLFTR)/(EELTR+ESFTR
       1+EGSTR+ELFTR)
        EUTR=ETR*CETR
        EWTR=ETR*(1.-CETR)
C
C       TOTAL USEFUL AND WASTED ENERGIES:
        EUSE=EURC+EUIN+EUTR
        EWAST=EWRC+EWIN+EWTR+EWTOT
C
C       TOTAL ENERGY FOR REGIONAL CONVERSION AND USE:
        ETRCU=EFUT+ESOL+EGEO+EFUS+ENUC+EHYD+EBIO+EIEL+ETSL+EGS+EILF
       1+EOL+ECL
C
C
C       NO. OF PLANTS EQUIVALENT TO ALL CONVERSION PROCESSES
C       GASIFICATION AND LIQUEFACTION:
        PEGL=EBILF+EBIGS+ETSLF+ETSGS+EOLLF+EOLGS+ECLLF+ECLGS
C       GENERATION OF ELECTRICITY:
        PEEL=ELECE-ELIMP
C       GENERATION OF CENTRAL HEAT:
        PEHT=EHEAT-EHRC
C       GENERATION OF HYDROGEN:
        PEH2=EH2EL+EH2HT
C       TOTAL INSTALLED EQUIV. CAPACITY IN INPUT UNITS:
        PETOLD = PETT
        CAPOLD = CAPCUM
```

```
      PETT=PEGL+PEEL+PEHT+PEH2
      PETT = PETT*1210.0
      CAPCUM = PEGL*PIEGL + PEEL*PIEEL + PEHT*PIEHT + PEH2*PIEH2
      CAPCUM = CAPCUM*1.210
      PLNEW = PETT - PETOLD
      CAPINV = CAPCUM - CAPOLD
      IF(LLL.NE. 0) GO TO 20
      CAPINV =0.0
      PLNEW = 0.0
   20 CONTINUE
      LLL = 1
      GLFUEL = EGS + EILF + EOL + ETSL
      GLFUCO = EGS*PEGS + EILF*PEILF + EOL*PEOL + ETSL*PETSL
      ECLCO = ECL*PECL
      ECOEN = EBIO + EIEL + EHYD + EGEO + ESOL
      ECOCO = EBIO*PEBIO + EIEL*PEIEL + EGEO*PEGEO + ESOL*PESOL
      FISFUS = ENUC + EFUS + EFUT
      FISFCO = ENUC*PENUC + EFUS*PEFUS + EFUT*PEFUT
      ENIMP = EINU + EIEL + EIGS + EIOL + EILF + EICL
      ENIMPC = EINU*PENUC + EIEL*PEIEL + EIGS*PEGS +EIOL*PEOL + EILF*PEI
     1LF + EICL*PECL
      EXBCVC = ENUEX*PENUC + EGSEX*PEGS + EOLEX*PEOL + ECLEX*PECL
      TOTCO = ECLCO + GLFUCO + ECOCO + FISFCO
      USEREN = ERC + EIN + ETR
      USERCO = EELUT*PREL + EHTUT*PRHT + ESFUS*PRSF + EGSTU*PRGS +
     1 ELFUS*PRLF + ESOUS*PRSP
      RETURN
      END
```

```
      SUBROUTINE BILD(EING,NR,NMAX)
      DIMENSION FELD(122),EING(5,121),Z(51),CL(5)
      DATA STR/"-"/,BL/" "/,SPA/"I"/
      DATA CL/"1","2","3","4","5"/
      XMAX = EING(1,1)
      XMIN = XMAX
      JJ = NMAX - 1
      DO 10 J = 1,JJ
      DO 10 I = 1,NR
      X = XMAX - EING(I,J)
      IF(X .LT. 0) XMAX = EING(I,J)
      X = XMIN - EING(I,J)
      IF(X .GT. 0) XMIN = EING(I,J)
   10 CONTINUE
      IF(XMAX .NE. XMIN) GO TO 15
      XMAX=XMAX + 0.5
      XMIN = XMIN - 0.5
   15 DIFF = XMAX - XMIN
      SPR = DIFF/50.0
      Z(1) = XMAX
      Z(51) = XMIN
      DO 20 K = 2,50
      Z(K) = Z(K-1) - SPR
   20 CONTINUE
      Y = SPR/2.0
      NZ = 50
      DO 80 K = 1,51
      NZ = NZ + 1
      IF(NZ .EQ. 51) GO TO 50
      DO 40 I1 = 2,122
   40 FELD(I1) = BL
      DO 45 I1 = 2,122,10
   45 FELD(I1) = SPA
      GO TO 60
   50 DO 55 I1 = 2,122
   55 FELD(I1) = STR
      NZ = 1
   60 CONTINUE
      FELD(1) = Z(K)
      DO 70 I = 1,NR
      DO 65 J = 2,122
      A = EING(I,J) - Z(K)
      IF(A .LT. -Y) GO TO 65
      IF(A .GT.  Y) GO TO 65
      FELD(J) = CL(I)
   65 CONTINUE
   70 CONTINUE
   80 WRITE(9,1000) (FELD(J), J=1,NMAX)
C
C
 1000 FORMAT(1X,E11.4,2X,115A1)
      RETURN
      END
```

References

[1] Oehmen, K.H., and Paul, W. "Construction of Population Submodels." IIASA Symposium Proceedings SP-74-3, pp. B362-B480.

[2] Clapham, W.B., Shook, T., and Warshaw, M.W. "A Regionalized Food Model for the Global System." IIASA Symposium Proceedings SP-74-3, pp. B500-B554.

[3] Mesarovic, M.D., Richardson, J.M. Jr., Shook, T., and Warshaw, M.W. "The Structural Description and Sensitivity Analysis of the Food Submodel." IIASA Symposium Proceedings SP-74-3, pp. B556-B626.

[4] Gottwald, M., and Pestel, R. "Environmental Impact Assessment." IIASA Symposium Proceedings SP-74-5 pp. B1122-B1276.

[5] Rechenmann, F. "Conversational Use of Multi-Layer Decision Models." IIASA Symposium Proceedings SP-74-6, pp. C232-C246.

[6] Cardenas, M.A., and Huerta, J.M. "Submodel of Global Water Cycle on Regional Basis." IIASA Symposium Proceedings SP-74-5, pp. B1278-B1391.

[7] Heyes, R.P., Jerdonek, R.A., and Kuper, A.B. "Global Energy Submodel." IIASA Symposium Proceedings SP-74-5, pp. B1084-B1119.

[8] Bossel, H. "Energy Supply Submodel." IIASA Symposium Proceedings SP-74-4, pp. B834-B970.