DYPHEMO APPLICATIONS: SIMULATION OF UK ENERGY SYSTEMS WITH A DYNAMIC PHYSICAL ENERGY MODEL

Dr Mark Barrett ERG 045

Energy Research Group,
The Open University,
Walton Hall,
Milton Keynes MK7 6AA
England.
Tel: 0908-653339

October 1982.

Abstract

A description of the structure and validation of the energy model are given in the report "A Dynamic Physical Energy Model of the UK" (Barrett, 1982). This volume contains concise descriptions of hypothetical changes to the present UK energy system and numerical and graphical output from the model's simulations of the new systems. The systems modelled incorporate demand reduced by behavioural change and conservation, improved efficiency and new technologies.

Acknowledgements

The latter development of the model and its use in these applications was supported by the Science and Engineering Research Council. This support was essential to the course of the work in this report.

ERRATA

The algorithm to calculate minimum storage requirements is not yet completed. The zero value stated in the analysis of system performance section of model output should therefore be ignored.

The graphs for electricity exceedance have incorrectly labelled x axes. The axis labelling should show a range of exceedance from 0 to 100 % (or 0 to 1.0).

There are small differences between the simulation results quoted in this report and those used in the report describing the model (Barrett, 1982). These are due to small changes in the model and input data.

CONTENTS

1. APPLICATIONS OF DYPHEMO

The sections below give technical details of the 1976 and other hypothetical energy systems simulated by DYPHEMO. The sequence of systems simulated follows a path arrived at by general policy considerations. Most importantly, the changes to the 1976 system considered progressively go "upstream" through the system. This is because of the obvious argument that any savings incurred downstream effect savings upstream, and not vice versa.

The sections in this companion volume are as follows.

(i) General description of output.

(ii) Simulation of 1976 system.

(iii) Simulation of 1976 system with behaviourally reduced demand.

(iv) Simulation of 1976 system with demand reduced by technical conservation.

(v) Simulation of 1976 system with improved efficiency and allocation.

(vi) Simulation of 1976 system with reduced demand and new technologies.

The main problem encountered in these applications is the difference between technical and social/political feasibility. There is no doubt that massive reductions in energy consumption throughout the energy system are possible whilst retaining energy standards. However, the extent to which these reductions are realised depends in part on the objectives of energy, economic and social policy. In these applications, the savings assumed lie, perhaps uncomfortably, between the technically possible and the socially feasible. This latter is extremely difficult to determine with any exactitude.

The methods which might possibly be employed to change the system are not discussed in the applications. Amongst the possible ways of encouraging or enforcing reductions in primary energy consumption are :

- public investment
- education
- law/regulation/standards

- fiscal incentives
- financial grants

Perhaps the most important general assumption in these applications pertains to energy demands. In general, it is assumed that the types, mix and magnitudes of useful energy demands remain unchanged. This assumption was made in order to investigate certain options given demand.

It is likely that energy demands will change significantly in some sectors; for example, it seems that "high energy" industries (such as iron and steel) may be gradually replaced by "low energy", high technology industries. This sort of restructuring is assumed not to occur in these applications.

Fossil fuels can be used both as energy sources which provide work and heat, and as chemical feedstocks in various material manufacturing industries. Because of the potential competition for the same resource for these two purposes, feedstocks were included in DYPHEMO. However, in general, the methods used to conserve energy (e.g. insulation), cannot be used to reduce feedstock demand. In addition, the complexity of material and energy flows in the chemical industry is such that to date, there has been no reliable detailed surveying and analysis (p 57, IIED, 1979). It has therefore been assumed that feedstock demand remains unchanged in all the applications given below.

Some discussion of the problems encountered in using a model such as DYPHEMO and of the results of these applications are given in the volume "A Dynamic Physical Energy Model of the UK" (Barrett, 1982).

2. DESCRIPTION OF OUTPUT

The following description of the general layout of the output from the model should help, although I hope the output is largely self explanatory.

Lineprinter output

The output is in three basic sections.

(i) Technical data specifying the system are given in this order:

- demands and user converters
- user stores
- electricity generators
- energy industry stores
- energy industry converters
- natural energy stores

A complete technical description of each of the systems simulated is given despite the fact that some of the data are unchanged from system to system. In particular, energy demand use patterns and natural energy reserves are the same for all the systems posited.

(ii) Simulated energy flows

This section gives the hourly or monthly energy flows and totals over the period simulated in this order

- meteorological values
- useful energy demands

- fuel deliveries

- user store levels

- electricity flows

- fuel used in power stations

- fuel flows from energy industry stores

- primary fuel extracted

These flows are then summarised in tables.

(iii) Analysis of system behaviour

This section of output gives some analysis of the system performance.

At present this consists of flow exceedance data for electricity and the maximum flow rates for electricity, solid, liquid and gas.

<u>Graphplotter</u>

Output from the graphplotter is simply the results of the simulation presented in graphical form.

These outputs of energy flows and overall system performance can relate to a time period of a day or a year. It is assumed that annual performance is of more general interest than diurnal performance and so most of the output is for the year. The fuel flows are given in both numerical and graphical form for the 1976 system. To avoid excessive bulk, the output of performance for the intermediate systems (behaviour, conservation, efficiency) is somewhat reduced.

Extensive graphical output is given, however, for the last system which incorporates some features from each of the previous systems.

3. 1976 SYSTEM

The system simulated in this section is based on data defining the system as it was in 1976. A description of these data and their sources is given in the volume "A Dynamic Physical Energy Model of the UK" (Barrett, 1982).

DYPHEMO OUTPUT

This output is from a D ynamic PH ysical E nergy M odel
There are four main sections of output:
1. LAYOUT OF ENERGY SYSTEM COMPONENTS
2. DESCRIPTION OF ENERGY SYSTEM
3. SIMULATED PERFORMANCE OF ENERGY SYSTEM
4. ANALYSIS OF SYSTEM PERFORMANCE

1. LAYOUT OF ENERGY SYSTEM

The diagram below shows the basic arrangement of the components of the UK physical energy system and the flows of energy between them. The lists of types of each component are not exhaustive for converters and stores.
The components are numbered 1 to 7.

```
 __________     ___________      ___________      ___________
|1.DEMANDS|    |2.USER     |    |7.INCOME   |    |6.NATURAL  |
|         |    |CONVERTERS|     |  SOURCES  |    |  STORES   |
|Work     |<--|Boiler      |<----| Solar,wind|   | Coal,oil  |
|Transport|    |Motor      |    | wave,tidal|    | gas,      |
|Light    |    |Collector  |    | hydro     |    | uranium   |
|Heat>120 |    |___________|    |___________|    |___________|
|Cooking  |       /!\    /\          |              /
|Heat<120 |        !      \          |             /
|Hot water|        !       \         |            /
|Space    |        !        \        |           /
|_________|       \!/        \      \!/         /
                   !          \______!_______\/_
             |3.USER      |   |4.ENERGY IN|   |5.ENERGY IN|
             |  STORES    |   | CONVERTERS|   |  STORES   |
             |Bunker,tank|    | Power stat|<-->|Bunker,tank|
             |H/W tank    |   | Refinery  |   |Pumped     |
             |El. storage|    | Gasifier  |   |           |
             |___________|    |___________|   |___________|
```

2. UK ENERGY SYSTEM DESCRIPTION
1976 system.

SYSTEM DESCRIPTION

Technical data are given; these specify the components:
DEMAND
USER CONVERTERS
USER STORES
CONVENTIONAL ELECTRICICITY GENERATION
AMBIENT ELECTRICITY GENERATION
ENERGY INDUSTRY CONVERTERS
INDUSTRY STORES
PRIMARY RESERVES
These data with climatic data determine the simulated energy flows with time.

USEFUL ENERGY DEMAND DATA

TEMPORAL USE PATTERNS

The numbers below refer to the hourly use levels for the various sectors. The first two rows of numbers for each pattern refer to the weekday pattern; the second two the weekend pattern.

Proportion houses with active occupants

0.4	0.1	0.1	0.1	0.2	0.4	0.5	0.6	0.5	0.4	0.4	0.5
0.4	0.4	0.5	0.6	0.7	0.9	0.8	0.8	0.7	0.8	0.7	0.5
0.3	0.1	0.0	0.0	0.0	0.0	0.3	0.5	0.6	0.7	0.7	0.6
0.6	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.3

Average = 0.50

Domestic cooking: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.7	0.9	1.2	1.0	0.8	1.7
2.2	1.7	1.2	1.8	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3
0.1	0.1	0.1	0.1	0.1	0.4	0.6	0.7	1.2	1.0	0.8	1.7
2.2	1.7	1.1	1.5	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3

Average = 1.00

Domestic hot water: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.7	1.6	1.4	0.8	2.0	1.6	1.2
0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.8	1.6	1.4	0.8	2.0	1.6	1.2

Average = 1.00

Domestic transport: % daily traffic

0.9	0.3	0.1	0.1	0.2	0.3	1.0	4.5	6.8	4.8	5.0	5.2
5.5	5.2	5.7	5.8	7.3	8.2	7.3	6.4	4.7	3.7	3.1	2.1
2.3	1.0	0.6	0.3	0.3	0.4	0.9	2.2	3.0	4.1	6.3	7.5
8.0	7.1	9.1	9.4	9.0	8.3	7.7	7.8	6.6	5.1	4.3	3.6

Average = 4.18

Industrial general: proportion of average demand

0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1.4	1.4	1.4	1.5
1.3	1.4	1.4	1.3	1.2	1.1	0.9	0.9	0.9	0.9	0.9	0.9
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.9	1.0	1.0	1.0
0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Average = 1.00

Industrial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

Commercial general: proportion of average demand

0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	1.2	1.6	1.7	1.7
1.7	1.7	1.7	1.7	1.6	1.3	1.1	1.0	0.9	0.9	0.9	0.9
0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.8	1.1	1.1	1.2
1.1	1.1	1.2	1.2	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.6

Average = 1.00

Commercial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

CHARACTERISTICS OF DEMANDS

DOMESTIC		
Number of occupied houses	=	19.49 mill
Miscellaneous electricity:		
Miscellaneous appliances	=	4800.0 MW
Fridges and freezers	=	897.0 MW
Light:		
Useful light per house	=	10.0 W
Cooking:		
Average useful demand per house	=	23.5 W
Hot water:		
Monthly mains temperatures (C)		

7.0	6.0	7.0	9.0	10.0	11.0	13.0	15.0	13.0	11.0	10.0	9.0

Demand temperature (C)	=	55.0 C
Hourly demand volume	=	5.3 l.
Space heating:		
House internal temperature	=	16.0 C
House fabric loss	=	250.0 W/C
House ventilation loss	=	97.0 W/C
Incidental fudge factor	=	0.9
Transport:		
Number of cars	=	14.0 mill
Average useful power per car	=	178.3 W

INDUSTRIAL		
Number of industrial people	=	10.6 million
Kinetic:		
Average useful demand	=	2811.0 MW
Light:		
Useful light per person	=	70.0 W
Process heat > 120 C:		
Average useful demand	=	12029.0 MW
Process heat < 120 C:		
Average useful demand	=	10122.0 MW
Hot water:		
Average useful demand	=	3488.0 MW
Space heating:		
Internal temperature	=	16.5 C
Fabric loss per person	=	65.0 W/C
Ventilation loss per person	=	75.0 W/C
Incidental fudge factor	=	0.3
Transport:		
Average diesel motor demand	=	2324.0 MW

COMMERCIAL		
Number of commercial people	=	26.6 million
Miscellaneous electricity:		
Average useful demand	=	1046.0 MW
Light:		
Useful light per person	=	80.0 W
Cooking:		
Average useful demand	=	412.4 MW
Hot water:		
Average useful demand	=	2405.0 MW
Space heating:		
Internal temperature	=	17.0 C
Fabric loss per person	=	25.0 W/C
Ventilation loss per person	=	55.0 W/C
Incidental fudge factor	=	0.4
Transport:		
Average plane and ship demand	=	2511.0 MW
Average electric train demand	=	228.0 MW
IRON AND STEEL		
All energy:		
Total average demand	=	9820.0 MW
FEEDSTOCKS		
Total average demand	=	18106.0 MW

USER CONVERTERS

User converters are arranged in the sequences:

SECTOR	OUTPUT	INPUT
Domestic	Mis. Electric	Gas
Industrial	Mechanical	Liquid
Commercial	Light	Solid
Iron & Steel	Process > 120	Electricity
Feedstocks	Cooking	Solar
	Process <120	
	Hot water	
	Space	
	Transport	

A value of 9.9 means the efficiency is variable

DOMESTIC USER CONVERTERS (E) means double entry	POPULATION (millions)	EFFICIENCY
Fridges and freezers (U)	19.49	1.00
Electric appliances (U)	19.49	1.00
Incandescent lights	19.49	0.13
Gas cooker	10.70	0.11
Electric cooker	8.80	0.20
Gas individual H/W heater	4.11	0.43
Gas C/H H/W heater (E)	3.80	0.40
Gas heat pump H/W heater (E)	0.00	9.90
Oil C/H H/W heater (E)	0.20	0.50
Solid C/H H/W heater (E)	5.19	0.41
Solid CHP H/W heater (E)	0.00	0.67
Electric H/W heater	6.18	0.72
Electric heat pump H/W heater (E)	0.00	9.90
Solar individual H/W heater	0.00	9.90
Solar space & H/W heater (E)	0.00	9.90
Gas individual space heater	4.14	0.50
Gas C/H space heater	4.16	0.75
Gas heat pump space heater	0.00	9.90
Oil C/H space heater	3.45	0.65
Solid individual space heater	2.45	0.25
Solid C/H space heater	2.72	0.65
Solid CHP space heater	0.00	0.67
Electric on peak space heater	0.44	1.00
Electric off peak space heater	2.13	9.90
Electric heat pump space heater	0.00	9.90
Solar space & H/W heater	0.00	9.90
Solar passive house	0.00	9.90
Liquid fuelled car	14.00	0.12
Electric car	0.00	0.80

MISCELLANEOUS DATA ON DOMESTIC CONVERTERS		
Solar water heater:		
Area of collector	=	5.0 m2
Volume of tank	=	200.0 l.
Loss coeff. of tank	=	20.0 W/C
Active solar house:		
Area of collector	=	20.0 m2
Volume of tank	=	40.0 m3
Insulation on tank	=	28.1 cm.
Specific loss of tank	=	10.0 W/C
Passive solar house:		
Area of south glazing	=	15.0 m2
Transmittance of glazing	=	0.7
Specific loss (day)	=	150.0 W/C
Specific loss (night)	=	125.0 W/C
Ventilation loss	=	50.0 W/C

INDUSTRIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Oil fuelled motor	526.00	0.17
Electric fuelled motor	2285.00	0.35
Fluorescent lights (U)	744.80	0.40
Gas heater > 120 C	3071.00	0.60
Gas CHP heater > 120 C	691.00	0.56
Liquid heater > 120 C	2941.00	0.60
Liquid CHP heater > 120 C	1243.00	0.56
Solid heater > 120 C	1952.00	0.60
Solid CHP heater > 120 C	368.00	0.56
Electric heater > 120 C	1763.00	1.00
Gas heater < 120 C	2205.00	0.60
Gas CHP heater < 120 C	907.00	0.56
Liquid heater < 120 C	3817.00	0.60
Liquid CHP heater < 120 C	1634.00	0.56
Solid heater < 120 C	932.00	0.60
Solid CHP heater < 120 C	484.00	0.56
Electric heater < 120 C	143.00	1.00
Gas H/W heater	618.00	0.60
Gas CHP H/W heater	195.00	0.56
Liquid H/W heater	1771.00	0.60
Liquid CHP H/W heater	351.00	0.56
Solid H/W heater	352.00	0.60
Solid CHP H/W heater	104.00	0.56
Electric H/W heater	97.00	1.00
Gas space heater (U)	1.85	0.60
Gas CHP space heater (U)	0.00	0.56
Liquid space heater (U)	5.31	0.60
Liquid CHP space heater (U)	0.00	0.56
Solid space heater (U)	1.05	0.60
Solid CHP space heater (U)	2.10	0.56
Electric space heater (U)	0.33	1.00
Diesel transport motors	2324.00	0.17

COMMERCIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Miscellaneous electric	1046.00	1.00
Fluorescent lights (U)	2125.60	0.40
Gas cooker	279.00	0.20
Liquid cooker	12.70	0.20
Solid cooker	12.70	0.20
Electric cooker	108.00	0.40
Gas H/W heater	571.00	0.60
Gas CHP H/W heater	0.00	0.56
Liquid H/W heater	1300.00	0.60
Liquid CHP H/W heater	0.00	0.56
Solid H/W heater	280.00	0.60
Solid CHP H/W heater	0.00	0.56
Electric H/W heater	254.00	1.00
Gas space heater (U)	4.86	0.60
Gas CHP space heater (U)	0.00	0.56
Liquid space heater (U)	15.39	0.60
Liquid CHP space heater (U)	0.00	0.56
Solid space heater (U)	4.05	0.60
Solid CHP space heater (U)	0.00	0.56
Electric space heater (U)	2.27	1.00
Ships and aeroplanes	2511.00	0.20
Electric trains	228.00	0.80

I&S, FEEDSTOCK USER CONVERTERS	POWER (MW)	EFFICIENCY
Gas I&S process	1211.00	0.78
Liquid I&S process	2312.00	0.54
Solid I&S process	5850.00	0.43
Electric I&S process	447.00	0.30
Gas feedstock use	3076.00	1.00
Liquid feedstock use	14871.00	1.00
Solid feedstock use	159.00	1.00

USER STORES	INPUT POWER	EFF. I/O	CAPACITY /UNIT	TOTAL CAPACITY	OUTPUT POWER	POP
DOMESTIC						
House oil tanks		1.0	11194.kWh	38621.GWh		3.4
Car petrol tanks		1.0	444.kWh	6222.GWh		14.0
Coal bunkers		1.0	17056.kWh	41786.GWh		5.2
El stor. heaters	7.5 kW	1.0	85. Wh/C		4. W/C	2.1
El car batteries	10.0 kW	.8	55. kWh	0. GWh		0.0
Solar H/W tanks			200. l		20.0 W/C	0.0
Active solar houses			40.0 m3		28.1 W/C	0.0
INDUSTRY						
Liq stores				30700. GWh		
Solid stores				15800. GWh		
COMMERCE						
Liq stores				14400. GWh		
Solid stores				168. GWh		

FOSSIL/FISSILE FUEL AND TYPE	ELECTRICITY GENERATION OUTPUT POWER	EFFICIENCY	MERIT
Domestic CHP	0.0 MW	0.25 (E)	1
Industrial CHP	2523.9 MW	0.11 (E)	1
Commercial CHP	0.0 MW	0.11 (E)	1
Pumped store	1000.0 MW	0.85	6
Nuclear	3.0 GW	0.29- 0.23	7
Solid	35.0 GW	0.35- 0.11	8
Oil	11.0 GW	0.34- 0.18	9
Gas	1.0 GW	0.35- 0.10	10
Gas turbine	2.0 GW	0.34- 0.18	11

Peaking plant (gas turbine and pumped storage) used if d(NET LOAD)/dt > 1250.0 MW/hr

Merit order of conventional stations:
nuclear (1),coal (2),oil (3),gas (4)

1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 3 2
3 2 3 2 3 2 4 3 2 3 2 3 2 3 2 3 2 3 2 3 2 2 2 2 2

AMBIENT ELECTRICITY GENERATION			
AMBIENT SOURCE	MAX OUTPUT	SIZE	MERIT
Aerogeneration Dispersed in UK Vcut= 3.0 ms-1 Vrat= 20.0 (ms-1) Radius=23 m.	0.00 GW	0. num	2
Wave power NW of Scotland Max. mech. (kWm-1)= 100.0 Max height(m.) 4.2	0.00 GW	0.0 km	3
Tidal power Severn estuary	0.0 + 0.0 GW	0.0+ 0.0 km2	4
Fresh hydro Dispersed in UK 3.2 TWhe/annum 24. hrs average= 366. MWe	1165.0 MW		5

ENERGY INDUSTRY CONVERTERS	POWER (GW)	EFFICIENCY
Gas extraction	85.	0.96
Gas from coal converter	0.	0.70
Gas transmission	102.	0.97
Oil extraction	120.	0.96
Oil from coal converter	0.	0.70
Oil refinery	144.	0.94
Oil distribution	144.	0.99
Coal mines	180.	0.95
Coal distribution	216.	0.97
Nuclear reprocessor	30.	0.50
Nuclear waste disposal	0.	9.90
Electricity transmission	62.	0.92

ENERGY INDUSTRY STORES	POWER (GW)	CAPACITY
Gas stores	85.0	228.0 GWh
Oil stores	120.0	262000.0 GWh
Solid stores	180.0	260000.0 GWh
Nuclear stores	30.0	1000.0 GWh
Pumped storage	1.0	29.1 GWhm
In at power	1000.0 MW	
Out if d(LOAD)/dt >	1250.0 MW/hr	
Biomass area	0.0 km2	
Efficiency biomass to gas	0.55	
Efficiency biomass to oil	0.50	

PRIMARY RESERVES	SIZE (TWh)
Gas reserves	15332.
Oil reserves	17279.
Coal reserves	563889.
Uranium reserves	50000.

3. PERFORMANCE OF ENERGY SYSTEM

The hourly or monthly values for the following variables are output:

- CLIMATE
- DEMANDS
- FUEL DELIVERIES
- USER STORES
- ELECTRICITY SUPPLY
- FUEL USED IN POWER STATIONS
- ENERGY INDUSTRY STORES
- PRIMARY FUEL

Note that calendar months are used.
This is followed by tables summarising:

- DEMANDS
- DELIVERIES
- ELECTRICITY PRODUCTION
- PRIMARY FUEL USE

SYSTEM PERFORMANCE FOR ONE YEAR
The figures below detail the performance of the energy system through a year.
UNLESS OTHERWISE STATED, QUANTITIES ARE IN GWh

CLIMATE

Solar (Whm-1)

39.	63.	97.	132.	161.	177.
175.	157.	126.	90.	58.	36.

Average = 109.3

Wind (ms-1)

9.	8.	8.	7.	7.	6.
6.	6.	7.	7.	8.	8.

Average = 7.4

Wave (kWm-1)

104.	96.	77.	54.	36.	26.
23.	26.	36.	54.	76.	96.

Average = 58.7

Tide (m)

10.	10.	10.	10.	10.	10.
10.	10.	10.	10.	10.	10.

Average = 10.0

Temperature (C)

6.	5.	5.	8.	12.	17.
18.	17.	13.	11.	6.	2.

Average = 10.0

USEFUL ENERGY DEMANDS
DOMESTIC USEFUL ENERGY DEMANDS

Light

68.	58.	60.	54.	53.	48.

50.	52.	54.	61.	63.	67.

Total = 689.4

Miscellaneous

2446.	2207.	2443.	2363.	2446.	2363.
2443.	2446.	2359.	2446.	2367.	2439.

Total = 28770.1

Cooking

340.	306.	339.	328.	340.	328.
339.	340.	328.	340.	329.	339.

Total = 3994.5

Hot Water

4256.	3925.	4257.	3948.	3990.	3776.
3725.	3547.	3605.	3902.	3862.	4080.

Total = 46872.8

Space heating

19845.	20109.	21049.	12300.	6242.	0.
0.	0.	4425.	7938.	18065.	29753.

Total = 139726.2

Transport

1677.	1501.	1688.	1703.	1836.	1882.
2008.	2019.	1961.	1928.	1780.	1768.

Total = 21750.3

INDUSTRIAL USEFUL ENERGY DEMANDS

Light

352.	297.	302.	266.	258.	235.
245.	260.	266.	310.	325.	346.

Total = 3460.9

Kinetic

2102.	1880.	2078.	2005.	2102.	2005.
2078.	2102.	1981.	2102.	2028.	2055.

Total = 24518.2

Heat > 120

8995.	8046.	8894.	8578.	8995.	8578.
8894.	8995.	8477.	8995.	8679.	8794.

Total = 104919.8

Heat < 120

7569.	6771.	7484.	7218.	7569.	7218.
7484.	7569.	7134.	7569.	7303.	7400.

Total = 88286.5

Hot water

2927.	2782.	3045.	2520.	2395.	2024.
2098.	2122.	2200.	2448.	2780.	3454.

Total = 30794.2

Space heat

3759.	4027.	4331.	2481.	1594.	464.
481.	486.	1271.	1812.	3447.	6083.

Total = 30234.2

Transport

1729.	1562.	1729.	1673.	1729.	1673.
1729.	1729.	1673.	1729.	1673.	1729.

Total = 20358.2

COMMERCIAL USEFUL ENERGY DEMANDS

Light

838.	698.	698.	605.	578.	524.
553.	588.	610.	722.	766.	825.

Total = 8005.1

Miscell Elec

785.	703.	777.	749.	785.	749.
777.	785.	740.	785.	758.	768.

Total = 9161.7

Process

310.	277.	306.	295.	310.	295.
306.	310.	292.	310.	299.	303.

Total = 3612.1

Hot water

1806.	1615.	1786.	1722.	1806.	1722.
1786.	1806.	1702.	1806.	1742.	1765.

Total = 21064.8

Space heat

9044.	9152.	9935.	6584.	3158.	0.
0.	0.	2267.	4016.	8437.	12669.

Total = 65262.4

Transport

1868.	1687.	1868.	1808.	1868.	1808.
1868.	1868.	1808.	1868.	1808.	1868.

Total = 21996.4

IRON AND STEEL

High T heat

7306.	6599.	7306.	7070.	7306.	7070.
7306.	7306.	7070.	7306.	7070.	7306.

Total = 86023.2

FEEDSTOCKS

Feedstocks

13471.	12167.	13471.	13036.	13471.	13036.
13471.	13471.	13036.	13471.	13036.	13471.

Total = 158608.6

TOTAL USEFUL DEMANDS

Work

10608.	9540.	10583.	10300.	10767.	10480.
10904.	10951.	10523.	10859.	10414.	10627.

Total = 126554.9

Light

1257.	1054.	1060.	925.	888.	807.
847.	900.	930.	1093.	1154.	1239.

Total = 12155.4

High T heat					
16950.	15229.	16846.	16272.	16950.	16272.
16846.	16950.	16168.	16950.	16376.	16741.
	Total =	198549.7			

Low T heat					
7569.	6771.	7484.	7218.	7569.	7218.
7484.	7569.	7134.	7569.	7303.	7400.
	Total =	88286.5			

Hot water					
8989.	8322.	9088.	8190.	8191.	7522.
7609.	7475.	7507.	8156.	8384.	9299.
	Total =	98731.8			

Space heat					
32648.	33288.	35315.	21366.	10994.	464.
481.	486.	7964.	13765.	29948.	48505.
	Total =	235222.8			

TOTAL USE DEMAND					
78021.	74203.	80375.	64272.	55359.	42763.
44170.	44330.	50225.	58392.	73579.	93811.
	Total =	759501.1			

DOMESTIC FUEL DELIVERIES

Gas					
21235.	20586.	21959.	15477.	11257.	5593.
5594.	5409.	9362.	12505.	19646.	27323.
	Total =	175945.7			

Liquid					
7671.	7382.	7804.	5098.	2938.	78.
76.	73.	2184.	3631.	7050.	9726.
	Total =	53710.3			

Solid					
17004.	16978.	17868.	11390.	7070.	2453.
2419.	2304.	5517.	8230.	15470.	23998.
	Total =	130700.7			

Electricity					
8937.	8335.	9085.	7659.	6707.	5138.
5231.	5178.	6085.	7071.	8428.	9920.
	Total =	87773.3			

CHP (heat)					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

Solar (heat)					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

Transport (liq)					
13974.	12509.	14068.	14189.	15299.	15682.
16736.	16829.	16341.	16064.	14832.	14730.
	Total =	181252.7			

Transport (elec)

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

Total = 0.0

TOTAL

68822.	65789.	70784.	53812.	43271.	28943.
30057.	29793.	39488.	47501.	65425.	85697.

Total = 629382.8

INDUSTRIAL FUEL DELIVERIES

Gas

10921.	10010.	11021.	10017.	10140.	9288.
9631.	9740.	9473.	10218.	10472.	11546.

Total = 122477.2

Liquid

20645.	19157.	21050.	18545.	18402.	16454.
17060.	17253.	17104.	18627.	19733.	22678.

Total = 226708.2

Solid

7417.	7063.	7730.	6363.	6023.	5063.
5250.	5309.	5528.	6163.	7041.	8802.

Total = 77752.4

Electricity

7386.	6588.	7212.	6828.	7066.	6670.
6921.	7029.	6709.	7206.	7082.	7319.

Total = 84015.9

CHP (heat)

5274.	4881.	5366.	4758.	4742.	4262.
4419.	4469.	4412.	4795.	5044.	5748.

Total = 58173.3

Solar (heat)

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

Total = 0.0

Transport (liq)

10171.	9187.	10171.	9843.	10171.	9843.
10171.	10171.	9843.	10171.	9843.	10171.

Total = 119754.4

Transport (elec)

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

Total = 0.0

TOTAL

61814.	56885.	62550.	56354.	56544.	51581.
53452.	53971.	53069.	57181.	59215.	66265.

Total = 688881.3

COMMERCIAL FUEL DELIVERIES

Gas

4519.	4366.	4771.	3688.	2725.	1680.

1742.	1762.	2352.	2986.	4272.	5585.
	Total =	40449.5			
Liquid					
10405.	10333.	11247.	7953.	4723.	1597.
1656.	1675.	3767.	5551.	9760.	13868.
	Total =	82536.2			
Solid					
2696.	2681.	2918.	2052.	1200.	380.
394.	398.	951.	1418.	2527.	3608.
	Total =	21223.3			
Electricity					
4047.	3582.	3758.	3199.	2894.	2435.
2547.	2648.	2829.	3327.	3774.	4299.
	Total =	39339.8			
CHP (heat)					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			
Solar (heat)					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			
Transport (liq)					
9341.	8437.	9341.	9040.	9341.	9040.
9341.	9341.	9040.	9341.	9040.	9341.
	Total =	109981.8			
Transport (elec)					
170.	153.	170.	164.	170.	164.
170.	170.	164.	170.	164.	170.
	Total =	1997.3			
TOTAL					
31177.	29554.	32204.	26096.	21053.	15296.
15850.	15993.	19103.	22793.	29538.	36870.
	Total =	295527.7			

I&S AND FEEDSTOCKS DELIVERIES

I&S, Gas					
1155.	1043.	1155.	1118.	1155.	1118.
1155.	1155.	1118.	1155.	1118.	1155.
	Total =	13600.5			
I&S Liquid					
3185.	2877.	3185.	3083.	3185.	3083.
3185.	3185.	3083.	3185.	3083.	3185.
	Total =	37505.8			
I&s, Solid					
10122.	9142.	10122.	9795.	10122.	9795.
10122.	10122.	9795.	10122.	9795.	10122.
	Total =	119176.7			
I&S, Electricity					
1109.	1001.	1109.	1073.	1109.	1073.

1109.	1109.	1073.	1109.	1073.	1109.
	Total =	13052.4			

I&S, TOTAL

15571.	14064.	15571.	15069.	15571.	15069.
15571.	15571.	15069.	15571.	15069.	15571.
	Total =	183335.4			

Feedstocks, Gas

2289.	2067.	2289.	2215.	2289.	2215.
2289.	2289.	2215.	2289.	2215.	2289.
	Total =	26945.8			

Feedstock, Liquid

11064.	9993.	11064.	10707.	11064.	10707.
11064.	11064.	10707.	11064.	10707.	11064.
	Total =	130270.0			

Feedstock, Solid

118.	107.	118.	114.	118.	114.
118.	118.	114.	118.	114.	118.
	Total =	1392.8			

Feedstock, TOTAL

13471.	12167.	13471.	13036.	13471.	13036.
13471.	13471.	13036.	13471.	13036.	13471.
	Total =	158608.6			

TOTAL FUEL DELIVERIES

Gas

40119.	38073.	41195.	32514.	27565.	19894.
20410.	20355.	24519.	29154.	37723.	47898.
	Total =	379418.6			

Liquid

52971.	49742.	54350.	45386.	40312.	31918.
33042.	33250.	36845.	42059.	50332.	60522.
	Total =	530730.4			

Solid

37357.	35971.	38755.	29715.	24534.	17806.
18303.	18251.	21906.	26051.	34948.	46648.
	Total =	350246.0			

Electricity

21478.	19506.	21164.	18758.	17776.	15316.
15808.	15964.	16695.	18713.	20357.	22646.
	Total =	224181.3			

CHP (heat)

5274.	4881.	5366.	4758.	4742.	4262.
4419.	4469.	4412.	4795.	5044.	5748.
	Total =	58173.3			

Solar (heat)

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

Transport (liq)

33486.	30132.	33580.	33071.	34811.	34565.

36248.	36341.	35223.	35576.	33714.	34241.

Total = 410988.9

Transport (elec)

170.	153.	170.	164.	170.	164.
170.	170.	164.	170.	164.	170.

Total = 1997.3

TOTAL

190855.	178460.	194580.	164368.	149909.	123925.
128400.	128800.	139765.	156517.	182283.	217874.

Total = 1955735.9

USER STORES

Coal bunkers GWh

40788.	40786.	40808.	40984.	41159.	41395.
41420.	41429.	41240.	41124.	40870.	40664.

Average = 41055.5

Oil tanks GWh

37944.	37981.	37994.	38100.	38227.	38491.
38554.	38558.	38310.	38198.	38024.	37927.

Average = 38192.4

Petrol tanks GWh

5908.	5903.	5901.	5894.	5888.	5880.
5873.	5873.	5873.	5880.	5888.	5894.

Average = 5887.8

El stor heat C

351.	365.	362.	358.	303.	241.
241.	241.	251.	323.	348.	390.

Average = 314.5

El car batts MWh

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

Average = 0.0

Solar HW tanks C

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

Average = 0.0

Solar sp tanks C

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

Average = 0.0

Pass sol in GWh

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

Average = 0.0

Comm liquid GWh

29382.	29390.	29391.	29419.	29429.	29448.
29449.	29445.	29438.	29427.	29401.	29370.

Average = 29415.7

Comm solid GWh

15202.	15205.	15206.	15225.	15234.	15247.

15248.	15246.	15239.	15233.	15214.	15190.
	Average =	15224.2			

Ind liquid GWh

13801.	13795.	13796.	13841.	13896.	13952.
13954.	13953.	13912.	13884.	13815.	13763.
	Average =	13863.5			

Ind solid GWh

147.	146.	146.	149.	153.	159.
159.	159.	155.	152.	147.	145.
	Average =	151.5			

ELECTRICITY DEMAND,SUPPLIES AND STORED

CHP

1036.	959.	1054.	935.	931.	837.
868.	878.	867.	942.	991.	1129.
	Total =	11426.9			

Aerogeneration

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

Wave power

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

Tidal power

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

Freshwater hydro

272.	246.	272.	263.	272.	263.
272.	272.	263.	272.	263.	272.
	Total =	3203.6			

Pumped storage

112.	212.	200.	197.	186.	150.
140.	136.	169.	202.	108.	151.
	Total =	1963.0			

Nuclear

2232.	2016.	2232.	2160.	2232.	2160.
2232.	2232.	2160.	2232.	2160.	2232.
	Total =	26280.0			

Coal

16394.	14821.	16192.	14880.	14441.	12458.
12891.	12980.	13563.	15013.	15667.	16959.
	Total =	176257.8			

Oil

3499.	3251.	3398.	2416.	1747.	1234.
1254.	1308.	1585.	2169.	3155.	4016.
	Total =	29029.5			

Gas

259.	239.	214.	74.	40.	32.

6.	23.	40.	63.	191.	342.
	Total =	1522.0			

User storage

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

Pumped storage

-177.	-287.	-284.	-271.	-259.	-208.
-194.	-188.	-234.	-278.	-151.	-209.
	Total =	-2739.5			

Tidal storage

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

TOTAL DEMAND

23530.	21369.	23188.	20568.	19506.	16826.
17367.	17536.	18326.	20525.	22305.	24800.
	Total =	245846.3			

TOTAL SENT OUT

23803.	21744.	23562.	20924.	19850.	17134.
17662.	17829.	18647.	20893.	22535.	25100.
	Total =	249682.8			

FUEL USED IN POWER STATIONS

Nuclear heat

8051.	7272.	8051.	7791.	8051.	7791.
8051.	8051.	7791.	8051.	7791.	8051.
	Total =	94789.3			

Coal

49305.	44578.	48641.	44483.	42982.	36915.
38206.	38478.	40313.	44814.	47057.	51214.
	Total =	526985.4			

Oil

10472.	9743.	10172.	7191.	5188.	3658.
3716.	3879.	4707.	6446.	9430.	12080.
	Total =	86682.7			

Gas

899.	825.	728.	251.	134.	105.
16.	71.	139.	215.	636.	1175.
	Total =	5195.0			

FUEL FLOWS FROM ENERGY INDUSTRY STORES

Gas

41018.	38898.	41923.	32765.	27699.	19999.
20426.	20426.	24659.	29368.	38359.	49073.
	Total =	384613.6			

Oil

107846.	89569.	98221.	85747.	80496.	70585.
72969.	73469.	76507.	83874.	93199.	106676.
	Total =	1039157.9			

Solid					
90267.	80485.	87490.	74366.	67710.	55047.
56491.	56738.	62039.	70674.	81697.	97627.
	Total =	880631.7			
Nuclear heat					
8051.	7272.	8051.	7791.	8051.	7791.
8051.	8051.	7791.	8051.	7791.	8051.
	Total =	94789.3			
Solid for gas					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			
Solid for oil					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			
Biomass					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Total =	0.0			

ENERGY INDUSTRY STORES(GWh)

Gas					
171.	168.	170.	181.	190.	199.
200.	200.	193.	187.	173.	154.
	Average =	182.1			
Liquid					
218841.	203748.	187780.	176609.	175162.	181856.
192672.	203318.	210693.	212160.	205168.	185476.
	Average =	196123.6			
Solid					
251401.	259877.	259879.	259894.	259906.	259921.
259922.	259921.	259911.	259902.	259883.	259865.
	Average =	259190.1			
Nuclear (heat)					
989.	989.	989.	989.	989.	989.
989.	989.	989.	989.	989.	989.
	Average =	989.1			
Pumped store GWh					
23.	21.	23.	24.	24.	24.
24.	24.	24.	24.	24.	24.
	Average =	23.7			
Tidal store GWhm					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Average =	0.0			
Biomass					
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
	Average =	0.0			

PRIMARY FUEL USE

Gas

44070.	41772.	45021.	35186.	29746.	21476.
21936.	21935.	26481.	31538.	41193.	52677.
	Total =	413030.2			

Liquid

93000.	84000.	93000.	90000.	93000.	90000.
93000.	93000.	90000.	93000.	90000.	93000.
	Total =	1095000.0			

Solid

122837.	87341.	94943.	80701.	73478.	59736.
61304.	61571.	67324.	76694.	88657.	105944.
	Total =	980530.7			

Nuclear heat

16283.	14543.	16101.	15582.	16101.	15582.
16101.	16101.	15582.	16101.	15582.	16101.
	Total =	189760.4			

SUMMARIES FOR ONE YEAR
ENERGY IN GWh

SUMMARY OF USEFUL ENERGY DEMANDS

	Dom	Ind	Com	I&S	Feed	TOTAL
Work	0.	24518.	0.	0.	0.	24518.
Miscellane	28770.	0.	9162.	0.	0.	37932.
Transport	21750.	20358.	21996.	0.	0.	64105.
Light	689.	3461.	8005.	0.	0.	12155.
High Temp	0.	104920.	0.	86023.	0.	190943.
Cooking	3995.	0.	3612.	0.	0.	7607.
Low temp	0.	88287.	0.	0.	0.	88287.
Hot water	46873.	30794.	21065.	0.	0.	98732.
Space	139726.	30234.	65262.	0.	0.	235223.
Feedstocks	0.	0.	0.	0.	158609.	158609.
TOTAL	241803.	302572.	129103.	86023.	158609.	918110.

SUMMARY OF FUEL DELIVERIES

	Dom	Ind	Com	I&S	Feed	TOTAL
Gas	175946.	122477.	40449.	13600.	26946.	379419.
Liquid	53710.	226708.	82536.	37506.	130270.	530730.
Solid	130701.	77752.	21223.	119177.	1393.	350246.
Electricit	87773.	84016.	39340.	13052.	0.	224181.
CHP (heat)	0.	58173.	0.	0.	0.	58173.
Solar (hea	0.	0.	0.	0.	0.	0.
Transport	181253.	119754.	109982.	0.	0.	410989.
Transport	0.	0.	1997.	0.	0.	1997.
TOTAL	629383.	688881.	295528.	183335.	158609.	1955736.

SUMMARY OF ELECTRICITY PRODUCTION

	Electricity	Fuel used	Effic.	Load factor
CHP	11426.9			0.52
Aero	0.0			0.00
Wave	0.0			0.00
Tide	0.0			0.00
Hydro	3203.6			0.31
Pumped	1963.0			0.22
Nuclear	26280.0	94789.3	0.28	1.00
Coal	176257.8	526985.4	0.33	0.57
Oil	29029.5	86682.7	0.33	0.30
Gas	1522.0	5195.0	0.29	0.17
Other storage	0.0			0.00
Pumped storage	-2739.5			0.00
Tidal storage	0.0			0.00
Total demand	245846.3			0.45
TOTAL SENT OUT	249682.8			0.42

SUMMARY OF PRIMARY FUEL FLOWS	
Gas	384613.6
Oil	1039157.9
Coal	880631.7
Nuclear (heat)	94789.3
Coal for gas	0.0
Coal for oil	0.0
Biomass	0.0

GROSS PRIMARY FUEL EXTRACTED	
Gas	413030.2
Oil	1095000.0
Coal	980530.7
Nuclear	189760.4
TOTAL FOSS/FISS	2678321.3

4. PERFORMANCE ANALYSIS
This section of output gives some analysis of the performance of the energy system over the simulated time period.

GAS
Maximum flow rate of gas delivery was
93.51 GW
Minimum storage requirement between component 2 and 6 was 0.0 in interval 12

LIQUID
Maximum flow rate of liquid delivery was
104.14 GW
Minimum storage requirement between component 2 and 6 was 0.0 in interval 11

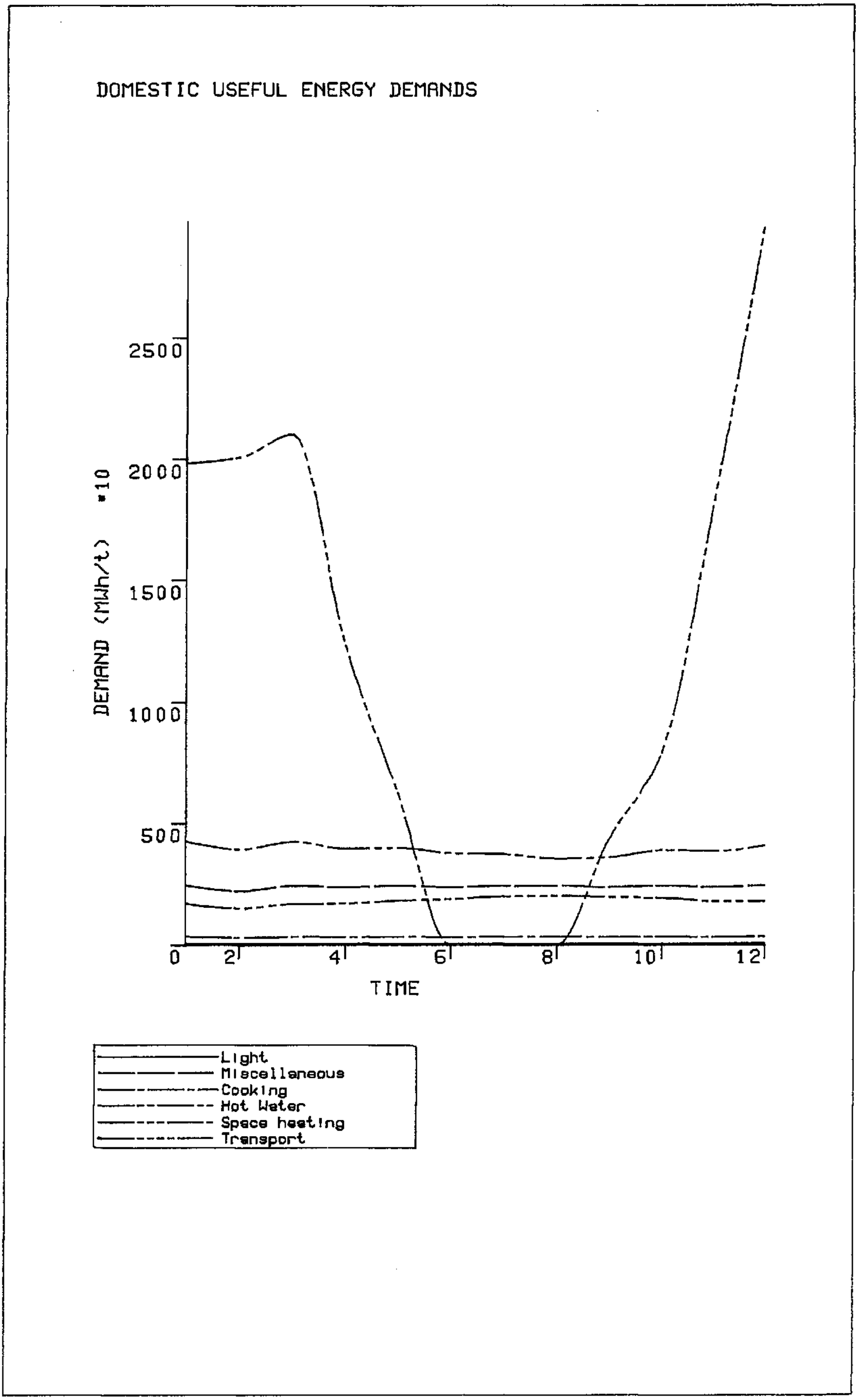
SOLID
Maximum flow rate of solid delivery was
89.07 GW
Minimum storage requirement between component 2 and 6 was 0.0 in interval 10

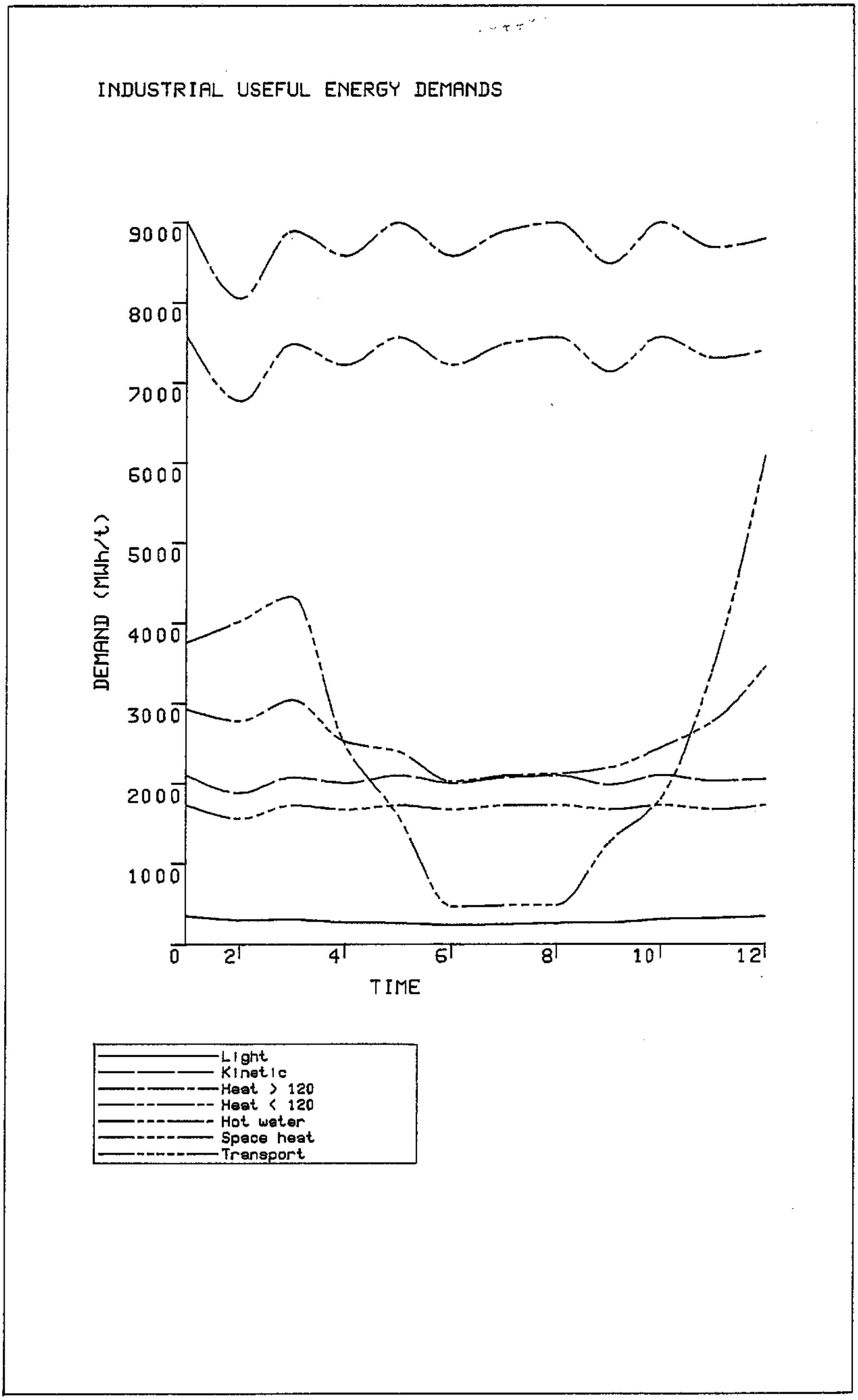
ELECTRICITY

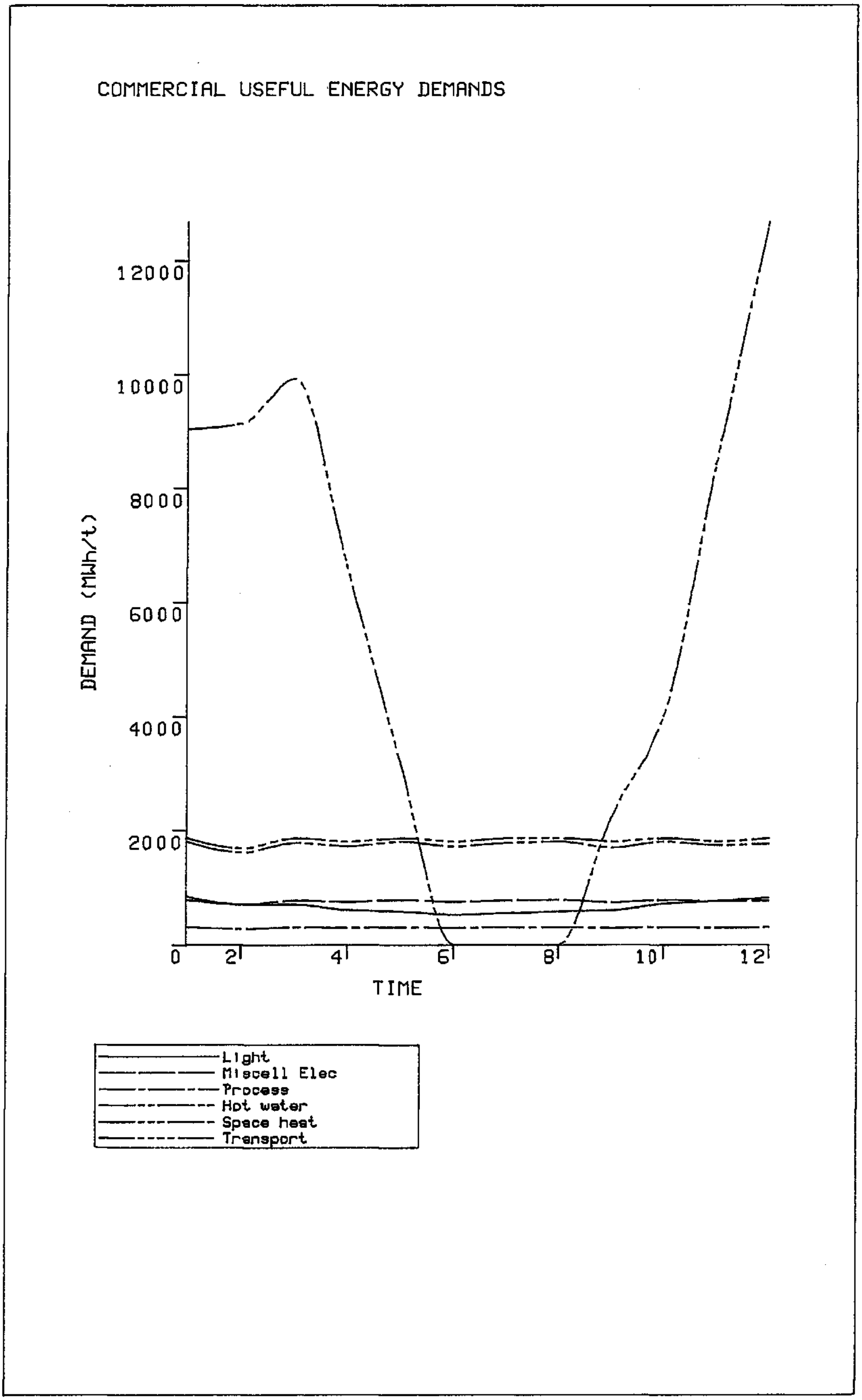
FLOW DURATION CURVES
Numbers are powers (GW)
Columns are percentage of time flow exceeded.

	0	10	20	30	40	50	60	70	80	90	100
CHP	2.0	1.5	1.5	1.3	1.3	1.3	1.0	1.0	1.0	0.8	0.5
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydro	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Pump	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nucl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Coal	27.5	23.3	23.0	22.0	21.0	21.0	20.0	19.3	18.3	15.8	8.0
Oil	10.0	6.0	5.0	4.8	4.0	3.3	3.0	2.0	1.0	0.0	0.0
Gas	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Store	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pump	-1.0	-1.0	-1.0	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dem	43.3	35.3	33.3	30.8	29.5	28.3	27.0	25.5	23.3	20.3	11.8
Sent	43.3	35.5	33.5	31.5	29.8	28.8	27.5	26.0	23.8	20.5	12.0

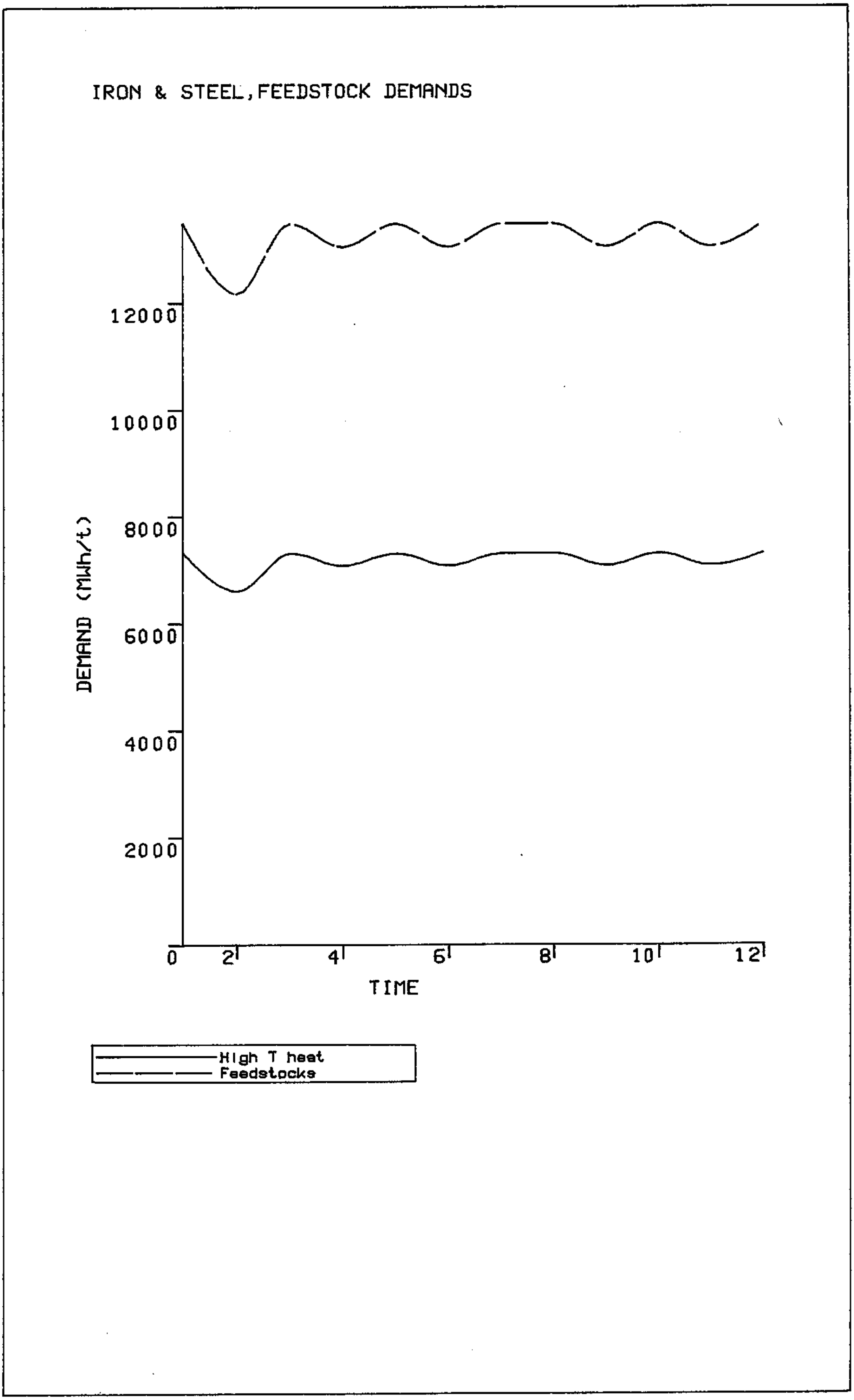
Maximum electrical power sent out was 43492.8 MW
in the 18 th hour of the 365 th day of the year.

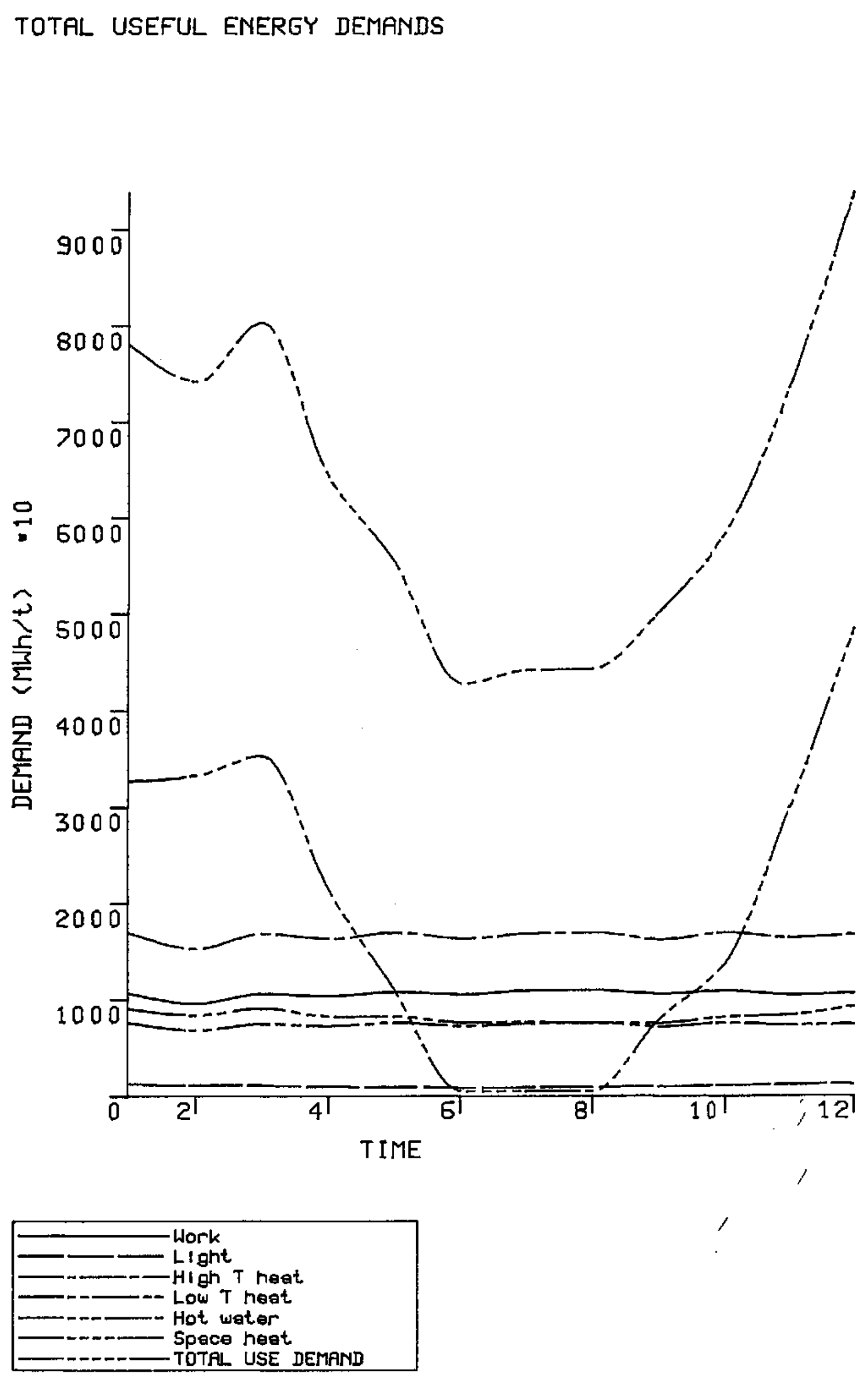

DOMESTIC USEFUL ENERGY DEMANDS
DEMAND (MWh/t) *10
2500
2000
1500
1000
500
0
2
4
6
8
10
12
TIME
Light
Miscellaneous
Cooking
Hot Water
Space heating
Transport


INDUSTRIAL USEFUL ENERGY DEMANDS
9000
8000
7000
6000
5000
4000
3000
2000
1000
DEMAND (MWh/t)
0
2
4
6
8
10
12
TIME
Light
Kinetic
Heat > 120
Heat < 120
Hot water
Space heat
Transport

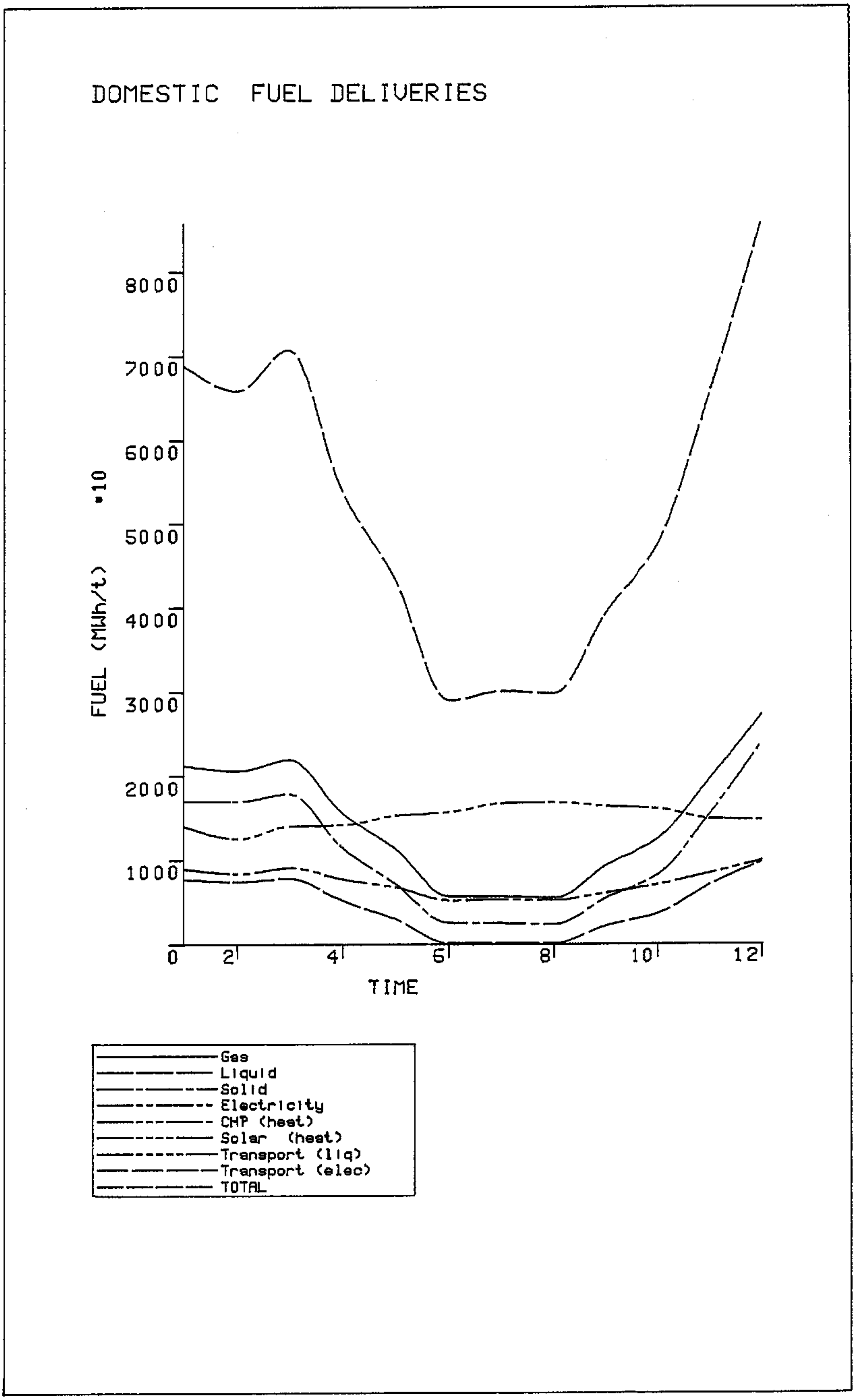


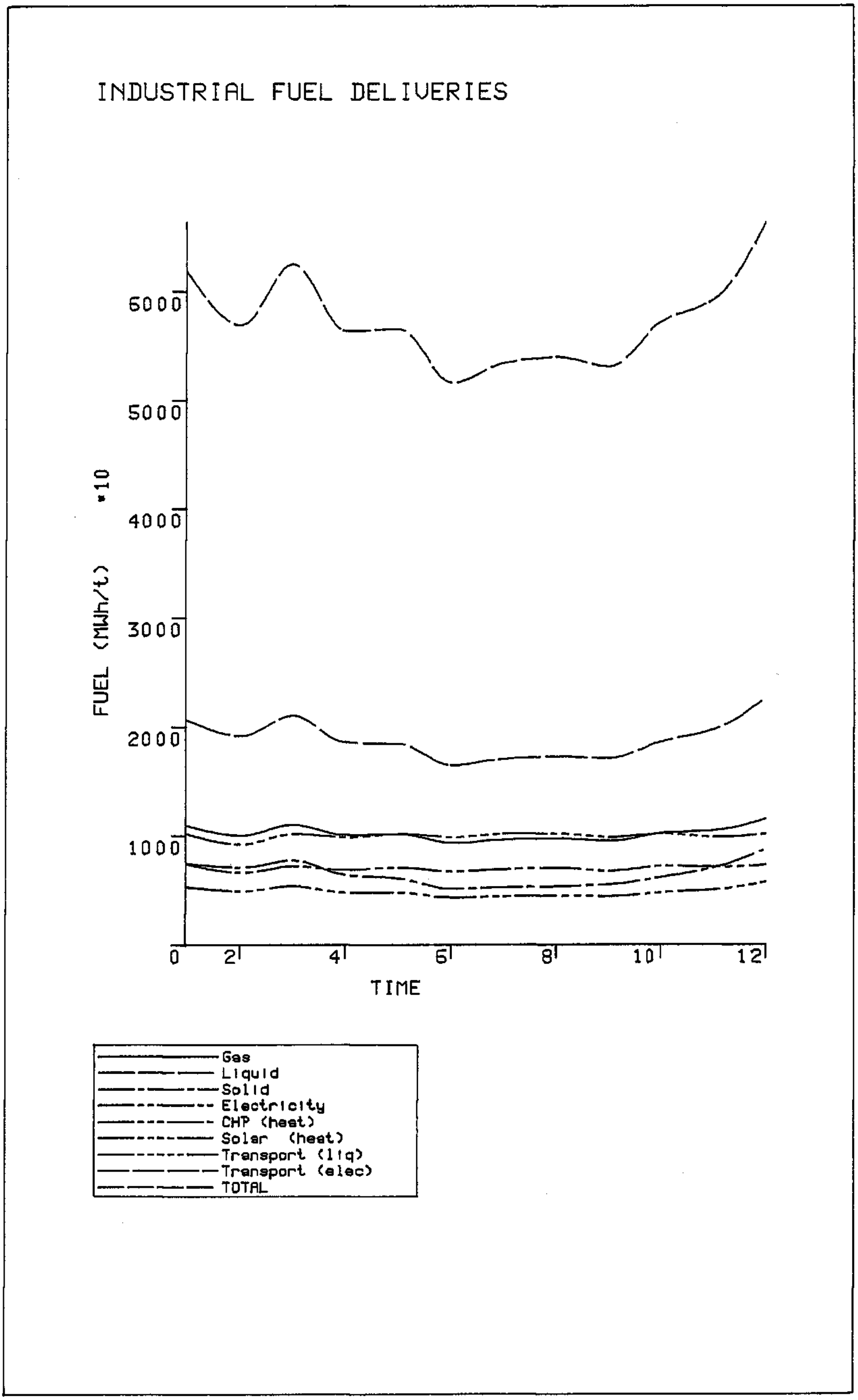
COMMERCIAL USEFUL ENERGY DEMANDS
DEMAND (MWh/t)
12000
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
Light
Miscell Elec
Process
Hot water
Space heat
Transport

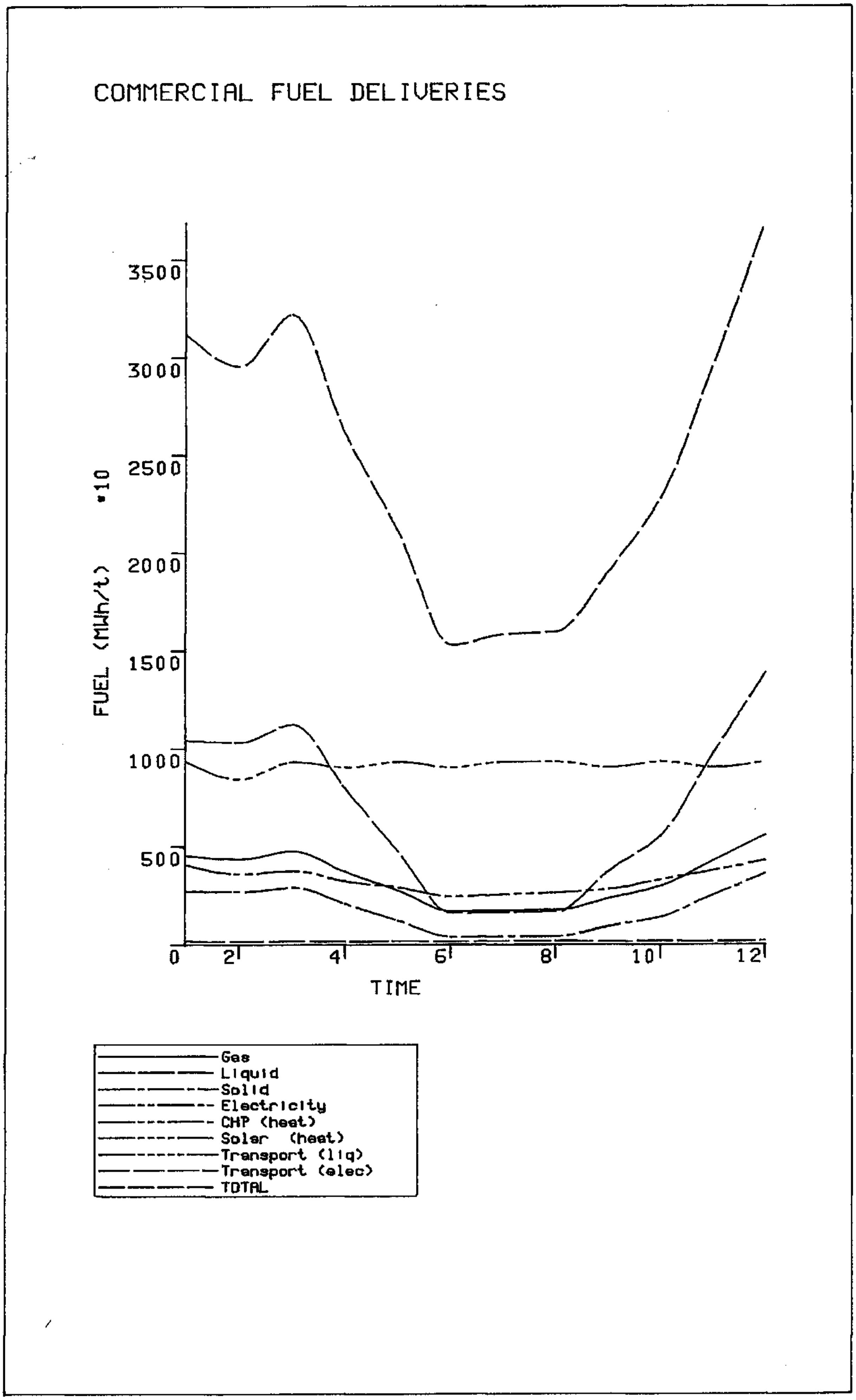

IRON & STEEL,FEEDSTOCK DEMANDS
12000
10000
8000
6000
4000
2000
DEMAND (MWh/t)
0
2
4
6
8
10
12
TIME
High T heat
Feedstocks



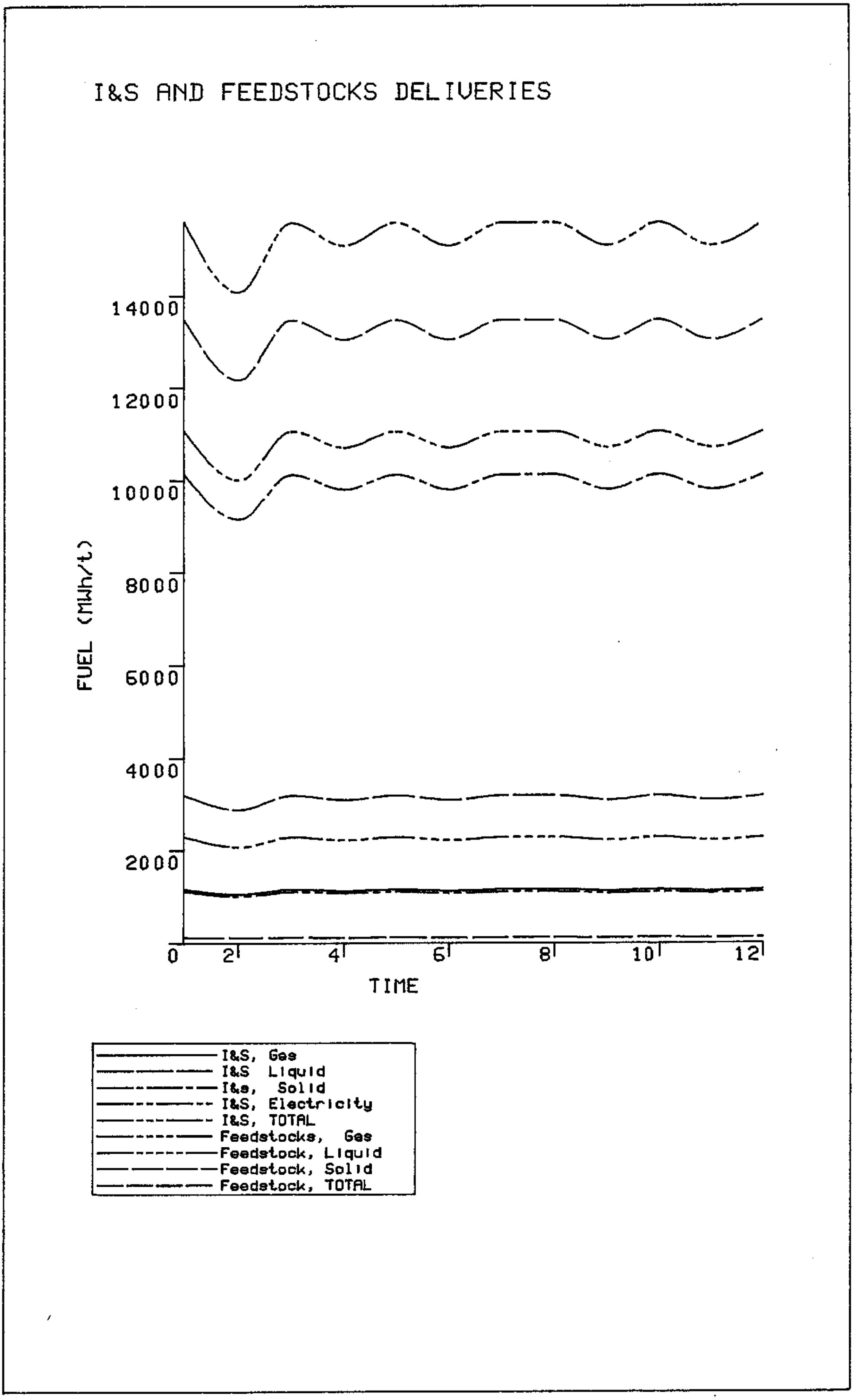
TOTAL USEFUL ENERGY DEMANDS
DEMAND (MWh/t) *10
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Work
Light
High T heat
Low T heat
Hot water
Space heat
TOTAL USE DEMAND

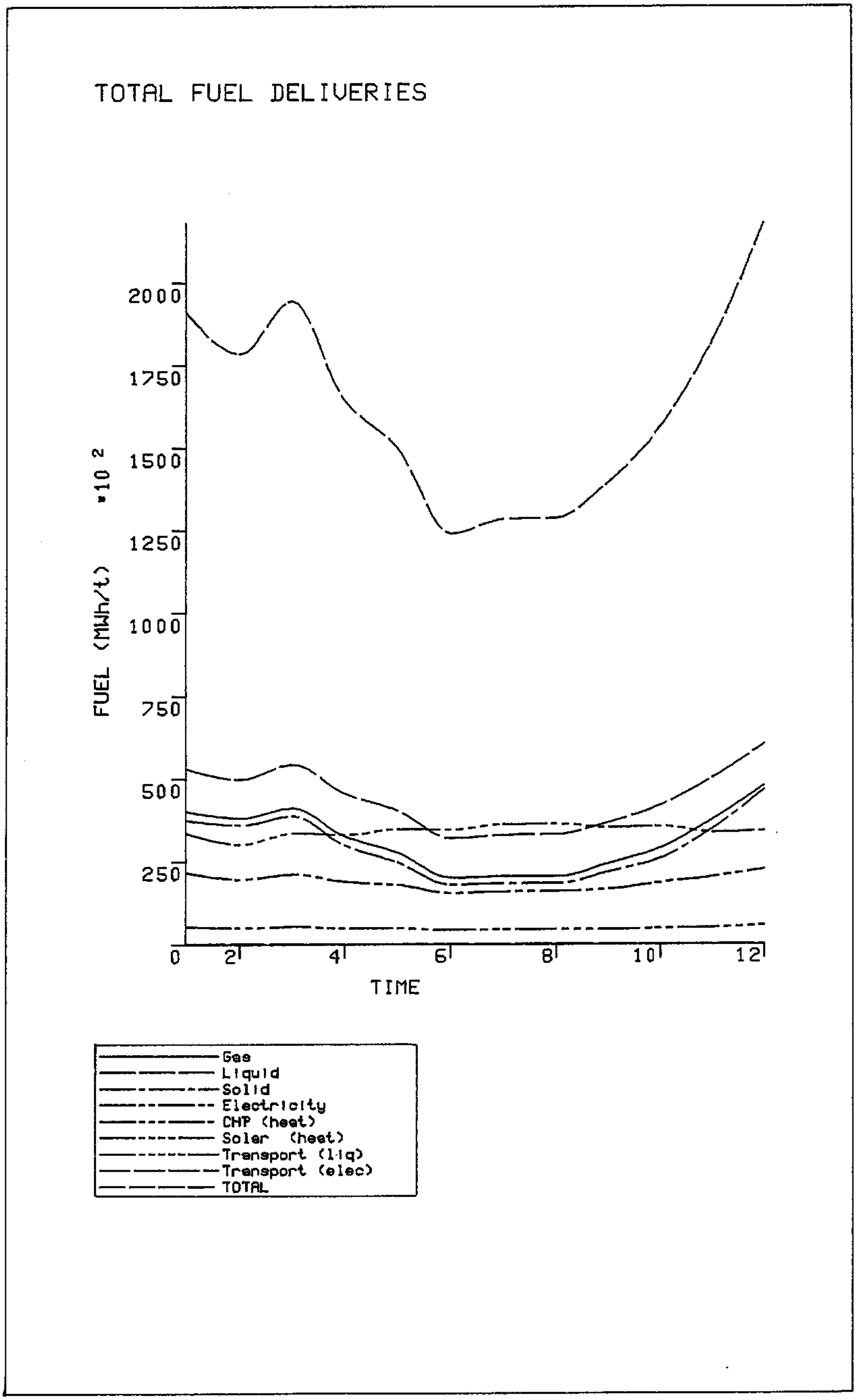

DOMESTIC FUEL DELIVERIES
8000
7000
6000
5000
4000
3000
2000
1000
FUEL (MWh/t) *10
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL


INDUSTRIAL FUEL DELIVERIES
FUEL (MWh/t) *10
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL

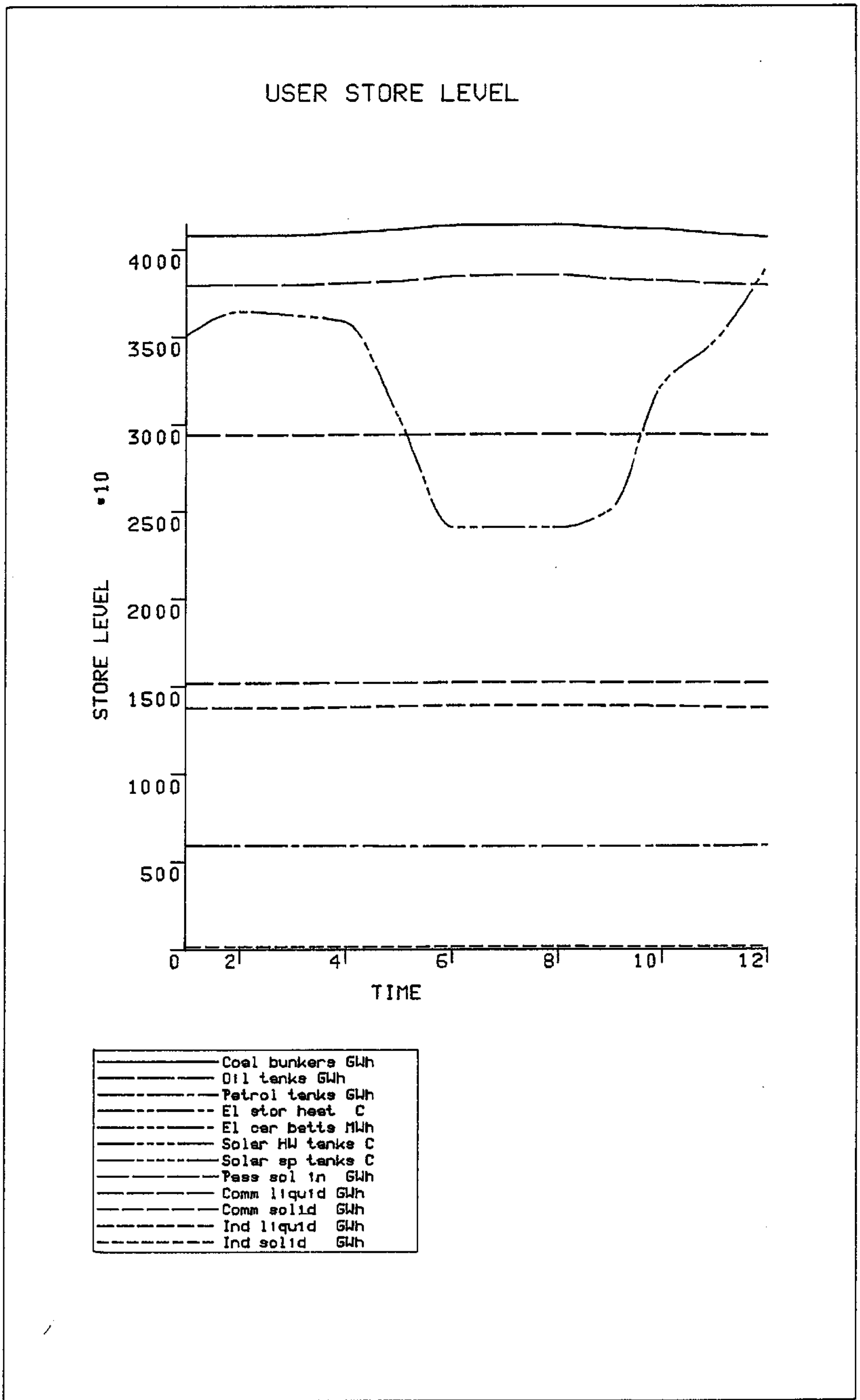


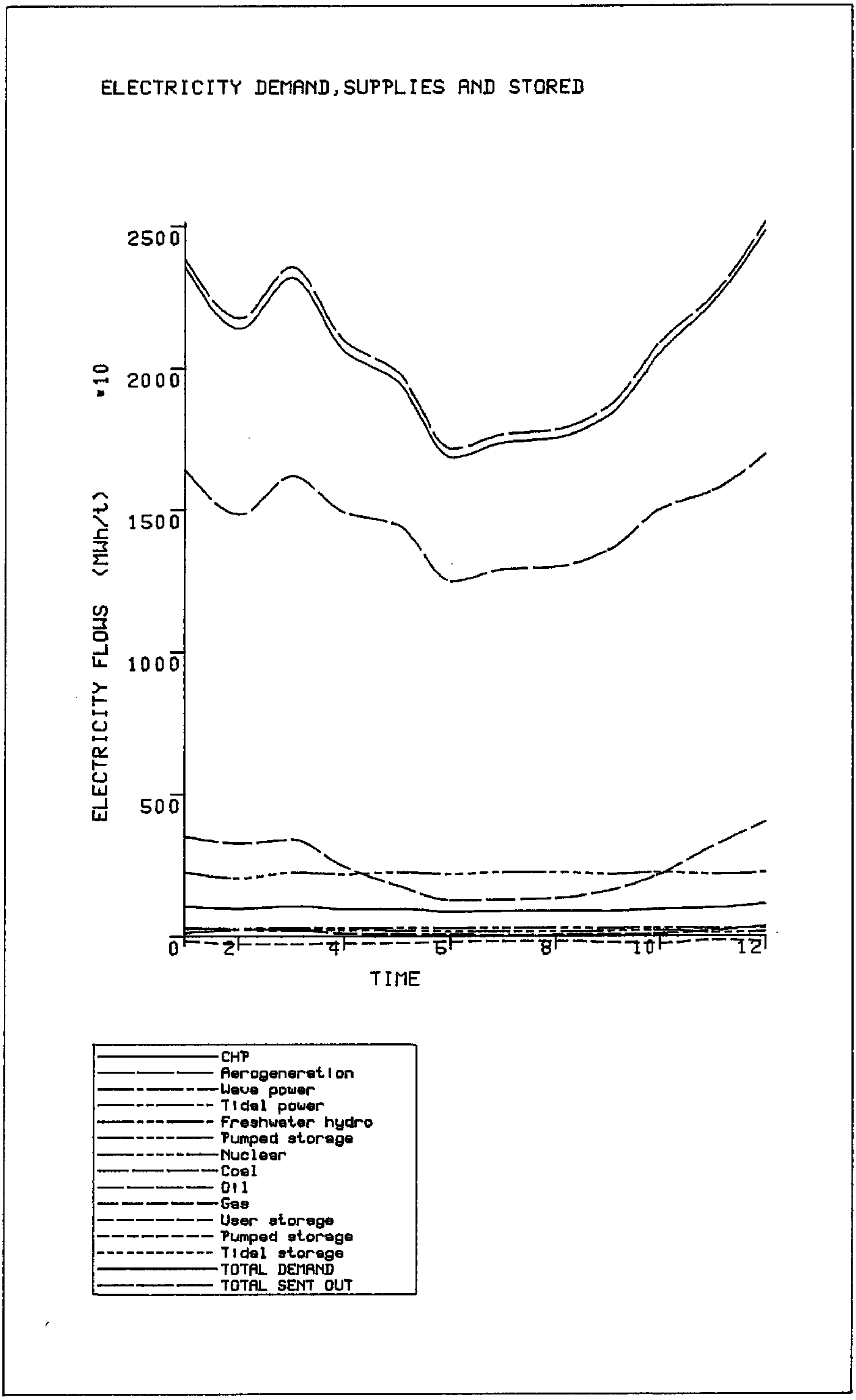
COMMERCIAL FUEL DELIVERIES
3500
3000
2500
2000
1500
1000
500
FUEL (MWh/t) *10
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL


I&S AND FEEDSTOCKS DELIVERIES
FUEL (MWh/t)
14000
12000
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
I&S, Gas
I&S Liquid
I&s, Solid
I&S, Electricity
I&S, TOTAL
Feedstocks, Gas
Feedstock, Liquid
Feedstock, Solid
Feedstock, TOTAL

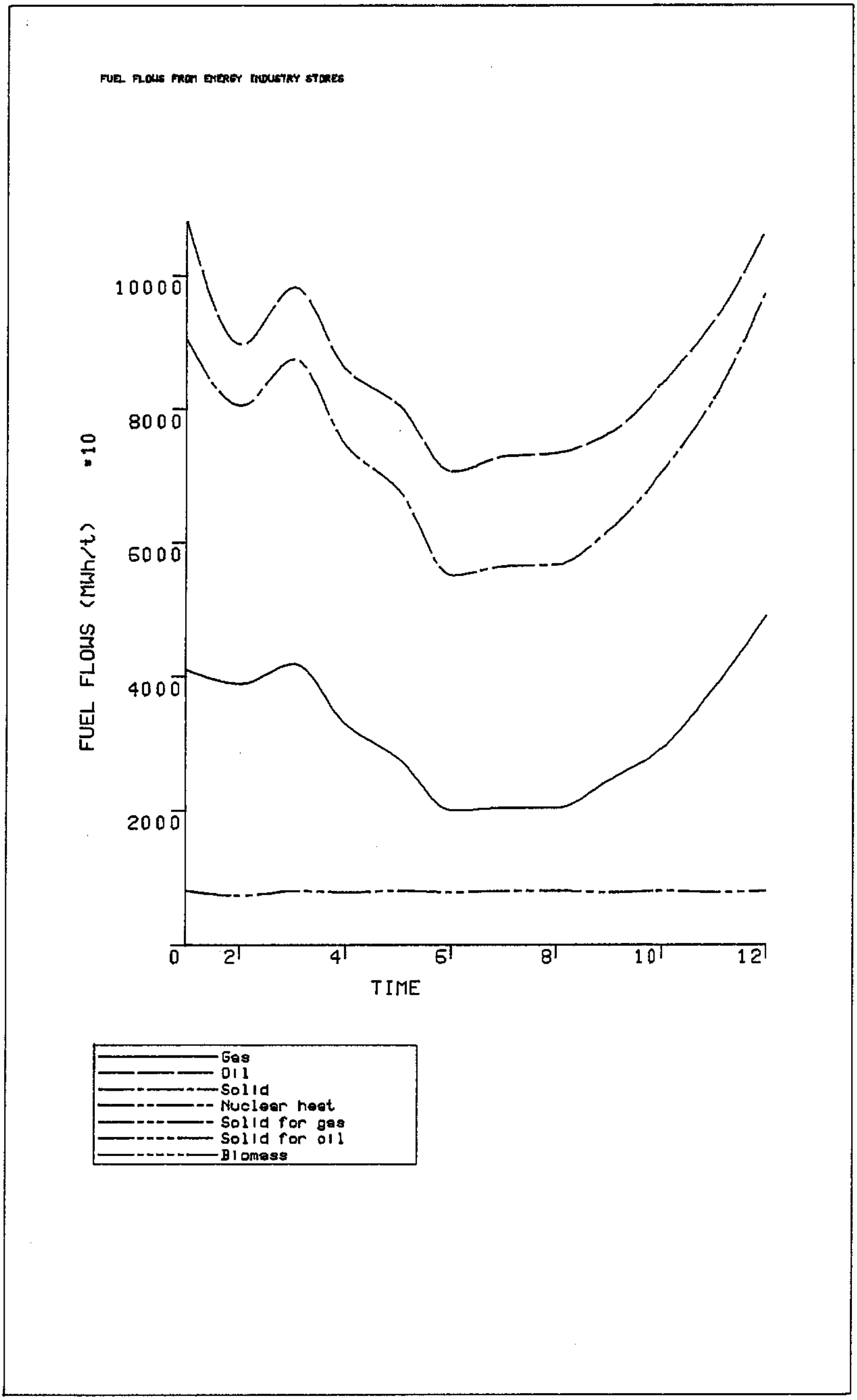


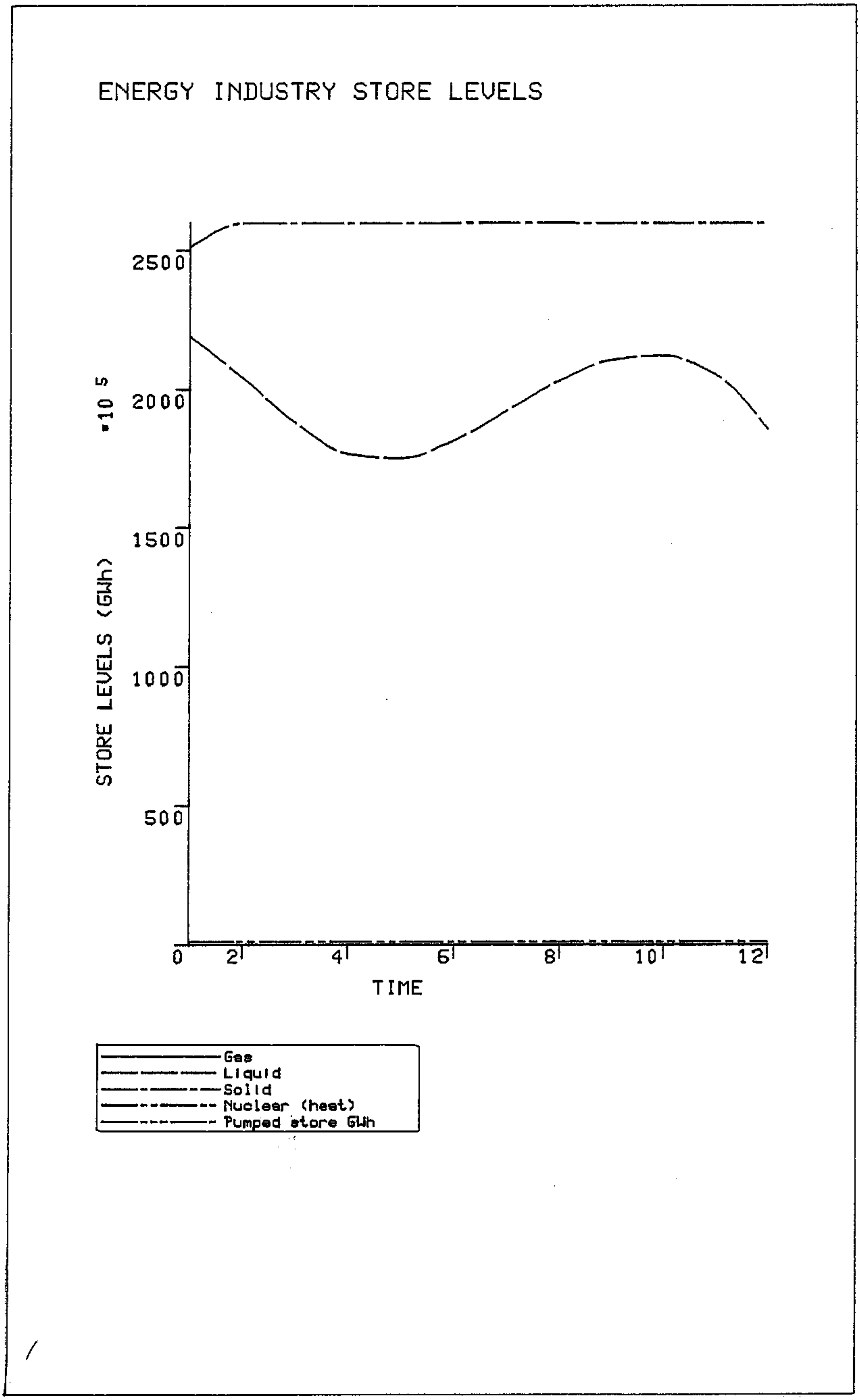
TOTAL FUEL DELIVERIES
FUEL (MWh/t) *10 2
2000
1750
1500
1250
1000
750
500
250
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL

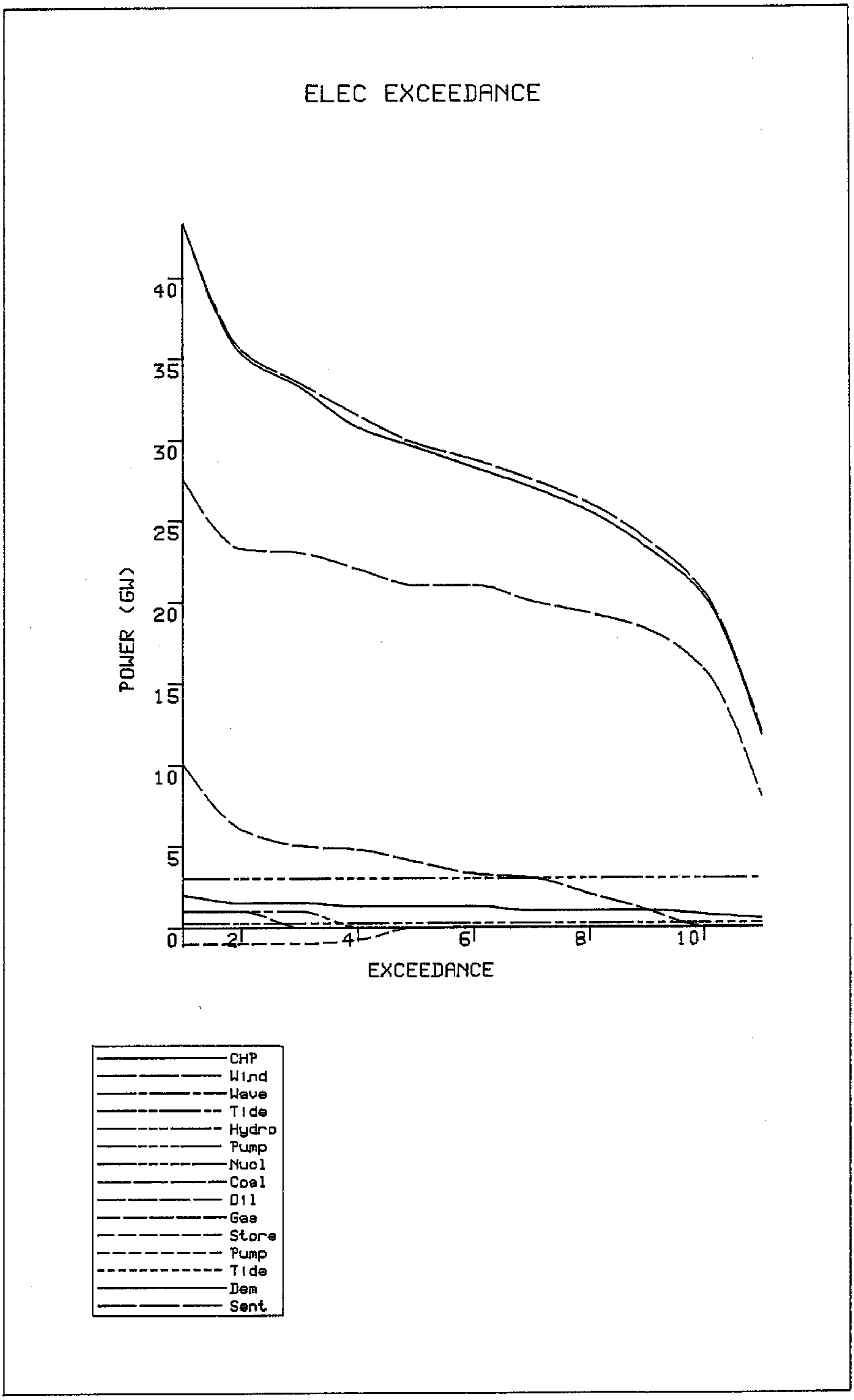

USER STORE LEVEL
STORE LEVEL *10
4000
3500
3000
2500
2000
1500
1000
500
0
2
4
6
8
10
12
TIME
Coal bunkers GWh
Oil tanks GWh
Petrol tanks GWh
El stor heat C
El car batts MWh
Solar HW tanks C
Solar sp tanks C
Pass sol in GWh
Comm liquid GWh
Comm solid GWh
Ind liquid GWh
Ind solid GWh



ELECTRICITY DEMAND, SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t) *10
2500
2000
1500
1000
500
0
2
4
6
8
10
12
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT

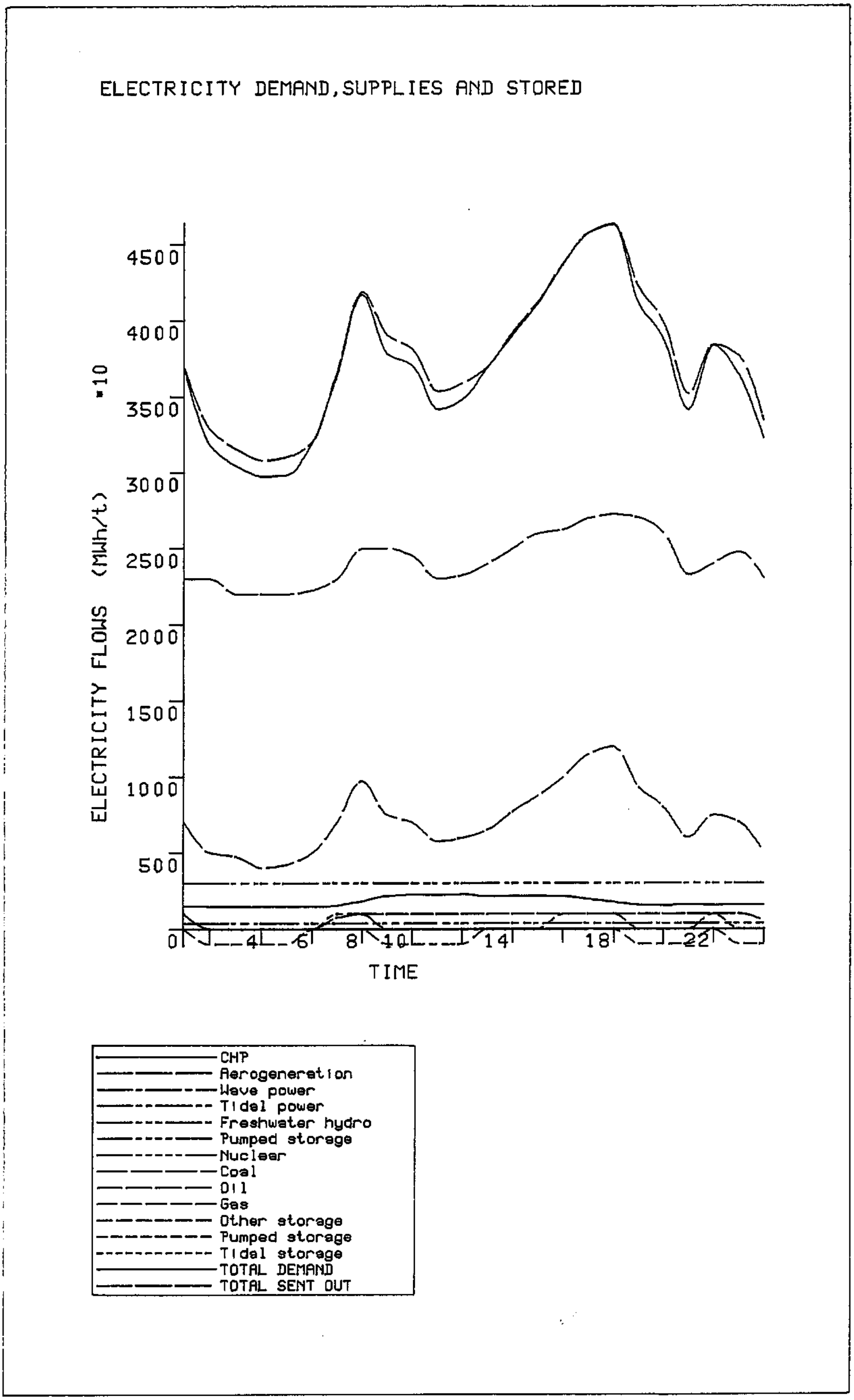

FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass

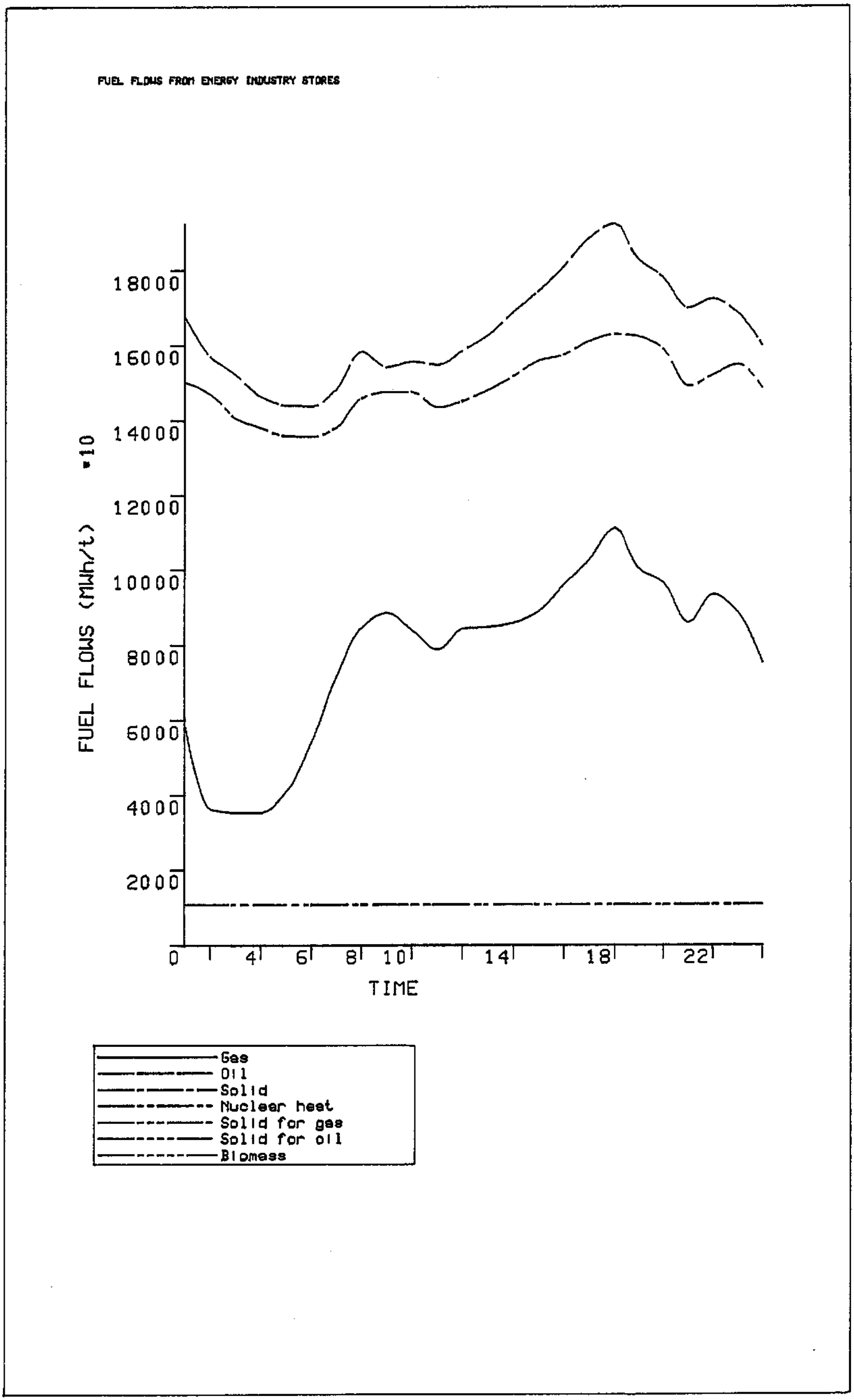

ENERGY INDUSTRY STORE LEVELS
2500
2000
1500
1000
500
*10 5
STORE LEVELS (GWh)
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Nuclear (heat)
Pumped store GWh



ELEC EXCEEDANCE
POWER (GW)
0
5
10
15
20
25
30
35
40
2
4
6
8
10
EXCEEDANCE
CHP
Wind
Wave
Tide
Hydro
Pump
Nucl
Coal
Oil
Gas
Store
Pump
Tide
Dem
Sent

The following graphs show the flows of certain fuels on a 0 degree Centigrade air temperature day for the 1976 system. The first shows electricity demand, storage and generation. The second shows the flows of fuel from system stores into the distribution system that dekivers fuels to consumers.


ELECTRICITY DEMAND,SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t) *10
4500
4000
3500
3000
2500
2000
1500
1000
500
0
4
6
8
10
14
18
22
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
Other storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT



FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
4
6
8
10
14
18
22
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass

4. REDUCTION OF UK USEFUL ENERGY DEMAND BY BEHAVIOURAL CHANGE

4.1 Objective of system change

4.1.1 Introduction

Perhaps the cheapest, simplest and most rapid way of reducing overall energy consumption is by using existing installed demand technologies more efficiently. It is certain that savings in some sectors can be considerable. For example, human energy monitors in a secondary school reduced total energy consumption by 36 % without changing thermostat settings (p 127, IIED, 1979). These sorts of savings are made by changes in behaviour which might be brought about by education, law or fiscal incentive. The inconvenience caused by changing behaviour can be minimal (e.g. turning off lights or closing windows) although some changes would require more substantial reorganisation (e.g. increased use of buses and trains for passenger traffic). The behavioural method of reducing energy demand is likely to be the most apparent to the consumer. Changes in "energy behaviour" of consumers could make dramatic changes in energy consumption. However, the very nature of such changes make them more difficult to quantify than other purely technical changes.

4.1.2 Objective and methods

The objective is to reduce useful energy demands by behavioural changes whilst maintaining or improving "energy standards". This latter implies that energy consumers continue to enjoy the same levels of thermal comfort, travel the same number of kilometres each year and so on.

These behavioural changes require no or negligible technical change.

The methods of behaviourally reducing demands may be summarised as follows:

(i) Using demand technologies more efficiently.

Close windows and doors when possible. Increase car sharing. Improve load factors of all vehicles and craft. Improve energy scheduling of manufacturing processes. Better arrangements for natural lighting.

(ii) Using user converters more efficiently.

Improve the use of heating, lighting and other energy systems in all sectors. In particular ensure converter operators understand how to control converters..

(iii) Technology switch.

Switch from energy inefficient to efficient technologies that already exist. The main option here is the switch from cars to buses and trains.

4.2 The behaviourally changed system

The following sections will take 1976 useful demands and estimate the changes that might be made by altered behaviour. Each demand is discussed briefly and figures for the percentage change and the 1976 and the new demand are given. A question mark by an assumed change means that the change is the author's estimate and is not substantiated by a referenced work.

4.3 Domestic sector

4.3.1 Miscellaneous appliances

More careful attention to switching appliances off when not needed will save 2.5 % (?) of electricity consumption; 1976 demand of 4800 MW falls to 4680 MW.

4.3.2 Fridges and freezers

Electricity use of these appliances can be reduced by 2.5 % (?) keeping doors shut when possible, regular defrosting and by keeping internal and external heat exchangers clear. Demand reduced from 897 MW to 875 MW.

4.3.3 Light

Domestic light demand can be reduced by 2.5 % (?) by turning lights off when not needed, arranging tasks to use natural light, keeping windows clean and surfaces light where possible and by arranging lumieres so that they concentrate on the task to be illumined. Useful light demand per house falls from 10 W to 9.8 W.

4.3.4 Cooking

Improved scheduling in the preparation of meals can marginally reduce energy demand by 2.5 % (?). Useful cooking demand drops from 23.5 W to 23.0 W per house.

4.3.5 Hot water

Useful energy demand for hot water can be reduced by using "cold" water washing powders (4.5 %, p13, EP 48). Better control of existing systems could further reduce consumption by 2.5 % (?): for example it is probable that many people think that it is best to keep electric immersion heaters on all the time. These savings, a total 7 %, are assumed to reduce the hot water demand temperature from 55 C to 52 C.

4.3.6 Space heating

Space heat demand can be reduced by ensuring that the house heat loss coefficient is minimised and that the heating system is controlled properly. The former is accomplished by keeping windows and doors closed when possible and by drawing curtains at night.The latter entails heating the right parts of the house to the required temperature (and no more) at the right time. It is assumed that the potential savings from these two measures are taken up by increased thermal comfort. This assumption is made because it is so difficult to quantify savings due to changed behaviour.

4.3.7 Cars

It is firstly assumed that 15 % of car passenger.kilometres (p.km) are switched from cars to buses. This will cause 50 % of this 15 % of car demand to be added to diesel demand since buses are on average twice as efficient in terms of p.km per MJ as cars. (If buses displace urban car traffic the efficiency difference might increase.) A further 15 % of car p.km switches to trains. It is assumed that the main result of this is an increased train load factor and therefore only 40 % of the 15 % is added to train demand. The overall reduction in car demand due to the switch is therefore 30 % (?) and the average car demand is thereby reduced from 178.3 W to 124.8 W. It is assumed that the number of cars remains unchanged.

The remaining car demand is reduced by 15 % due to better driving, 3 % due to more passengers per car (Laker, 1981) and 2 % due to improved maintenance (IIED, 1979). Useful demand per car is thus further reduced from 124.8 W to 99.8 W.

A reduction of legal maximum road speeds would further reduce car demand, but this implies a change in standards.

4.4 Industrial sector

4.4.1 Light

Useful light demand in the industrial sector can be reduced as follows (p 25, IIED, 1979):

- planning arrangments of tasks to use natural light.
- keeping windows clean and surfaces light.
- maintaining lumiere efficiency by cleaning and replacing
- cleaning workplaces during daylight
- people's awareness

- reduction of light levels where excessive

- concentration of existing lumieres on tasks

Total reduction 15 % (?)

Useful light demand per person changes from 70 W to 60 W.

4.4.2 Kinetic, process and hot water demand

Energy demand for these tasks can be reduced by (p43, IIED, 1979) :

- turning off idle equipment
- maintenance
- scheduling of processes
- minor modifications

Total reduction 10 %(?)

This 10 % saving makes the following changes to industrial demands:

Kinetic	2811 -> 2530 MW
High temp. process	12029 -> 10826 MW
Low temp. process	10122 -> 9110 MW
Hot water	3488 -> 3139 MW

4.4.3 Space heating

Industrial space heat demand can be reduced by similar methods to those used in the domestic sector. Simple maintenance, control and repairs to industrial buildings could reduce heat loss.

It is assumed that these measures do reduce losses but that any potential savings are taken up by increased comfort.

4.4.4 Transport

Extra demands of 187 MW and 75 MW due to the switch from cars to buses and trains respectively have to be added to diesel demand which becomes 2586 MW instead of 2324 MW.

Savings on this new demand are as follows (p 165, IIED, 1979) :

- buses and coaches: education/maintenance 3 %

- lorries: better load factor and driving 10 %
- better driving and load factor 10 %

These savings lead to the diesel demand being reduced from 2586 MW to 2437 MW.

4.5 Commercial sector

4.5.1 Light

The same measures and savings assumed for the industrial sector are assumed to apply. Useful light demand in this sector thereby reduces from 80 W to 68 W per person.

4.5.2 Miscellaneous electricity, cooking and hot water

The same methods can be used here as in the industrial sector. It is assumed that the consequent savings are the same (10 %).

Miscellaneous electric	1046 -> 941 MW.
Cooking demand	412 -> 371 MW.
Hot water demand	2405 ->2165 MW.

4.5.3 Space heating

Savings can be made here using the same methods as in the industrial sector. However, temperatures are usually higher and so the scope for saving is generally greater.

It is assumed that better control of heating systems reduces the average temperature from 17.0 C to 16.0 C (?) and that keeping windows and doors closed when possible reduces the ventilation loss from 55 $W.C^{-1}$ to 45 $W.C^{-1}$ (?). This leads to smaller savings than might be indicated by certain case studies. (For example, the 36 % savings made in a school by energy monitoring (p 127, IIED, 1979)).

It is possible that certain institutional buildings could be used more effectively by flexitime work hours or multipurpose use. (For example, some modern school campuses cater for evening and weekend education and recreation as well as daytime secondary education.)

4.5.4 Transport

It is assumed that a 2.5 % (?) reduction in ship demand is made by slower sailing speeds when possible and by improving the load factor by better scheduling. Similar measures cause a 2.5 % (?) saving in planes, although more attention is already paid to these methods of saving fuel. The useful demand due to ships and planes is reduced from 2511 MW to 2448 MW.

An extra demand of 150 MW due to the switch to trains from cars must be added to the 1976 train demand. It is assumed that half of this extra demand, 75 MW, is added to electric and diesel train demand. Electric train demand thus increases from 228 MW to 303 MW. Diesel demand increases from 215 MW to 290 MW. It is assumed that better driving reduces train demand by 10 % (p 165, IIED). Electric train demand thereby reduces from 303 MW to 273 MW, diesel train demand from 290 MW to 262 MW.

4.6 Iron and steel

Of the 30 % overall savings possible in this sector (p 53, IIED, 1979), it is assumed that 5 % savings are possible by means of improved scheduling and control. Useful energy demand thereby decreases from 9820 MW to 9329 MW.

DYPHEMO OUTPUT

This output is from a D ynamic PH ysical E nergy M odel
There are four main sections of output:

1. LAYOUT OF ENERGY SYSTEM COMPONENTS
2. DESCRIPTION OF ENERGY SYSTEM
3. SIMULATED PERFORMANCE OF ENERGY SYSTEM
4. ANALYSIS OF SYSTEM PERFORMANCE

1. LAYOUT OF ENERGY SYSTEM

The diagram below shows the basic arrangement of the components of the UK physical energy system and the flows of energy between them. The lists of types of each component are not exhaustive for converters and stores.
The components are numbered 1 to 7.

```
|1.DEMANDS|    |2.USER     |     |7.INCOME     |    |6.NATURAL   |
|         |    |CONVERTERS |     |  SOURCES    |    |  STORES    |
|Work     |<--|Boiler      |<----| Solar,wind  |    | Coal,oil   |
|Transport|    |Motor      |     | wave,tidal  |    | gas,       |
|Light    |    |Collector  |     | hydro       |    | uranium    |
|Heat>120 |    |___________|     |_____________|    |____________|
|Cooking  |        /!\     /\          |            /
|Heat<120 |         |        \         |           /
|Hot water|         |         \        |          /
|Space    |         |          \       |         /
|_________|        \|/          \     \|/       /
                    !            \_____!______\/
               |3.USER      |    |4.ENERGY IN |    |5.ENERGY IN|
               |  STORES    |    | CONVERTERS |    |  STORES   |
               |Bunker,tank |    | Power stat |<-->|Bunker,tank|
               |H/W tank    |    | Refinery   |    |Pumped     |
               |El. storage |    | Gasifier   |    |           |
               |____________|    |____________|    |___________|
```

2. UK ENERGY SYSTEM DESCRIPTION

Behaviourally reduced demand.

SYSTEM DESCRIPTION

Technical data are given; these specify the components:

DEMAND
USER CONVERTERS
USER STORES
CONVENTIONAL ELECTRICICITY GENERATION
AMBIENT ELECTRICITY GENERATION
ENERGY INDUSTRY CONVERTERS
INDUSTRY STORES
PRIMARY RESERVES

These data with climatic data determine the simulated energy flows with time.

USEFUL ENERGY DEMAND DATA

TEMPORAL USE PATTERNS

The numbers below refer to the hourly use levels for the various sectors. The first two rows of numbers for each pattern refer to the weekday pattern; the second two the weekend pattern.

Proportion houses with active occupants

0.4	0.1	0.1	0.1	0.2	0.4	0.5	0.6	0.5	0.4	0.4	0.5
0.4	0.4	0.5	0.6	0.7	0.9	0.8	0.8	0.7	0.8	0.7	0.5
0.3	0.1	0.0	0.0	0.0	0.0	0.3	0.5	0.6	0.7	0.7	0.6
0.6	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.3

Average = 0.50

Domestic cooking: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.7	0.9	1.2	1.0	0.8	1.7
2.2	1.7	1.2	1.8	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3
0.1	0.1	0.1	0.1	0.1	0.4	0.6	0.7	1.2	1.0	0.8	1.7
2.2	1.7	1.1	1.5	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3

Average = 1.00

Domestic hot water: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.7	1.6	1.4	0.8	2.0	1.6	1.2
0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.8	1.6	1.4	0.8	2.0	1.6	1.2

Average = 1.00

Domestic transport: % daily traffic

0.9	0.3	0.1	0.1	0.2	0.3	1.0	4.5	6.8	4.8	5.0	5.2
5.5	5.2	5.7	5.8	7.3	8.2	7.3	6.4	4.7	3.7	3.1	2.1
2.3	1.0	0.6	0.3	0.3	0.4	0.9	2.2	3.0	4.1	6.3	7.5
8.0	7.1	9.1	9.4	9.0	8.3	7.7	7.8	6.6	5.1	4.3	3.6

Average = 4.18

Industrial general: proportion of average demand

0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1.4	1.4	1.4	1.5
1.3	1.4	1.4	1.3	1.2	1.1	0.9	0.9	0.9	0.9	0.9	0.9
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.9	1.0	1.0	1.0
0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Average = 1.00

Industrial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

Commercial general: proportion of average demand

0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	1.2	1.6	1.7	1.7
1.7	1.7	1.7	1.7	1.6	1.3	1.1	1.0	0.9	0.9	0.9	0.9
0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.8	1.1	1.1	1.2
1.1	1.1	1.2	1.2	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.6

Average = 1.00

Commercial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

CHARACTERISTICS OF DEMANDS

DOMESTIC

Number of occupied houses	=	19.49 mill
Miscellaneous electricity:		
Miscellaneous appliances	=	4680.0 MW
Fridges and freezers	=	875.0 MW
Light:		
Useful light per house	=	9.8 W
Cooking:		
Average useful demand per house	=	23.0 W
Hot water:		
Monthly mains temperatures (C)		

7.0	6.0	7.0	9.0	10.0	11.0	13.0	15.0	13.0	11.0	10.0	9.0

Demand temperature (C)	=	52.0 C
Hourly demand volume	=	5.3 l.
Space heating:		
House internal temperature	=	16.0 C
House fabric loss	=	250.0 W/C
House ventilation loss	=	97.0 W/C
Incidental fudge factor	=	0.9
Transport:		
Number of cars	=	14.0 mill
Average useful power per car	=	99.8 W

INDUSTRIAL

	Number of industrial people	=	10.6 million
	Kinetic:		
	Average useful demand	=	2530.0 MW
	Light:		
	Useful light per person	=	60.0 W
	Process heat > 120 C:		
	Average useful demand	=	10827.0 MW
A	Process heat < 120 C:		
	Average useful demand	=	9119.0 MW
	Hot water:		
	Average useful demand	=	3148.0 MW
	Space heating:		
	Internal temperature	=	16.5 C
	Fabric loss per person	=	65.0 W/C
	Ventilation loss per person	=	75.0 W/C
	Incidental fudge factor	=	0.3
	Transport:		
	Average diesel motor demand	=	2437.0 MW

COMMERCIAL		
Number of commercial people	=	26.6 million
Miscellaneous electricity:		
Average useful demand	=	941.0 MW
Light:		
Useful light per person	=	68.0 W
Cooking:		
Average useful demand	=	371.0 MW
Hot water:		
Average useful demand	=	2165.0 MW
Space heating:		
Internal temperature	=	16.0 C
Fabric loss per person	=	25.0 W/C
Ventilation loss per person	=	45.0 W/C
Incidental fudge factor	=	0.4
Transport:		
Average plane and ship demand	=	2448.0 MW
Average electric train demand	=	273.0 MW
IRON AND STEEL		
All energy:		
Total average demand	=	9328.0 MW
FEEDSTOCKS		
Total average demand	=	18106.0 MW

USER CONVERTERS

User converters are arranged in the sequences:

SECTOR	OUTPUT	INPUT
Domestic	Mis. Electric	Gas
Industrial	Mechanical	Liquid
Commercial	Light	Solid
Iron & Steel	Process > 120	Electricity
Feedstocks	Cooking	Solar
	Process <120	
	Hot water	
	Space	
	Transport	

A value of 9.9 means the efficiency is variable

DOMESTIC USER CONVERTERS (E) means double entry	POPULATION (millions)	EFFICIENCY
Fridges and freezers (U)	19.49	1.00
Electric appliances (U)	19.49	1.00
Incandescent lights	19.49	0.13
Gas cooker	10.70	0.11
Electric cooker	8.80	0.20
Gas individual H/W heater	4.11	0.43
Gas C/H H/W heater (E)	3.80	0.40
Gas heat pump H/W heater (E)	0.00	9.90
Oil C/H H/W heater (E)	0.20	0.50
Solid C/H H/W heater (E)	5.19	0.41
Solid CHP H/W heater (E)	0.00	0.67
Electric H/W heater	6.18	0.72
Electric heat pump H/W heater (E)	0.00	9.90
Solar individual H/W heater	0.00	9.90
Solar space & H/W heater (E)	0.00	9.90
Gas individual space heater	4.14	0.50
Gas C/H space heater	4.16	0.75
Gas heat pump space heater	0.00	9.90
Oil C/H space heater	3.45	0.65
Solid individual space heater	2.45	0.25
Solid C/H space heater	2.72	0.65
Solid CHP space heater	0.00	0.67
Electric on peak space heater	0.44	1.00
Electric off peak space heater	2.13	9.90
Electric heat pump space heater	0.00	9.90
Solar space & H/W heater	0.00	9.90
Solar passive house	0.00	9.90
Liquid fuelled car	14.00	0.12
Electric car	0.00	0.80

MISCELLANEOUS DATA ON DOMESTIC CONVERTERS		
Solar water heater:		
Area of collector	=	5.0 m2
Volume of tank	=	200.0 l.
Loss coeff. of tank	=	20.0 W/C
Active solar house:		
Area of collector	=	20.0 m2
Volume of tank	=	40.0 m3
Insulation on tank	=	28.1 cm.
Specific loss of tank	=	10.0 W/C
Passive solar house:		
Area of south glazing	=	15.0 m2
Transmittance of glazing	=	0.7
Specific loss (day)	=	150.0 W/C
Specific loss (night)	=	125.0 W/C
Ventilation loss	=	50.0 W/C

INDUSTRIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Oil fuelled motor	473.00	0.17
Electric fuelled motor	2057.00	0.35
Fluorescent lights (U)	638.40	0.40
Gas heater > 120 C	2764.00	0.60
Gas CHP heater > 120 C	622.00	0.56
Liquid heater > 120 C	2647.00	0.60
Liquid CHP heater > 120 C	1119.00	0.56
Solid heater > 120 C	1757.00	0.60
Solid CHP heater > 120 C	331.00	0.56
Electric heater > 120 C	1587.00	1.00
Gas heater < 120 C	1985.00	0.60
Gas CHP heater < 120 C	816.00	0.56
Liquid heater < 120 C	3435.00	0.60
Liquid CHP heater < 120 C	1479.00	0.56
Solid heater < 120 C	839.00	0.60
Solid CHP heater < 120 C	436.00	0.56
Electric heater < 120 C	129.00	1.00
Gas H/W heater	565.00	0.60
Gas CHP H/W heater	175.00	0.56
Liquid H/W heater	1594.00	0.60
Liquid CHP H/W heater	316.00	0.56
Solid H/W heater	317.00	0.60
Solid CHP H/W heater	94.00	0.56
Electric H/W heater	87.00	1.00
Gas space heater (U)	1.85	0.60
Gas CHP space heater (U)	0.00	0.56
Liquid space heater (U)	5.31	0.60
Liquid CHP space heater (U)	0.00	0.56
Solid space heater (U)	1.05	0.60
Solid CHP space heater (U)	2.10	0.56
Electric space heater (U)	0.33	1.00
Diesel transport motors	2437.00	0.17

COMMERCIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Miscellaneous electric	941.00	1.00
Fluorescent lights (U)	1806.76	0.40
Gas cooker	251.00	0.20
Liquid cooker	11.40	0.20
Solid cooker	11.40	0.20
Electric cooker	97.20	0.40
Gas H/W heater	514.00	0.60
Gas CHP H/W heater	0.00	0.56
Liquid H/W heater	1170.00	0.60
Liquid CHP H/W heater	0.00	0.56
Solid H/W heater	252.00	0.60
Solid CHP H/W heater	0.00	0.56
Electric H/W heater	229.00	1.00
Gas space heater (U)	4.86	0.60
Gas CHP space heater (U)	0.00	0.56
Liquid space heater (U)	15.39	0.60
Liquid CHP space heater (U)	0.00	0.56
Solid space heater (U)	4.05	0.60
Solid CHP space heater (U)	0.00	0.56
Electric space heater (U)	2.27	1.00
Ships and aeroplanes	2448.00	0.20
Electric trains	273.00	0.80

I&S, FEEDSTOCK USER CONVERTERS	POWER (MW)	EFFICIENCY
Gas I&S process	1150.00	0.78
Liquid I&S process	2196.00	0.54
Solid I&S process	5557.00	0.43
Electric I&S process	425.00	0.30
Gas feedstock use	3076.00	1.00
Liquid feedstock use	14871.00	1.00
Solid feedstock use	159.00	1.00

USER STORES	INPUT POWER	EFF. I/O	CAPACITY /UNIT	TOTAL CAPACITY	OUTPUT POWER	POP
DOMESTIC						
House oil tanks		1.0	11194.kWh	38621.GWh		3.4
Car petrol tanks		1.0	444.kWh	6222.GWh		14.0
Coal bunkers		1.0	17056.kWh	41786.GWh		5.2
El stor. heaters	7.5 kW	1.0	85. Wh/C		4. W/C	2.1
El car batteries	10.0 kW	.8	55. kWh	0. GWh		0.0
Solar H/W tanks			200. l		20.0 W/C	0.0
Active solar houses			40.0 m3		28.1 W/C	0.0
INDUSTRY						
Liq stores				30700. GWh		
Solid stores				15800. GWh		
COMMERCE						
Liq stores				14400. GWh		
Solid stores				168. GWh		

FOSSIL/FISSILE ELECTRICITY GENERATION

FUEL AND TYPE	OUTPUT POWER	EFFICIENCY	MERIT
Domestic CHP	0.0 MW	0.25 (E)	1
Industrial CHP	2360.7 MW	0.11 (E)	1
Commercial CHP	0.0 MW	0.11 (E)	1
Pumped store	1000.0 MW	0.85	6
Nuclear	3.0 GW	0.29- 0.23	7
Solid	35.0 GW	0.35- 0.11	8
Oil	11.0 GW	0.34- 0.18	9
Gas	1.0 GW	0.35- 0.10	10
Gas turbine	2.0 GW	0.34- 0.18	11

Peaking plant (gas turbine and pumped storage) used if d(NET LOAD)/dt > 1250.0 MW/hr

Merit order of conventional stations:
nuclear (1),coal (2),oil (3),gas (4)

1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 3 2
3 2 3 2 3 2 4 3 2 3 2 3 2 3 2 3 2 3 2 3 2 2 2 2 2
3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AMBIENT ELECTRICITY GENERATION			
AMBIENT SOURCE	MAX OUTPUT	SIZE	MERIT
Aerogeneration Dispersed in UK Vcut= 3.0 ms-1 Vrat= 20.0 (ms-1) Radius=23 m.	0.00 GW	0. num	2
Wave power NW of Scotland Max. mech. (kWm-1)= 100.0 Max height(m.) 4.2	0.00 GW	0.0 km	3
Tidal power Severn estuary	0.0 + 0.0 GW	0.0+ 0.0 km2	4
Fresh hydro Dispersed in UK 3.2 TWhe/annum 24. hrs average= 366. MWe	1165.0 MW		5

ENERGY INDUSTRY CONVERTERS	POWER (GW)	EFFICIENCY
Gas extraction	85.	0.96
Gas from coal converter	0.	0.70
Gas transmission	102.	0.97
Oil extraction	120.	0.96
Oil from coal converter	0.	0.70
Oil refinery	144.	0.94
Oil distribution	144.	0.99
Coal mines	180.	0.95
Coal distribution	216.	0.97
Nuclear reprocessor	30.	0.50
Nuclear waste disposal	0.	9.90
Electricity transmission	62.	0.92

ENERGY INDUSTRY STORES	POWER (GW)	CAPACITY
Gas stores	85.0	228.0 GWh
Oil stores	120.0	262000.0 GWh
Solid stores	180.0	260000.0 GWh
Nuclear stores	30.0	1000.0 GWh
Pumped storage	1.0	29.1 GWhm
In at power 1000.0 MW		
Out if d(LOAD)/dt > 1250.0 MW/hr		
Biomass area	0.0 km2	
Efficiency biomass to gas 0.55		
Efficiency biomass to oil 0.50		

PRIMARY RESERVES	SIZE (TWh)
Gas reserves	15332.
Oil reserves	17279.
Coal reserves	563889.
Uranium reserves	50000.

SUMMARIES FOR ONE YEAR
ENERGY IN GWh

SUMMARY OF USEFUL ENERGY DEMANDS

	Dom	Ind	Com	I&S	Feed	TOTAL
Work	0.	22067.	0.	0.	0.	22067.
Miscellane	28055.	0.	8242.	0.	0.	36297.
Transport	12174.	21348.	21444.	0.	0.	54967.
Light	676.	2966.	6804.	0.	0.	10446.
High Temp	0.	94436.	0.	81713.	0.	176149.
Cooking	3910.	0.	3249.	0.	0.	7159.
Low temp	0.	79538.	0.	0.	0.	79538.
Hot water	43740.	28812.	18963.	0.	0.	91515.
Space	140234.	31360.	50835.	0.	0.	222428.
Feedstocks	0.	0.	0.	0.	158609.	158609.
TOTAL	228788.	280527.	109538.	81713.	158609.	859175.

SUMMARY OF FUEL DELIVERIES

	Dom	Ind	Com	I&S	Feed	TOTAL
Gas	173208.	111853.	33993.	12915.	26946.	358915.
Liquid	53779.	208452.	66653.	35624.	130270.	494778.
Solid	129030.	72667.	17092.	113208.	1393.	333391.
Electricit	85424.	75419.	33730.	12410.	0.	206983.
CHP (heat)	0.	53452.	0.	0.	0.	53452.
Solar (hea	0.	0.	0.	0.	0.	0.
Transport	101453.	125577.	107222.	0.	0.	334252.
Transport	0.	0.	2391.	0.	0.	2391.
TOTAL	542894.	647421.	261082.	174157.	158609.	1784163.

SUMMARY OF ELECTRICITY PRODUCTION

	Electricity	Fuel used	Effic.	Load factor
CHP	10499.5			0.51
Aero	0.0			0.00
Wave	0.0			0.00
Tide	0.0			0.00
Hydro	3203.6			0.31
Pumped	1668.0			0.19
Nuclear	26280.0	94789.3	0.28	1.00
Coal	167138.0	497669.4	0.34	0.55
Oil	21652.0	64401.9	0.34	0.22
Gas	561.0	1911.2	0.29	0.06
Other storage	0.0			0.00
Pumped storage	-2330.8			0.00
Tidal storage	0.0			0.00
Total demand	227580.8			0.42
TOTAL SENT OUT	231002.2			0.38

SUMMARY OF PRIMARY FUEL FLOWS	
Gas	360826.1
Oil	904326.1
Coal	834478.8
Nuclear (heat)	[illegible]4789.3
Coal for gas	0.0
Coal for oil	0.0
Biomass	0.0

GROSS PRIMARY FUEL EXTRACTED	
Gas	387506.7
Oil	1023117.0
Coal	930446.2
Nuclear	189760.4
TOTAL FOSS/FISS	2530830.4

```
4. PERFORMANCE ANALYSIS
This section of output gives some analysis
of the performance of the energy system  over
the simulated time period.
```

```
     GAS
Maximum flow rate of gas delivery was
       90.19 GW
Minimum storage requirement between component 2 and 6
was           0.0 in interval  12
```

```
     LIQUID
Maximum flow rate of liquid delivery was
       95.73 GW
Minimum storage requirement between component 2 and 6
was           0.0 in interval  12
```

```
     SOLID
Maximum flow rate of solid delivery was
       86.50 GW
Minimum storage requirement between component 2 and 6
was           0.0 in interval  12
```

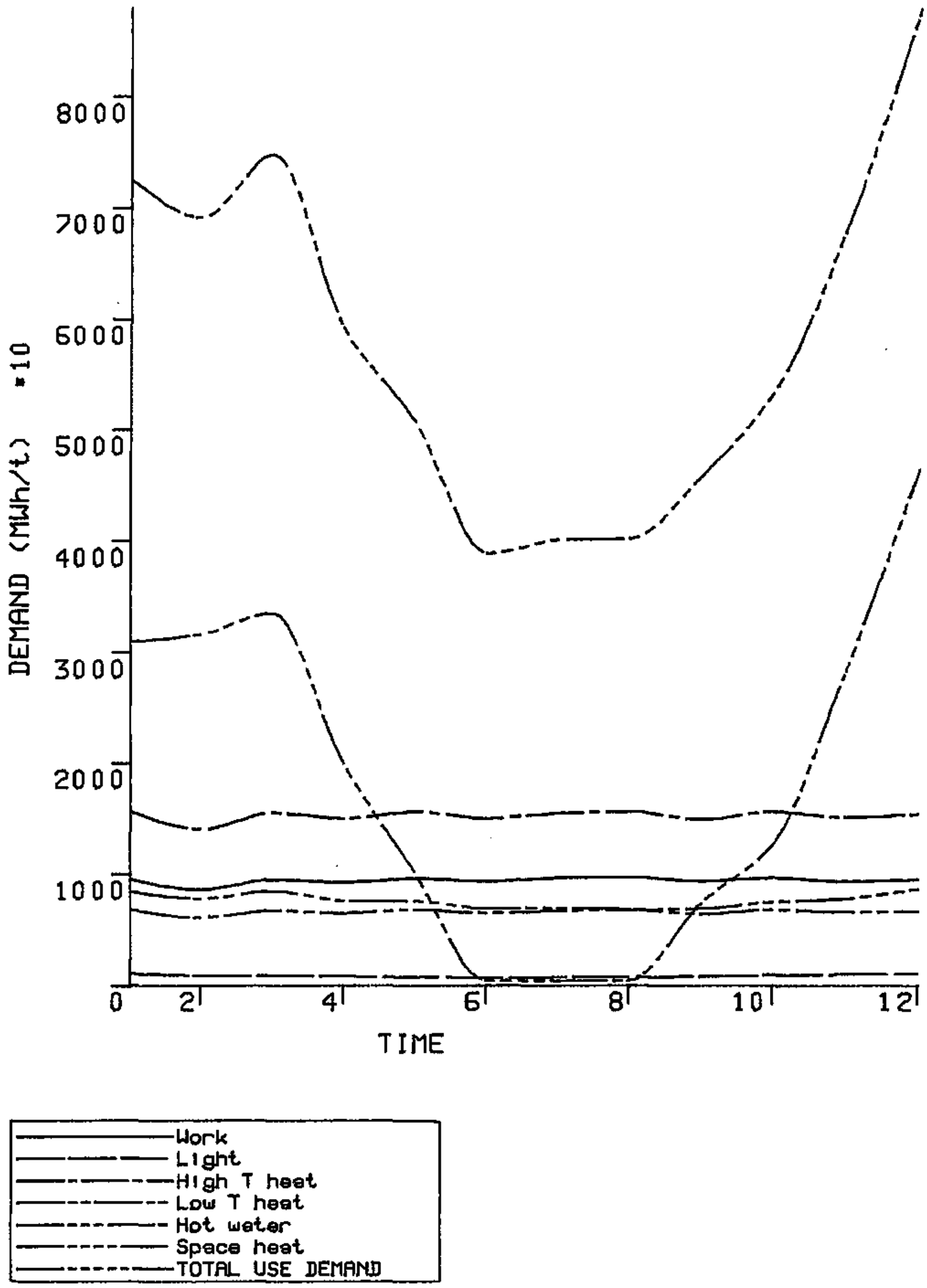
ELECTRICITY

FLOW DURATION CURVES
Numbers are powers (GW)
Columns are percentage of time flow exceeded.

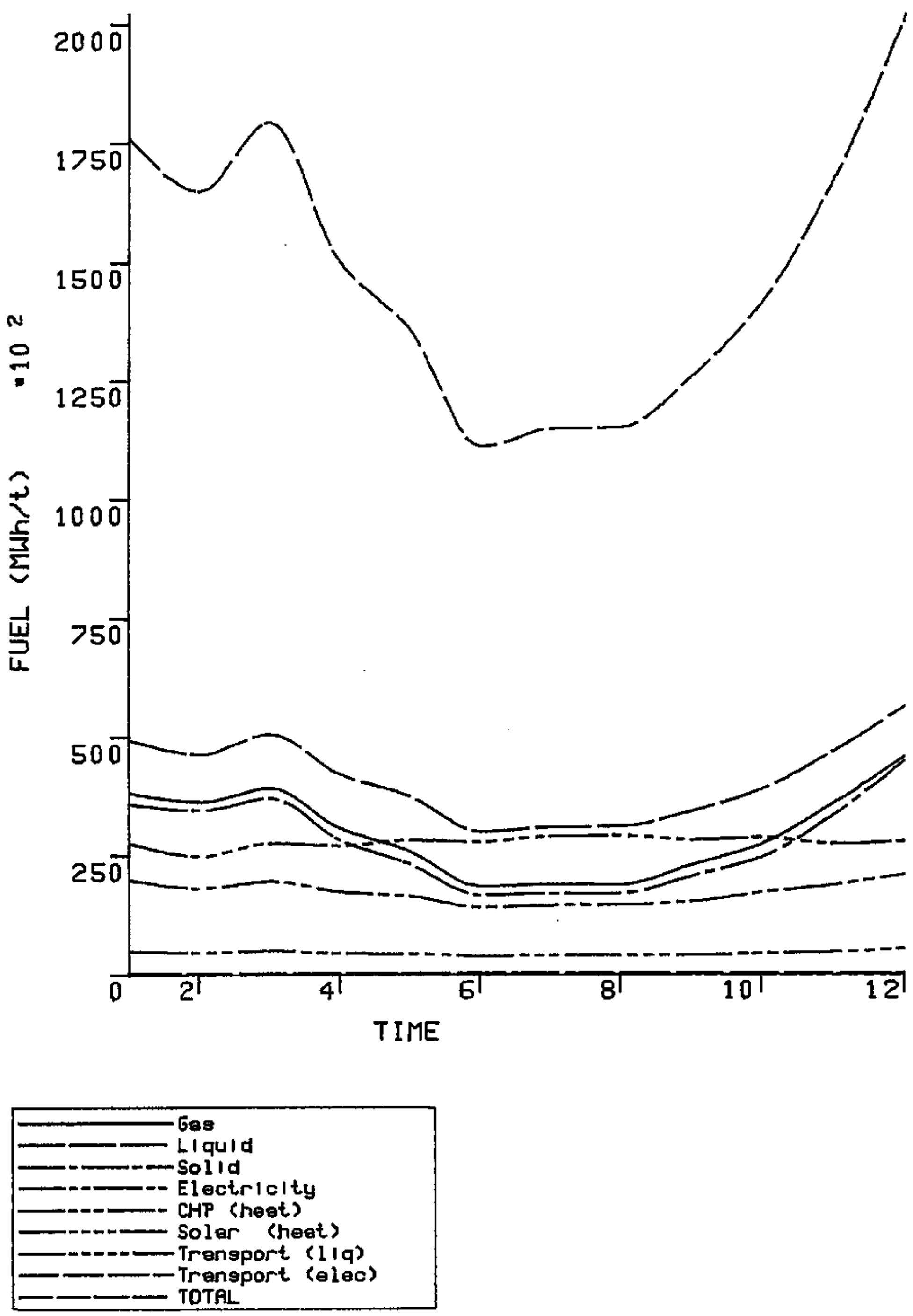
	0	10	20	30	40	50	60	70	80	90	100
CHP	1.8	1.5	1.3	1.3	1.3	1.0	1.0	1.0	0.8	0.8	0.5
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydro	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Pump	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nucl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Coal	26.0	22.5	21.8	21.0	20.0	20.0	19.0	18.3	17.5	14.3	7.0
Oil	8.8	5.0	4.0	3.5	3.0	2.3	2.0	1.0	0.0	0.0	0.0
Gas	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Store	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pump	-1.0	-1.0	-1.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dem	40.3	32.8	30.5	28.5	27.3	26.0	25.0	23.5	21.8	19.0	10.8
Sent	40.5	33.0	30.8	29.0	27.8	26.5	25.5	24.0	22.0	19.0	10.8

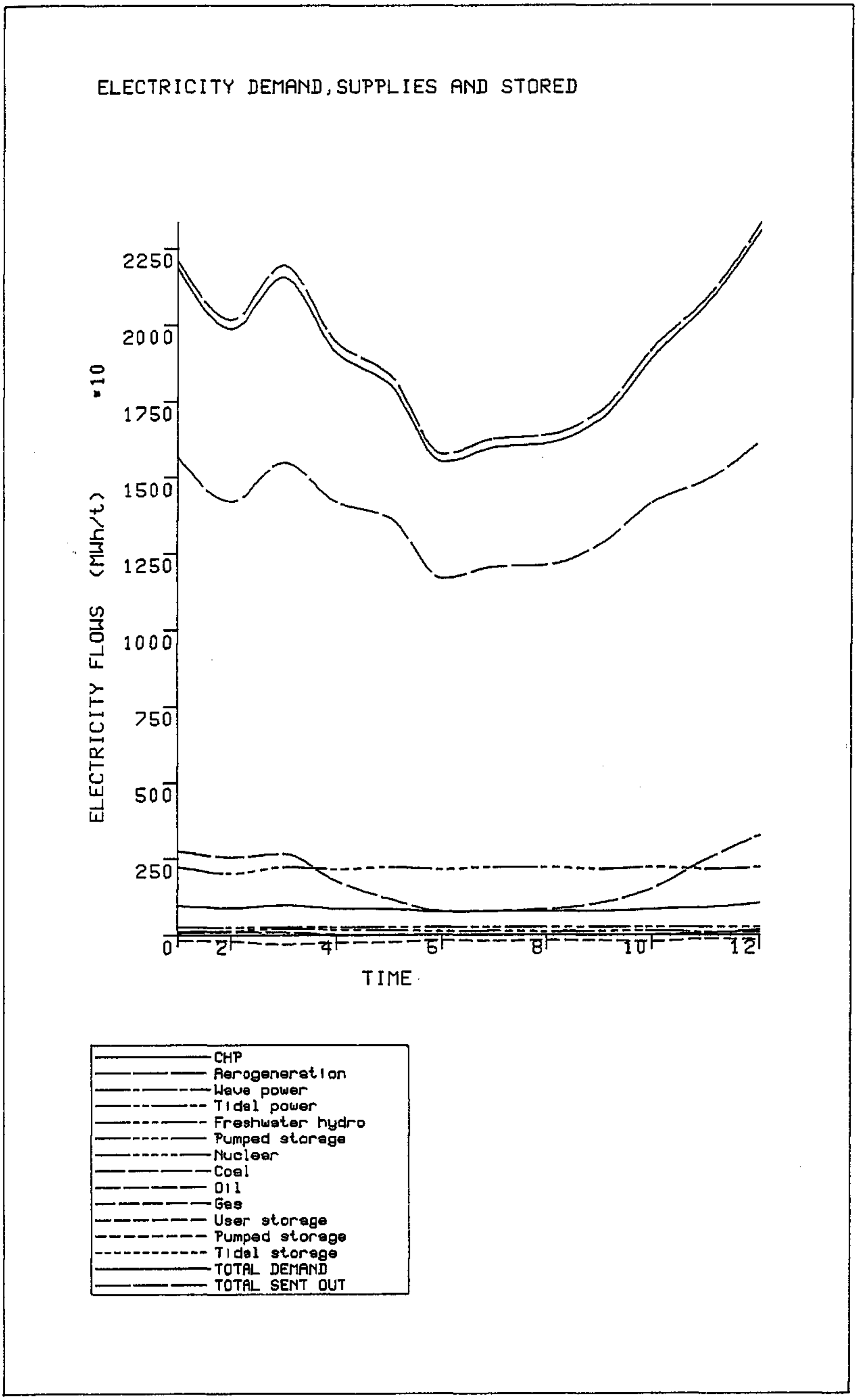
Maximum electrical power sent out was 40637.4 MW
in the 18 th hour of the 365 th day of the year.

TOTAL USEFUL ENERGY DEMANDS

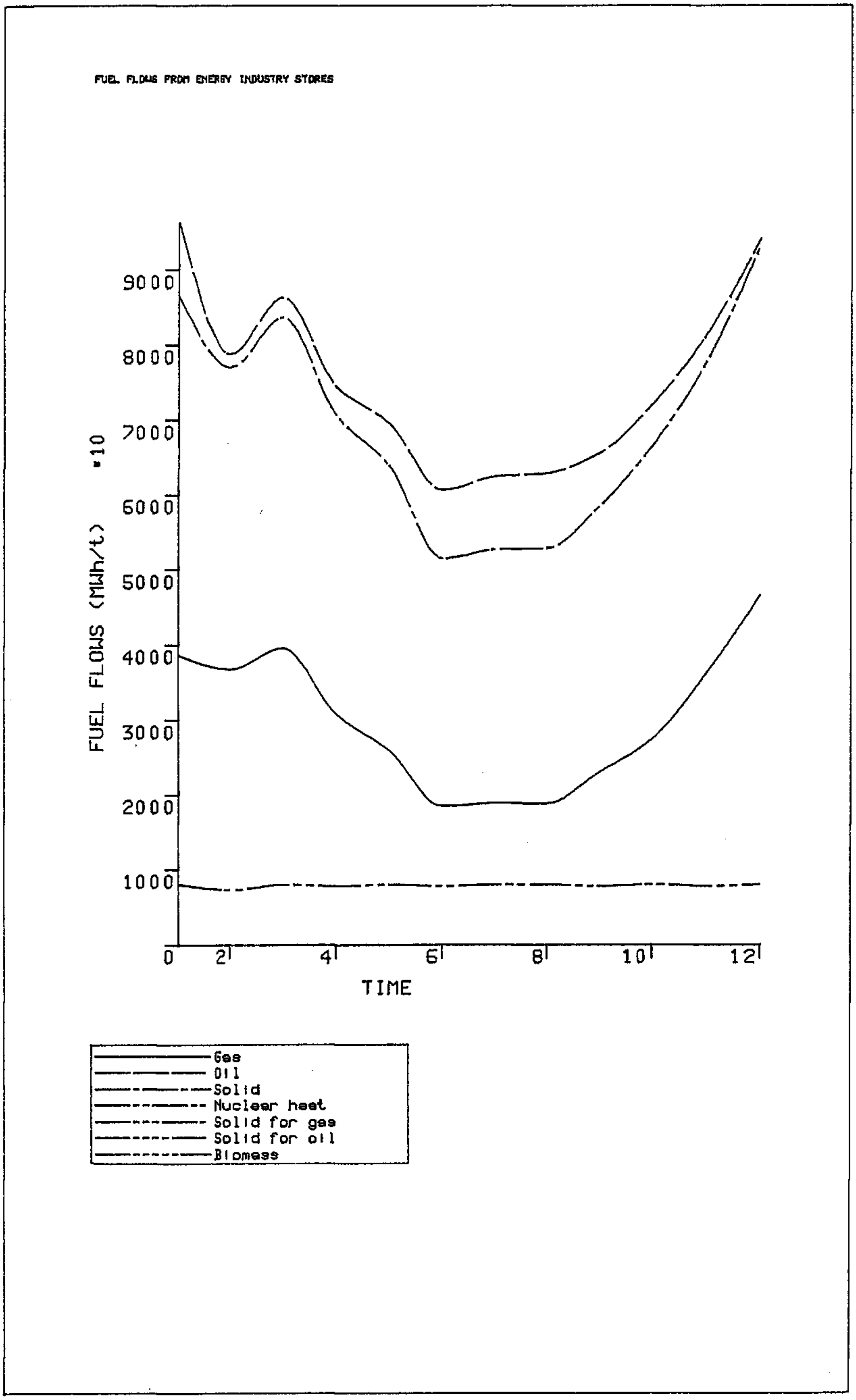


TOTAL FUEL DELIVERIES

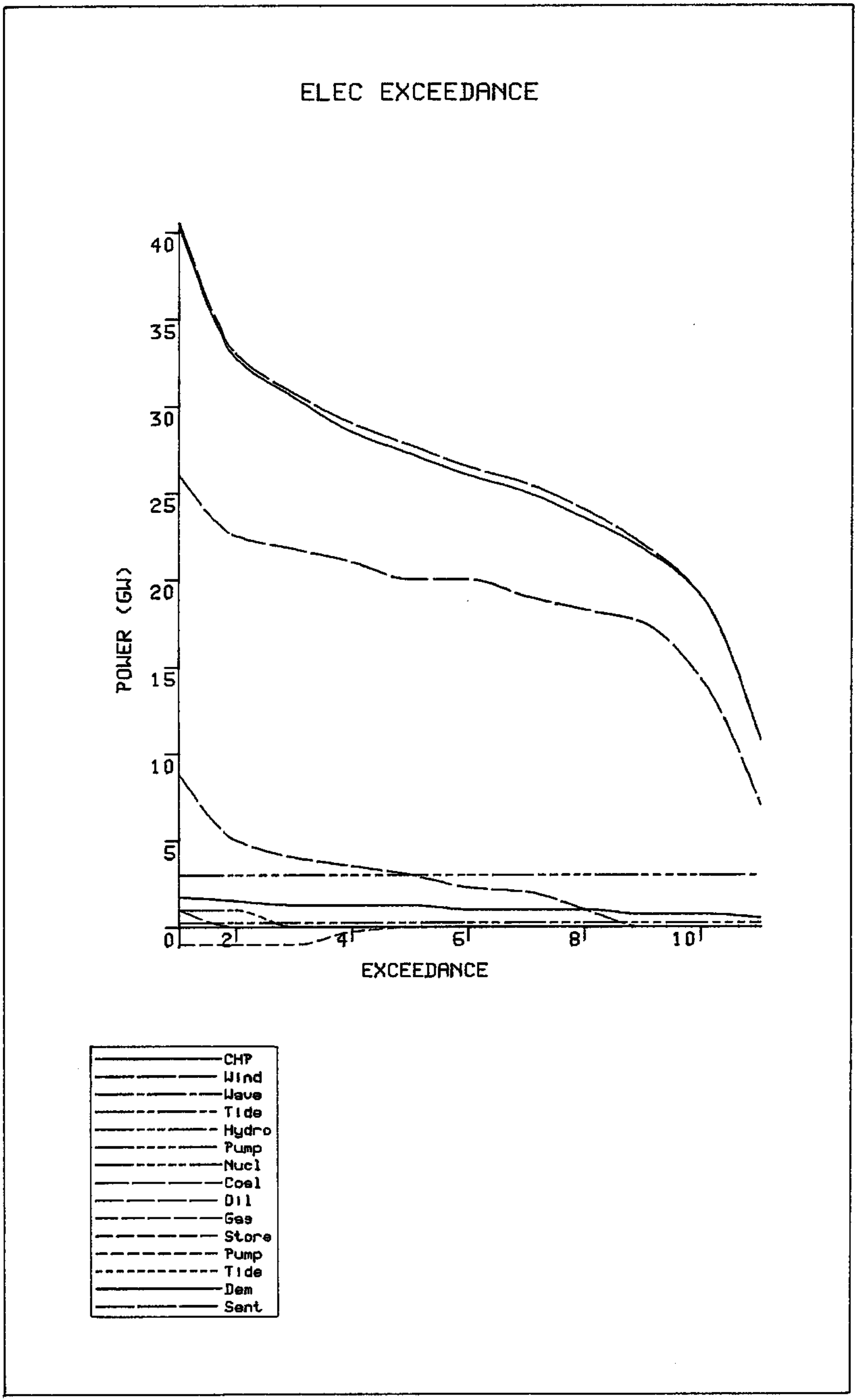




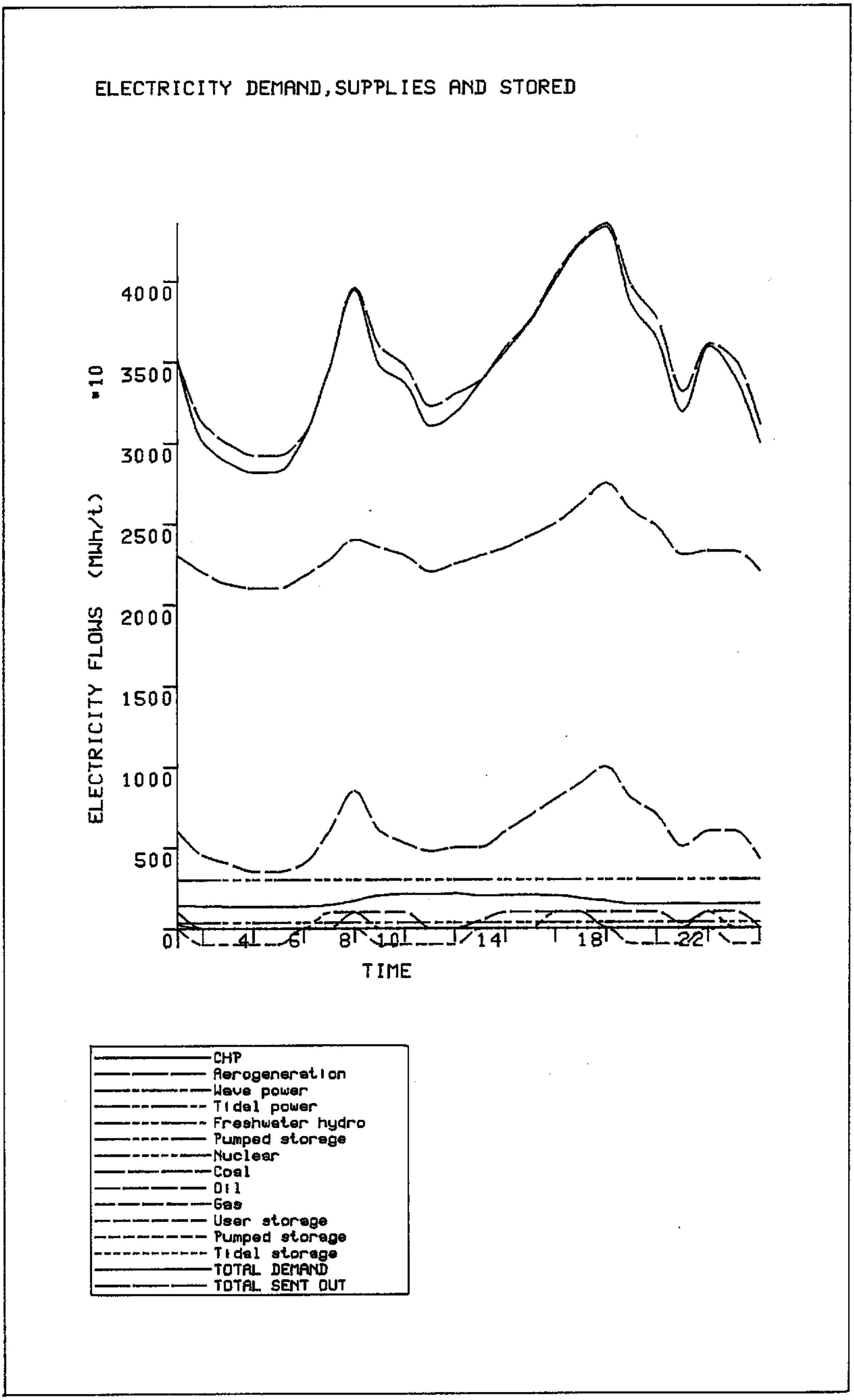
ELECTRICITY DEMAND,SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t) *10
2250
2000
1750
1500
1250
1000
750
500
250
0
2
4
6
8
10
12
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT

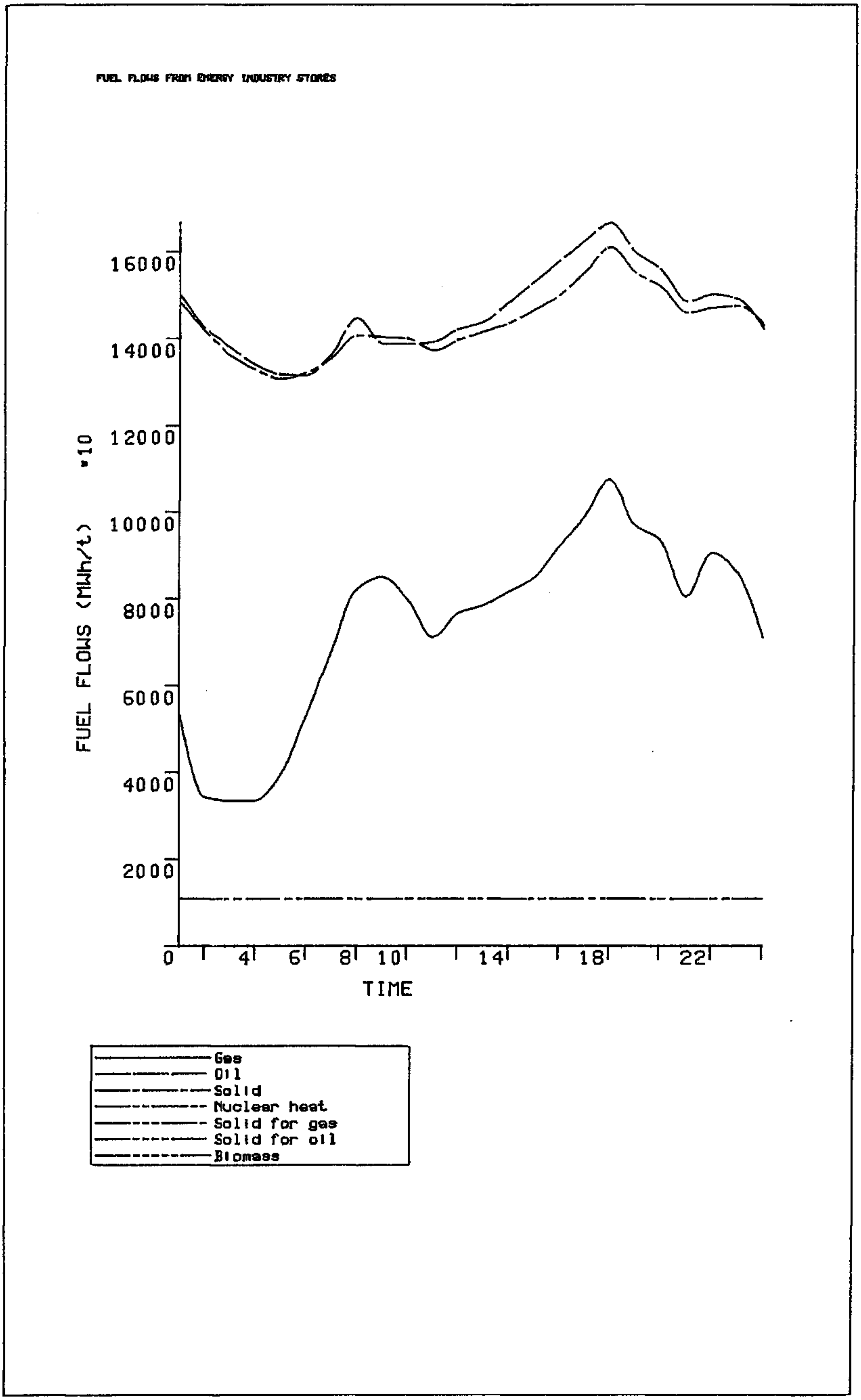


FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass


ELEC EXCEEDANCE
POWER (GW)
40
35
30
25
20
15
10
5
0
2
4
6
8
10
EXCEEDANCE
CHP
Wind
Wave
Tide
Hydro
Pump
Nucl
Coal
Oil
Gas
Store
Pump
Tide
Dem
Sent

The two graphs below depict electricity and fossil fuel flows for a 0 degree centigrade day for the system with behaviourally reduced demand.


ELECTRICITY DEMAND, SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t) *10
4000
3500
3000
2500
2000
1500
1000
500
0
4
6
8
10
14
18
22
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT



FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
16000
14000
12000
10000
8000
6000
4000
2000
0
4
6
8
10
14
18
22
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass

5. REDUCTION OF UK USEFUL ENERGY DEMAND BY TECHNICAL CONSERVATION

5.1 Objective of system change

5.1.1 Introduction

The amount of useful energy required depends in part on the characteristics of certain demand technologies such as houses and cars. Many of these technologies can be improved or redesigned in such a way that less energy is used to accomplish the same task. Existing houses can be insulated, new ones can be made to use less energy by better design as well as insulation. The energy required for car transport can be decreased by reducing air drag, diminishing vehicle weight and the rolling resistance due to tyres. The conservation of energy (or more specifically the reduction of useful energy demand) by such means is dubbed technical conservation to differentiate it from behavioural conservaton.

The relatively rapid turnover of most demand technologies means that changed design could have a fairly rapid effect. However, buildings have relatively long lifetimes and are an important demand technology. Many existing buildings can be insulated or have their heat losses reduced in some other way.

5.1.2 Objective and methods

The objective is to reduce useful energy demand by technical change whilst maintaining or improving "energy standards".

The general methods of technical conservation are :

(i) Work - demand reduced by better controls

(ii) Light - daylight and time responsive control systems reduce demand

(iii) Process heat - insulation, heat recovery and control.

(iv) Hot water - improved control and spray taps/showers

(v) Space heat - insulation, draughtstripping and system control

5.2 Technical details of the system with conservation

The following sections will take 1976 useful demands and estimate the changes that might be made by technical conservation. Each demand is discussed briefly and figures for 1976, the percentage change and the new demand are given. A question mark by an assumed change means that the change is the author's estimate and is not substantiated by a referenced work.

5.3 Domestic sector

5.3.1 Miscellaneous electric appliances

Improved controls, recycling, insulation and improved electronic components can reduce the electricity consu,ption of miscellaneous electric appliances by 55 % (p 105, IIED, 1979). Electricity demand reduces from 4800 MW to 2160 MW.

5.3.2 Fridges and freezers

Improved control, insulation and heat pumps can reduce the consumption of these appliances by 65 % (p 105, IIED, 1979). Demand reduced from 897 MW to 314 MW.

5.3.3 Light

It is assumed that simple changes in building design and the placement and control of lumieres effects a 5 % (?) saving. Demand is thereby decreased from 10 W to 9.5 W per house.

5.3.4 Cooking

The use of cooking pots with lids, insulation and better thermal transfer and general design could reduce cooking demand by 2.5 % (?). These measures when applied to cookers, as opposed to kitchenware, are considered in the section on cooker efficiency. The 2.5 % saving assumed reduces demand from 23.5 W to 23 W per house.

5.3.5 Hot water

Reduction of hot water demand can be accomplished in the following ways (from p 12, EP 48) :

- Install showers and spray taps.	13 %
- Insulate pipework.	2 %
Total reduction	15 %

These measures reduce the volume of hot water demand from 127 to 108 litres per day per house.

5.3.6 Space heating

Insulation can reduce fabric losses by 30 % and 40 % in existing flats and dwellings respectively (p 100, IIED, 1979). It is assumed that an average 35 % reduction is possible. The average fabric loss thereby changes from 250 $W.C^{-1}$ to 163 $W.C^{-1}$.

Draughtstripping can reduce the ventilation loss by 50 % . The loss coefficient is therefore assumed to be 50 $W.C^{-1}$ instead of 97 $W.C^{-1}$ (p 100, IIED, 1979).

The control of heating systems can be improved by simple devices such as thermostatic radiator valves or more complex logic and time controllers. These devices can bring about zoned heating and keep the internal temperatures to the required minimum for the minimum time. It is assumed that these devices do not change average house temperatures, but do increase comfort levels.

5.3.7 Cars

The energy demand for car transport can be reduced as follows (from IIED, p 157, 1979):

- reduction of air drag coefficient	6 %
- reduction in tyre drag	3 %
- reduction in car weight	9 %
- improved control of engine	5 %
Total reduction	25 %

Average useful demand per car thereby falls from 178.3 W to 134 W.

5.4 Industrial sector

5.4.1 Motive power

Improved controllers and final drives can reduce kinetic demand by 10 % (?), from 2811 MW to 2530 MW.

5.4.2 Light

Light controls which respond to daylight intensities and better task lighting, lighter surfaces and spatial rearrangement (where possible) can reduce light demand by 5 % (?) ; from 70 W to 67 W per person.

5.4.3 Process and hot water

Demands for process heat and hot water can be reduced by (p 46, IIED, 1979) :

- insulation of tanks and pipes
- improved control
- heat recovery and recycling
- use of waste products

Total 10 % (?)

This 10 % saving causes the following changes to demands:

High temp. process 12029 -> 10826 MW

Low temp. process 10122 -> 9110 MW

Hot water 3488 -> 3139 MW

5.4.4 Space heating

Space heat demand can be reduced by :

- insulating building envelop 30 % (?)

This measure means that the fabric loss coefficient changes from 65 $W.C^{-1}$ to 46 $W.C^{-1}$.

- draughtstripping, flexible doors 25 % (?)

- controlled ventilation and heat recovery 25 % (?)

These two measures reduce the ventilation loss coefficient from 75 $W.C^{-1}$ to 38 $W.C^{-1}$.

- better heating system controllers

It is assumed that any potential savings are taken up by increased thermal comfort.

- increase in use of cascaded waste heat 50 % (?)

The incidental gain cascade factor is assumed to increase from 0.3 to 0.45

.

5.4.5 Transport

Similar measures (in kind) can be applied to industrial diesel transport vehicles as to cars, savings are as follows :

- light vans (same measures as for cars) 25 %
- lorries : reduction of air drag (p 165, IIED, 1979) 7 %
  reduction in weight (p 71, EP45) 3 %
- buses/coaches : general improvements (p 165, IIED) 8 %
- rail (diesel) (p 165, IIED, 1979) 40 %

Total transport demand met by diesel decreases from 2324 MW to 1870 MW because of these savings.

It is assumed that buses and coaches either travel slowly or are already streamlined to the point that savings due to reduced air drag are negligible.

5.5 Commercial sector

5.5.1 Miscellaneous electric

Improvements will be similar in kind to those for domestic appliances. However, because of a lack of information savings of 30 % (?) are conservatively assumed rather than 55 % as for the domestic sector. Demand therefore changes from 1046 MW to 732 MW.

5.5.2 Light

Lighting levels are generally higher in this sector than others; in fact they are sometimes excessive. Savings due to daylight and other controllers as well as other measures (described above in the industrial section on light) could be large. It is assumed that these measures reduce the light demand from 80 W/person to 72 W/person, that is by 10 % (?).

5.5.3 Cooking

A reduction of 10 % (?) in cooking demand is assumed; it reduces from 412 MW to 371 MW.

5.5.4 Hot water

A saving of 10 % is assumed as for the industrial sector; demand therefore reduces from 2405 MW to 2165 MW.

5.5.5 Space heating

Similar methods to those used in the industrial sector can be applied to achieve reduced space heat demand. The contruction type and use patterns of commercial buildings make large savings possible. Indeed, all new buildings in this sector could be made to have a zero or negligible space heat load. (For example, Wallasey school, Liverpool, is heated entirely by solar and other free incidental heat gains.)

The following savings are assumed:

- fabric loss coefficient 60 %

Fabric loss coefficient is 10 $W.C^{-1}$ rather than 25 $W.C^{-1}$.

- ventilation loss coefficient 30 %

Ventilation loss coefficient is 39 $W.C^{-1}$ rather than 55 $W.C^{-1}$.

- use of incidental gains 50 %

The incidental gain fudge factor increases from 0.4 to 0.6.

5.5.6 Transport

The energy demand for train transport can be reduced as follows (p 165, IIED) :

- reduced weight and drag	20 %
- regeneration and controls	25 %
- suspension and track	15 %
Total savings	60 %

Electric train demand changes from 228 MW to 91 MW because of these savings. Diesel train is reduced by the same proportion and consequently 86 MW must be subtracted from diesel demand.

It assumed that the design of ships' hulls and superstructure is already energy efficient.

5.6 Iron and steel

The complexity of this sector makes it difficult to separate out savings due to technical conservation, as opposed to behavioural or efficiency savings. However it is likely that there is considerable potential for reducing energy demand by reducing heat losses, recycling heat (and waste products) and better control. Of the 30 % savings thought practical for all measures, it is assumed that 15 % are due to technical conservation (?). On this assumption, demand reduces from 9820 MW to 8347 MW.

DYPHEMO OUTPUT

This output is from a D ynamic PH ysical E nergy M odel
There are four main sections of output:
1. LAYOUT OF ENERGY SYSTEM COMPONENTS
2. DESCRIPTION OF ENERGY SYSTEM
3. SIMULATED PERFORMANCE OF ENERGY SYSTEM
4. ANALYSIS OF SYSTEM PERFORMANCE

1. LAYOUT OF ENERGY SYSTEM

The diagram below shows the basic arrangement of the components of the UK physical energy system and the flows of energy between them. The lists of types of each component are not exhaustive for converters and stores.
The components are numbered 1 to 7.

```
 ___________     ____________      ____________      ____________
|1.DEMANDS|     |2.USER     |     |7.INCOME   |     |6.NATURAL  |
|         |     |CONVERTERS|      |  SOURCES  |     |  STORES   |
|Work     |<--|Boiler     |<----| Solar,wind|     | Coal,oil  |
|Transport|     |Motor      |     | wave,tidal|     | gas,      |
|Light    |     |Collector  |     | hydro     |     | uranium   |
|Heat>120 |     |___________|     |___________|     |___________|
|Cooking  |        /!\   /\             |              /
|Heat<120 |         |      \            |             /
|Hot water|         |       \           |            /
|Space    |         |        \          |           /
|_________|        \|/        \        \|/         /
                    !          \________!_______\/
                ____________      ____________      ____________
               |3.USER      |   |4.ENERGY IN|     |5.ENERGY IN|
               |  STORES    |   | CONVERTERS|     |  STORES   |
               |Bunker,tank|   | Power stat|<-->|Bunker,tank|
               |H/W tank    |   | Refinery  |     |Pumped     |
               |El. storage|   | Gasifier  |     |           |
               |___________|   |___________|     |___________|
```

2. UK ENERGY SYSTEM DESCRIPTION
Technical conservation.

SYSTEM DESCRIPTION
Technical data are given; these specify the components:
DEMAND
USER CONVERTERS
USER STORES
CONVENTIONAL ELECTRICICITY GENERATION
AMBIENT ELECTRICITY GENERATION
ENERGY INDUSTRY CONVERTERS
INDUSTRY STORES
PRIMARY RESERVES
These data with climatic data determine the simulated energy flows with time.

USEFUL ENERGY DEMAND DATA

TEMPORAL USE PATTERNS

The numbers below refer to the hourly use levels for the various sectors. The first two rows of numbers for each pattern refer to the weekday pattern; the second two the weekend pattern.

Proportion houses with active occupants

0.4	0.1	0.1	0.1	0.2	0.4	0.5	0.6	0.5	0.4	0.4	0.5
0.4	0.4	0.5	0.6	0.7	0.9	0.8	0.8	0.7	0.8	0.7	0.5
0.3	0.1	0.0	0.0	0.0	0.0	0.3	0.5	0.6	0.7	0.7	0.6
0.6	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.3

Average = 0.50

Domestic cooking: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.7	0.9	1.2	1.0	0.8	1.7
2.2	1.7	1.2	1.8	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3
0.1	0.1	0.1	0.1	0.1	0.4	0.6	0.7	1.2	1.0	0.8	1.7
2.2	1.7	1.1	1.5	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3

Average = 1.00

Domestic hot water: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.7	1.6	1.4	0.8	2.0	1.6	1.2
0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.8	1.6	1.4	0.8	2.0	1.6	1.2

Average = 1.00

Domestic transport: % daily traffic

0.9	0.3	0.1	0.1	0.2	0.3	1.0	4.5	6.8	4.8	5.0	5.2
5.5	5.2	5.7	5.8	7.3	8.2	7.3	6.4	4.7	3.7	3.1	2.1
2.3	1.0	0.6	0.3	0.3	0.4	0.9	2.2	3.0	4.1	6.3	7.5
8.0	7.1	9.1	9.4	9.0	8.3	7.7	7.8	6.6	5.1	4.3	3.6

Average = 4.18

Industrial general: proportion of average demand

0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1.4	1.4	1.4	1.5
1.3	1.4	1.4	1.3	1.2	1.1	0.9	0.9	0.9	0.9	0.9	0.9
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.9	1.0	1.0	1.0
0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Average = 1.00

Industrial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

Commercial general: proportion of average demand

0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	1.2	1.6	1.7	1.7
1.7	1.7	1.7	1.7	1.6	1.3	1.1	1.0	0.9	0.9	0.9	0.9
0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.8	1.1	1.1	1.2
1.1	1.1	1.2	1.2	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.6

Average = 1.00

Commercial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

CHARACTERISTICS OF DEMANDS

DOMESTIC

Number of occupied houses	=	19.49 mill
Miscellaneous electricity:		
Miscellaneous appliances	=	2160.0 MW
Fridges and freezers	=	314.0 MW
Light:		
Useful light per house	=	9.5 W
Cooking:		
Average useful demand per house	=	23.0 W
Hot water:		
Monthly mains temperatures (C)		
7.0 6.0 7.0 9.0 10.0 11.0 13.0 15.0 13.0 11.0 10.0 9.0		
Demand temperature (C)	=	55.0 C
Hourly demand volume	=	4.5 l.
Space heating:		
House internal temperature	=	16.0 C
House fabric loss	=	163.0 W/C
House ventilation loss	=	50.0 W/C
Incidental fudge factor	=	0.9
Transport:		
Number of cars	=	14.0 mill
Average useful power per car	=	134.0 W

INDUSTRIAL

Number of industrial people	=	10.6 million
Kinetic:		
Average useful demand	=	2530.0 MW
Light:		
Useful light per person	=	67.0 W
Process heat > 120 C:		
Average useful demand	=	10827.0 MW
Process heat < 120 C:		
Average useful demand	=	9119.0 MW
Hot water:		
Average useful demand	=	3148.0 MW
Space heating:		
Internal temperature	=	16.5 C
Fabric loss per person	=	46.0 W/C
Ventilation loss per person	=	38.0 W/C
Incidental fudge factor	=	0.4
Transport:		
Average diesel motor demand	=	1870.0 MW

```
COMMERCIAL
Number of commercial people  =          26.6 million
Miscellaneous electricity:
     Average useful demand   =        732.0  MW
Light:
     Useful light per person =         72.0  W
Cooking:
     Average useful demand   =        371.0 MW
Hot water:
     Average useful demand   =       2165.0  MW
Space heating:
     Internal temperature        =          16.0  C
     Fabric loss per person      =          10.0  W/C
     Ventilation loss per person =          39.0 W/C
     Incidental fudge factor     =           0.6
Transport:
     Average plane and ship demand =        2448.0  MW
     Average electric train demand =          91.0  MW
IRON AND STEEL
All energy:
     Total average demand =      8345.0  MW
FEEDSTOCKS
     Total average demand =     18106.0  MW
```

USER CONVERTERS

User converters are arranged in the sequences:

SECTOR	OUTPUT	INPUT
Domestic	Mis. Electric	Gas
Industrial	Mechanical	Liquid
Commercial	Light	Solid
Iron & Steel	Process > 120	Electricity
Feedstocks	Cooking	Solar
	Process <120	
	Hot water	
	Space	
	Transport	

A value of 9.9 means the efficiency is variable

DOMESTIC USER CONVERTERS (E) means double entry	POPULATION (millions)	EFFICIENCY
Fridges and freezers (U)	19.49	1.00
Electric appliances (U)	19.49	1.00
Incandescent lights	19.49	0.13
Gas cooker	10.70	0.11
Electric cooker	8.80	0.20
Gas individual H/W heater	4.11	0.43
Gas C/H H/W heater (E)	3.80	0.40
Gas heat pump H/W heater (E)	0.00	9.90
Oil C/H H/W heater (E)	0.20	0.50
Solid C/H H/W heater (E)	5.19	0.41
Solid CHP H/W heater (E)	0.00	0.67
Electric H/W heater	6.18	0.72
Electric heat pump H/W heater (E)	0.00	9.90
Solar individual H/W heater	0.00	9.90
Solar space & H/W heater (E)	0.00	9.90
Gas individual space heater	4.14	0.50
Gas C/H space heater	4.16	0.75
Gas heat pump space heater	0.00	9.90
Oil C/H space heater	3.45	0.65
Solid individual space heater	2.45	0.25
Solid C/H space heater	2.72	0.65
Solid CHP space heater	0.00	0.67
Electric on peak space heater	0.44	1.00
Electric off peak space heater	2.13	9.90
Electric heat pump space heater	0.00	9.90
Solar space & H/W heater	0.00	9.90
Solar passive house	0.00	9.90
Liquid fuelled car	14.00	0.12
Electric car	0.00	0.80

MISCELLANEOUS DATA ON DOMESTIC CONVERTERS		
Solar water heater:		
Area of collector	=	5.0 m2
Volume of tank	=	200.0 l.
Loss coeff. of tank	=	20.0 W/C
Active solar house:		
Area of collector	=	20.0 m2
Volume of tank	=	40.0 m3
Insulation on tank	=	28.1 cm.
Specific loss of tank	=	10.0 W/C
Passive solar house:		
Area of south glazing	=	15.0 m2
Transmittance of glazing	=	0.7
Specific loss (day)	=	150.0 W/C
Specific loss (night)	=	125.0 W/C
Ventilation loss	=	50.0 W/C

INDUSTRIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Oil fuelled motor	473.00	0.17
Electric fuelled motor	2057.00	0.35
Fluorescent lights (U)	712.88	0.40
Gas heater > 120 C	2764.00	0.60
Gas CHP heater > 120 C	622.00	0.56
Liquid heater > 120 C	2647.00	0.60
Liquid CHP heater > 120 C	1119.00	0.56
Solid heater > 120 C	1757.00	0.60
Solid CHP heater > 120 C	331.00	0.56
Electric heater > 120 C	1587.00	1.00
Gas heater < 120 C	1985.00	0.60
Gas CHP heater < 120 C	816.00	0.56
Liquid heater < 120 C	3435.00	0.60
Liquid CHP heater < 120 C	1479.00	0.56
Solid heater < 120 C	839.00	0.60
Solid CHP heater < 120 C	436.00	0.56
Electric heater < 120 C	129.00	1.00
Gas H/W heater	565.00	0.60
Gas CHP H/W heater	175.00	0.56
Liquid H/W heater	1594.00	0.60
Liquid CHP H/W heater	316.00	0.56
Solid H/W heater	317.00	0.60
Solid CHP H/W heater	94.00	0.56
Electric H/W heater	87.00	1.00
Gas space heater (U)	1.85	0.60
Gas CHP space heater (U)	0.00	0.56
Liquid space heater (U)	5.31	0.60
Liquid CHP space heater (U)	0.00	0.56
Solid space heater (U)	1.05	0.60
Solid CHP space heater (U)	2.10	0.56
Electric space heater (U)	0.33	1.00
Diesel transport motors	1870.00	0.17

COMMERCIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Miscellaneous electric	732.00	1.00
Fluorescent lights (U)	1913.04	0.40
Gas cooker	251.00	0.20
Liquid cooker	11.40	0.20
Solid cooker	11.40	0.20
Electric cooker	97.20	0.40
Gas H/W heater	514.00	0.60
Gas CHP H/W heater	0.00	0.56
Liquid H/W heater	1170.00	0.60
Liquid CHP H/W heater	0.00	0.56
Solid H/W heater	252.00	0.60
Solid CHP H/W heater	0.00	0.56
Electric H/W heater	229.00	1.00
Gas space heater (U)	4.86	0.60
Gas CHP space heater (U)	0.00	0.56
Liquid space heater (U)	15.39	0.60
Liquid CHP space heater (U)	0.00	0.56
Solid space heater (U)	4.05	0.60
Solid CHP space heater (U)	0.00	0.56
Electric space heater (U)	2.27	1.00
Ships and aeroplanes	2448.00	0.20
Electric trains	91.00	0.80

I&S, FEEDSTOCK USER CONVERTERS	POWER (MW)	EFFICIENCY
Gas I&S process	1029.00	0.78
Liquid I&S process	1965.00	0.54
Solid I&S process	4972.00	0.43
Electric I&S process	379.00	0.30
Gas feedstock use	3076.00	1.00
Liquid feedstock use	14871.00	1.00
Solid feedstock use	159.00	1.00

USER STORES	INPUT POWER	EFF. I/O	CAPACITY /UNIT	TOTAL CAPACITY	OUTPUT POWER	POP
DOMESTIC						
House oil tanks		1.0	11194.kWh	38621.GWh		3.4
Car petrol tanks		1.0	444.kWh	6222.GWh		14.0
Coal bunkers		1.0	17056.kWh	41786.GWh		5.2
El stor. heaters	7.5 kW	1.0	85. Wh/C		4. W/C	2.1
El car batteries	10.0 kW	.8	55. kWh	0. GWh		0.0
Solar H/W tanks			200. l		20.0 W/C	0.0
Active solar houses			40.0 m3		28.1 W/C	0.0
INDUSTRY						
Liq stores				30700. GWh		
Solid stores				15800. GWh		
COMMERCE						
Liq stores				14400. GWh		
Solid stores				168. GWh		

FOSSIL/FISSILE ELECTRICITY GENERATION

FUEL AND TYPE	OUTPUT POWER	EFFICIENCY	MERIT
Domestic CHP	0.0 MW	0.25 (E)	1
Industrial CHP	2014.2 MW	0.11 (E)	1
Commercial CHP	0.0 MW	0.11 (E)	1
Pumped store	1000.0 MW	0.85	6
Nuclear	3.0 GW	0.29- 0.23	7
Solid	35.0 GW	0.35- 0.11	8
Oil	11.0 GW	0.34- 0.18	9
Gas	1.0 GW	0.35- 0.10	10
Gas turbine	2.0 GW	0.34- 0.18	11

Peaking plant (gas turbine and pumped storage) used if d(NET LOAD)/dt > 1000.0 MW/hr

Merit order of conventional stations:
nuclear (1),coal (2),oil (3),gas (4)

1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 3 2
3 2 3 2 3 2 4 3 2 3 2 3 2 3 2 3 2 3 2 3 2 2 2 2 2
3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AMBIENT ELECTRICITY GENERATION			
AMBIENT SOURCE	MAX OUTPUT	SIZE	MERIT
Aerogeneration Dispersed in UK Vcut= 3.0 ms-1 Vrat= 20.0 (ms-1) Radius=23 m.	0.00 GW	0. num	2
Wave power NW of Scotland Max. mech. (kWm-1)= 100.0 Max height(m.) 4.2	0.00 GW	0.0 km	3
Tidal power Severn estuary	0.0 + 0.0 GW	0.0+ 0.0 km2	4
Fresh hydro Dispersed in UK 3.2 TWhe/annum 24. hrs average= 366. MWe	1165.0 MW		5

ENERGY INDUSTRY CONVERTERS	POWER (GW)	EFFICIENCY
Gas extraction	85.	0.96
Gas from coal converter	0.	0.70
Gas transmission	102.	0.97
Oil extraction	120.	0.96
Oil from coal converter	0.	0.70
Oil refinery	144.	0.94
Oil distribution	144.	0.99
Coal mines	180.	0.95
Coal distribution	216.	0.97
Nuclear reprocessor	30.	0.50
Nuclear waste disposal	0.	9.90
Electricity transmission	62.	0.92

ENERGY INDUSTRY STORES	POWER (GW)	CAPACITY
Gas stores	85.0	228.0 GWh
Oil stores	120.0	262000.0 GWh
Solid stores	180.0	260000.0 GWh
Nuclear stores	30.0	1000.0 GWh
Pumped storage	1.0	29.1 GWhm
In at power 1000.0 MW		
Out if d(LOAD)/dt > 1000.0 MW/hr		
Biomass area	0.0 km2	
Efficiency biomass to gas 0.55		
Efficiency biomass to oil 0.50		

PRIMARY RESERVES	SIZE (TWh)
Gas reserves	15332.
Oil reserves	17279.
Coal reserves	563889.
Uranium reserves	50000.

SUMMARIES FOR ONE YEAR
ENERGY IN GWh

SUMMARY OF USEFUL ENERGY DEMANDS	Dom	Ind	Com	I&S	Feed	TOTAL
Work	0.	22067.	0.	0.	0.	22067.
Miscellane	12161.	0.	6411.	0.	0.	18573.
Transport	16346.	16381.	21444.	0.	0.	54172.
Light	655.	3313.	7205.	0.	0.	11172.
High Temp	0.	94436.	0.	73102.	0.	167538.
Cooking	3910.	0.	3249.	0.	0.	7159.
Low temp	0.	79538.	0.	0.	0.	79538.
Hot water	40177.	23469.	18963.	0.	0.	82608.
Space	78359.	9633.	33422.	0.	0.	121414.
Feedstocks	0.	0.	0.	0.	158609.	158609.
TOTAL	151608.	248837.	90695.	73102.	158609.	722850.

SUMMARY OF FUEL DELIVERIES	Dom	Ind	Com	I&S	Feed	TOTAL
Gas	128367.	104009.	28684.	11556.	26946.	299562.
Liquid	36479.	185936.	49844.	31877.	130270.	434406.
Solid	82319.	58675.	12669.	101290.	1393.	256345.
Electricit	62851.	75445.	31413.	11067.	0.	180775.
CHP (heat)	0.	48109.	0.	0.	0.	48109.
Solar (hea	0.	0.	0.	0.	0.	0.
Transport	136219.	96360.	107222.	0.	0.	339801.
Transport	0.	0.	797.	0.	0.	797.
TOTAL	446236.	568534.	230629.	155790.	158609.	1559797.

SUMMARY OF ELECTRICITY PRODUCTION	Electricity	Fuel used	Effic.	Load factor
CHP	9450.1			0.54
Aero	0.0			0.00
Wave	0.0			0.00
Tide	0.0			0.00
Hydro	3203.6			0.31
Pumped	1450.0			0.17
Nuclear	26280.0	94789.3	0.28	1.00
Coal	150146.0	443930.4	0.34	0.49
Oil	9961.5	29483.3	0.34	0.10
Gas	0.0	0.0	0.00	0.00
Other storage	0.0			0.00
Pumped storage	-2029.3			0.00
Tidal storage	0.0			0.00
Total demand	197360.5			0.36
TOTAL SENT OUT	200491.2			0.33

SUMMARY OF PRIMARY FUEL FLOWS	
Gas	299562.4
Oil	814814.9
Coal	704033.5
Nuclear (heat)	94789.3
Coal for gas	0.0
Coal for oil	0.0
Biomass	0.0

GROSS PRIMARY FUEL EXTRACTED	
Gas	321716.6
Oil	936844.2
Coal	788888.5
Nuclear	189760.4
TOTAL FOSS/FISS	2237209.7

```
4. PERFORMANCE ANALYSIS
This section of output gives some analysis
of the performance of the energy system  over
the simulated time period.
```

```
     GAS
Maximum flow rate of gas delivery was
       66.15 GW
Minimum storage requirement between component 2 and 6
was            0.0 in interval  12
```

```
     LIQUID
Maximum flow rate of liquid delivery was
       75.38 GW
Minimum storage requirement between component 2 and 6
was            0.0 in interval  12
```

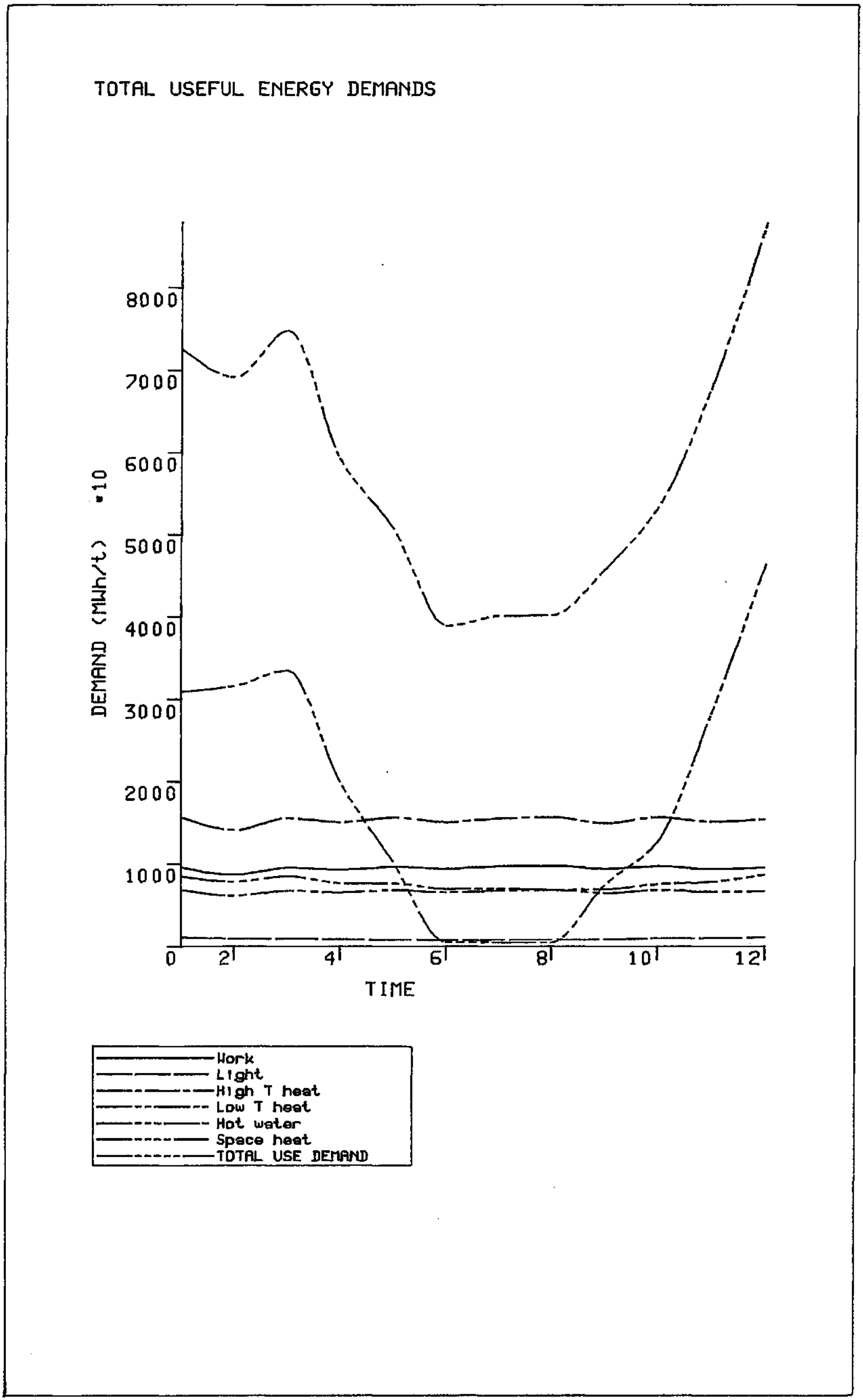
```
     SOLID
Maximum flow rate of solid delivery was
       58.00 GW
Minimum storage requirement between component 2 and 6
was            0.0 in interval  12
```

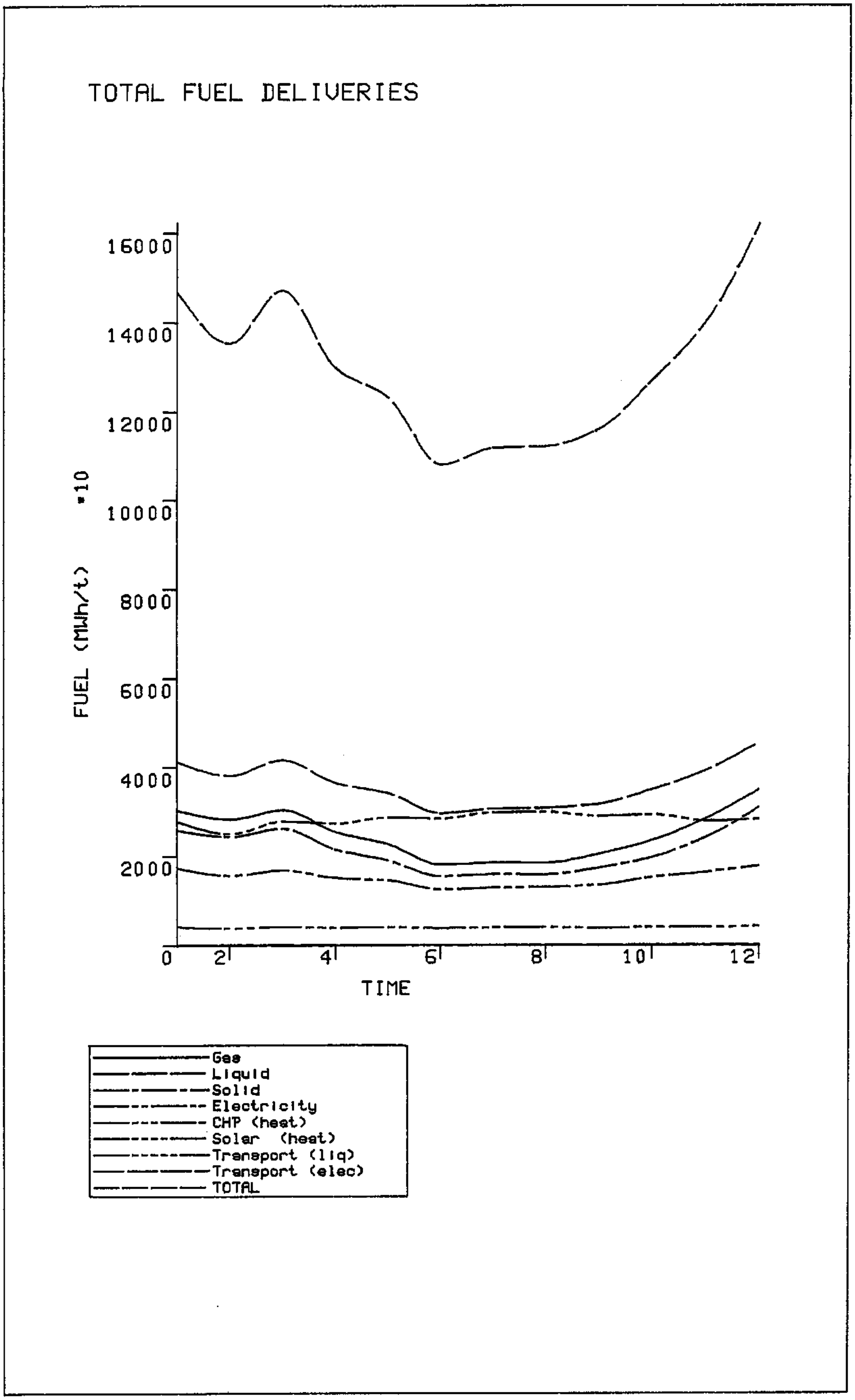
ELECTRICITY

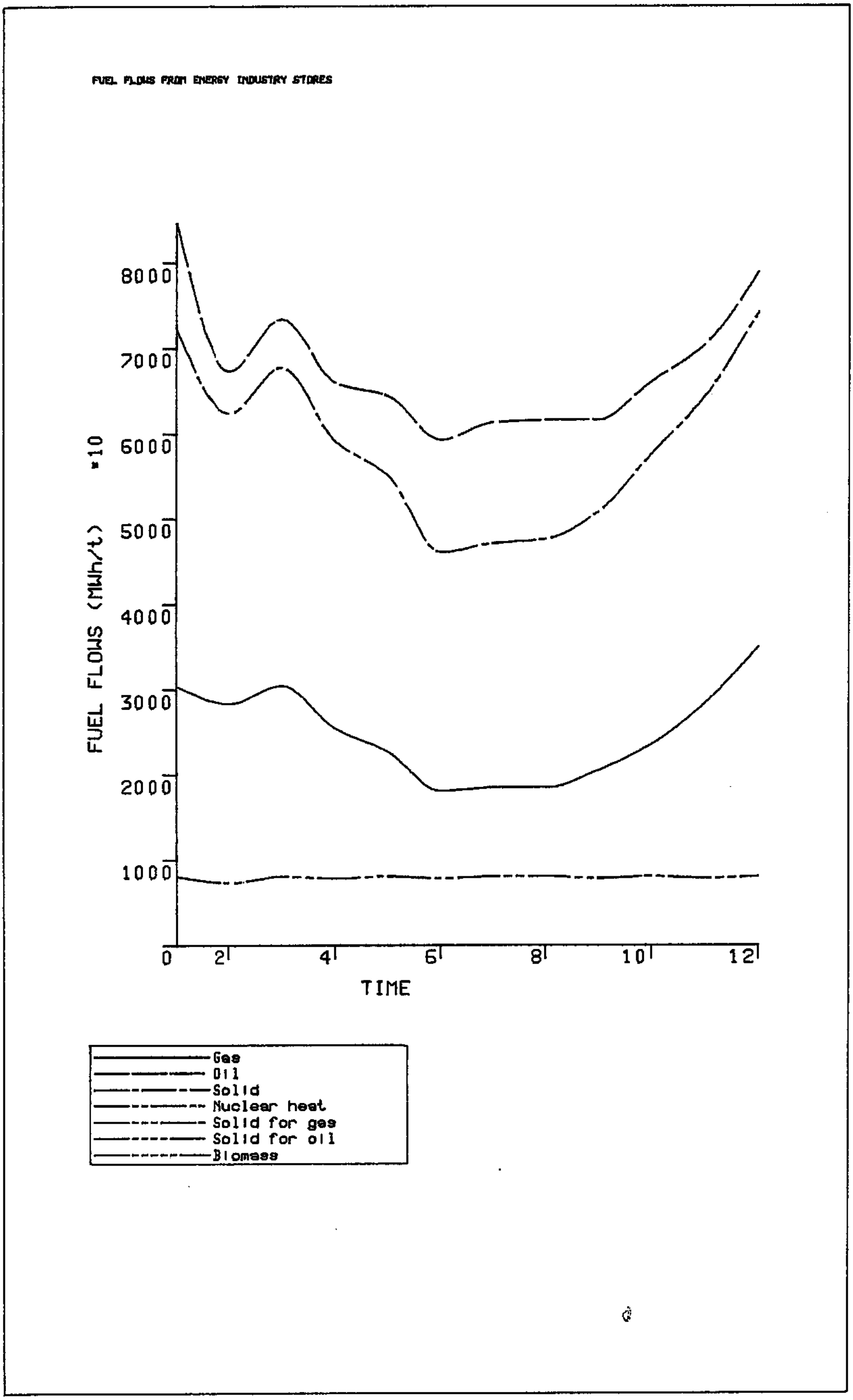
FLOW DURATION CURVES
Numbers are powers (GW)
Columns are percentage of time flow exceeded.

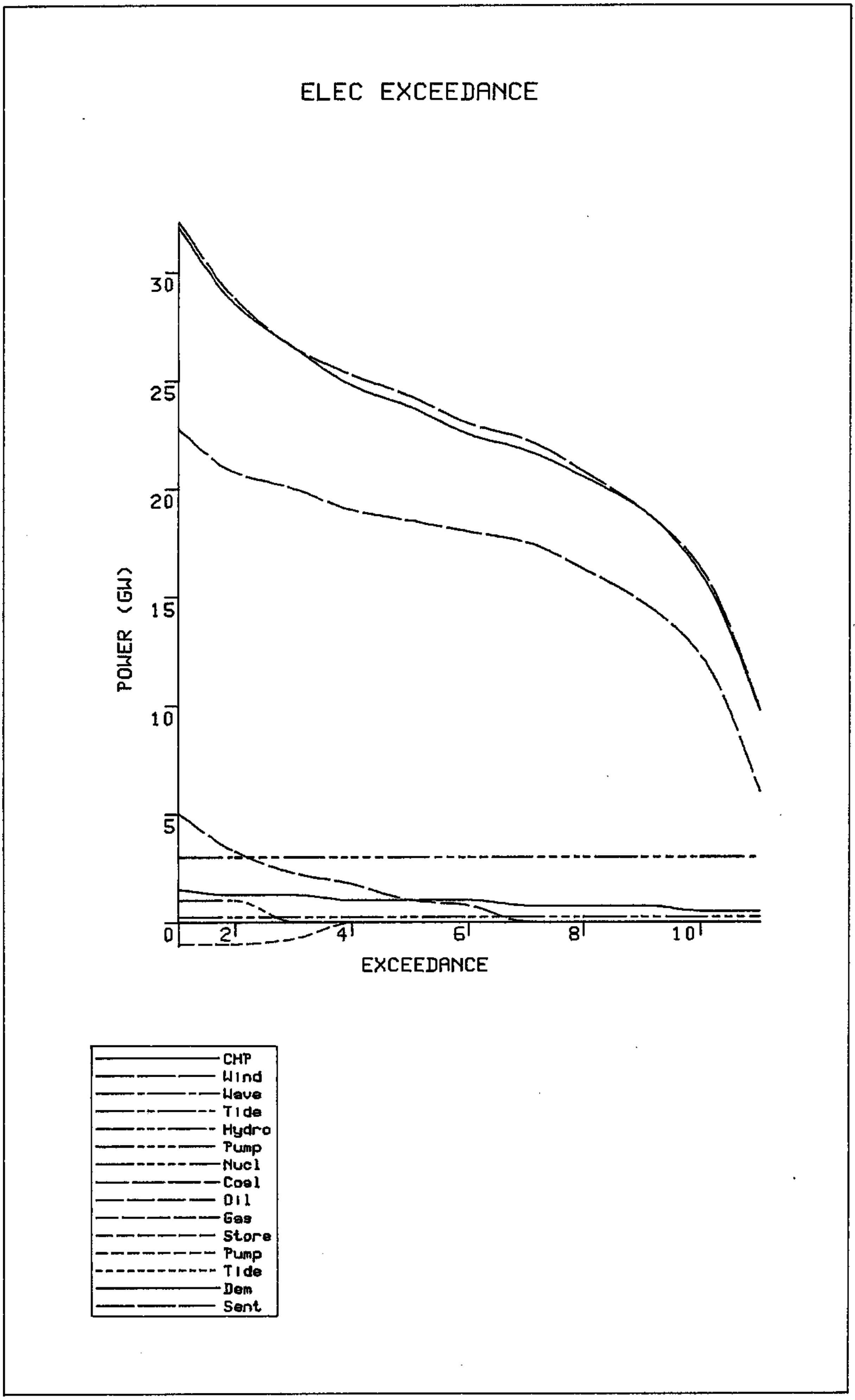
	0	10	20	30	40	50	60	70	80	90	100
CHP	1.5	1.3	1.3	1.0	1.0	1.0	0.8	0.8	0.8	0.5	0.5
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydro	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Pump	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nucl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Coal	22.8	20.8	20.0	19.0	18.5	18.0	17.5	16.3	14.8	12.3	6.0
Oil	5.0	3.3	2.3	1.8	1.0	0.8	0.0	0.0	0.0	0.0	0.0
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Store	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pump	-1.0	-1.0	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dem	32.0	28.5	26.5	24.8	23.8	22.5	21.8	20.5	19.0	16.0	9.8
Sent	32.3	28.8	26.5	25.3	24.3	23.0	22.3	20.8	19.0	16.3	9.8

Maximum electrical power sent out was 32422.7 MW
in the 17 th hour of the 365 th day of the year.

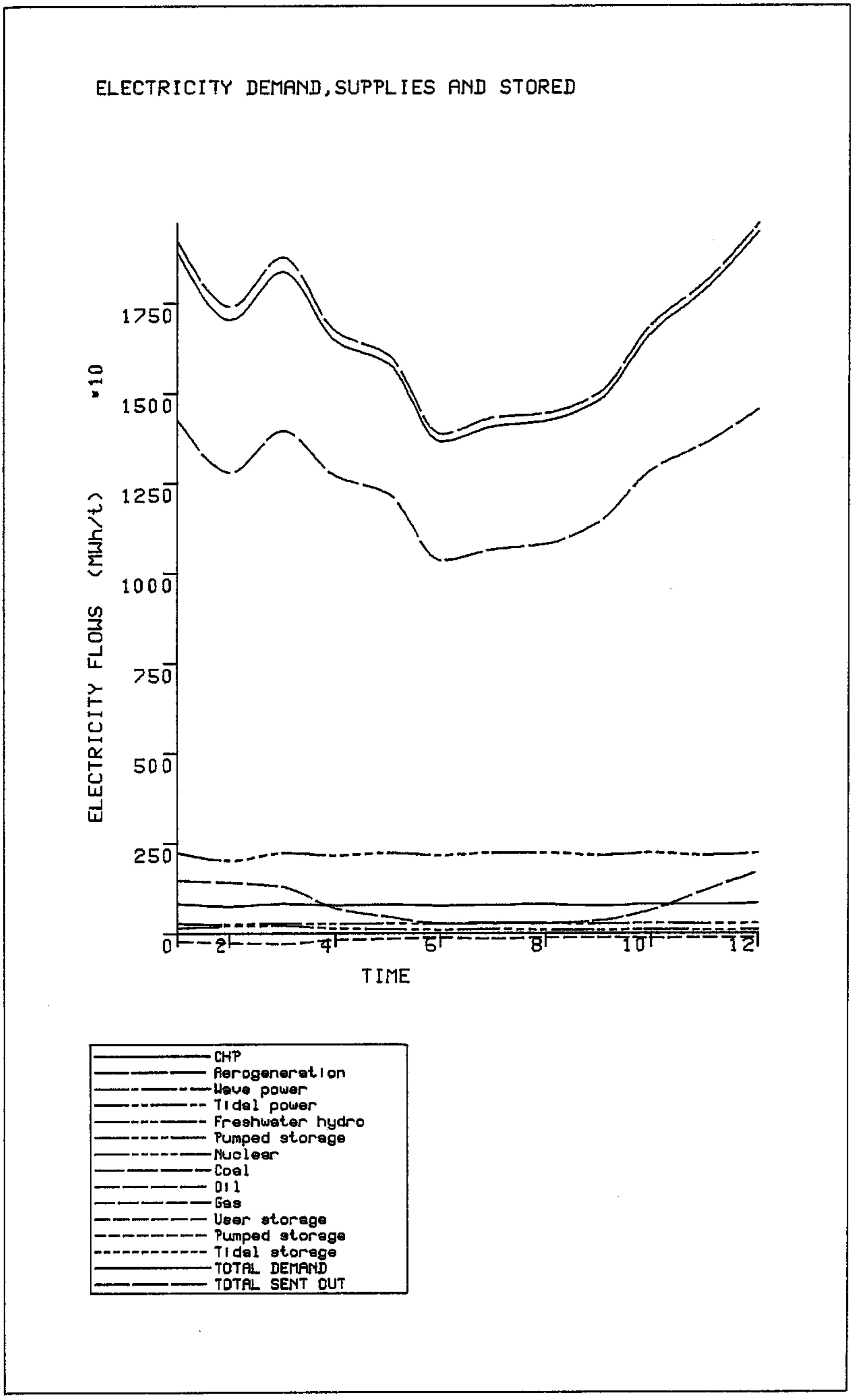

TOTAL USEFUL ENERGY DEMANDS
DEMAND (MWh/t) *10
8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Work
Light
High T heat
Low T heat
Hot water
Space heat
TOTAL USE DEMAND


TOTAL FUEL DELIVERIES
16000
14000
12000
10000
8000
6000
4000
2000
FUEL (MWh/t) *10
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL

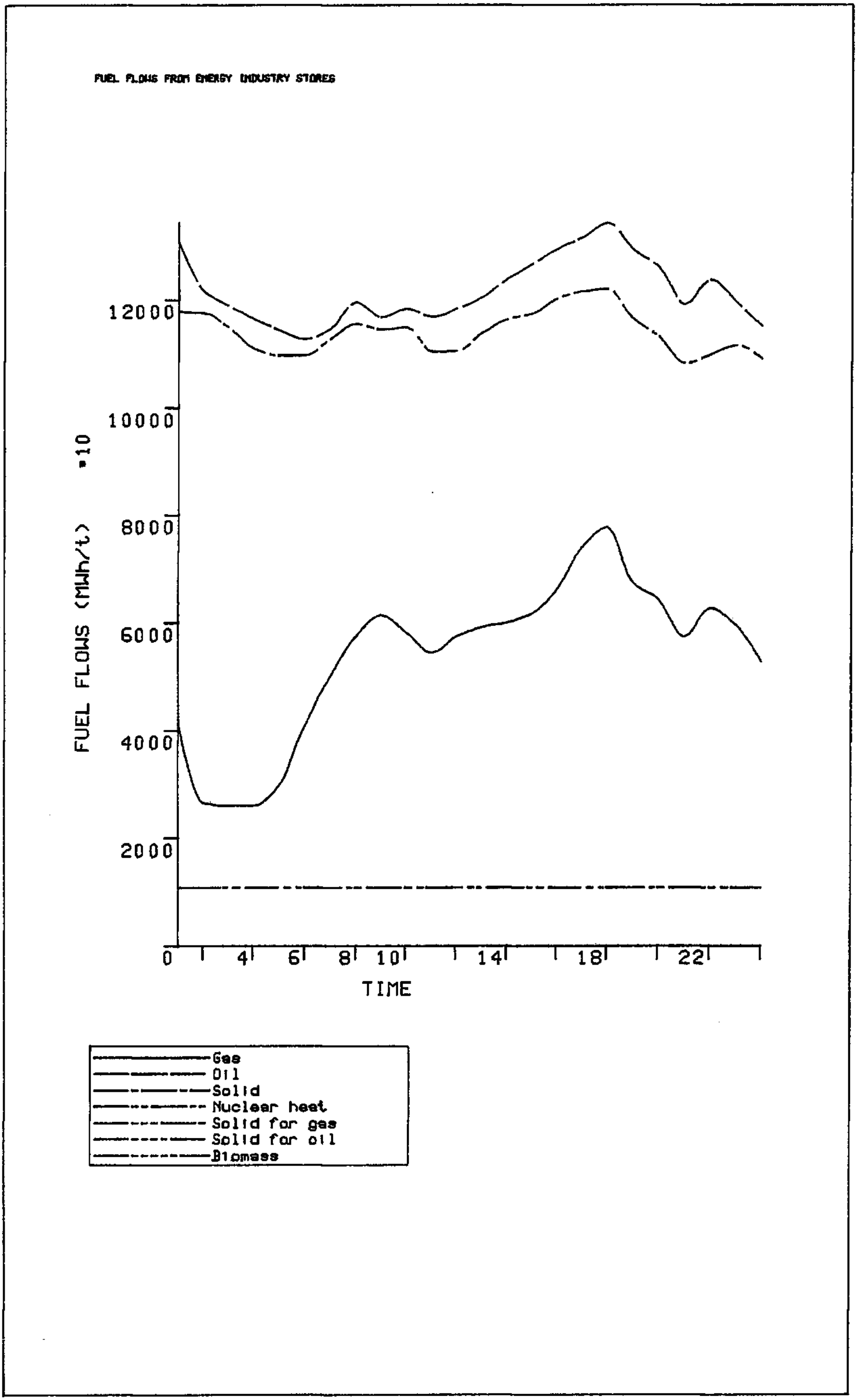

FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
8000
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass

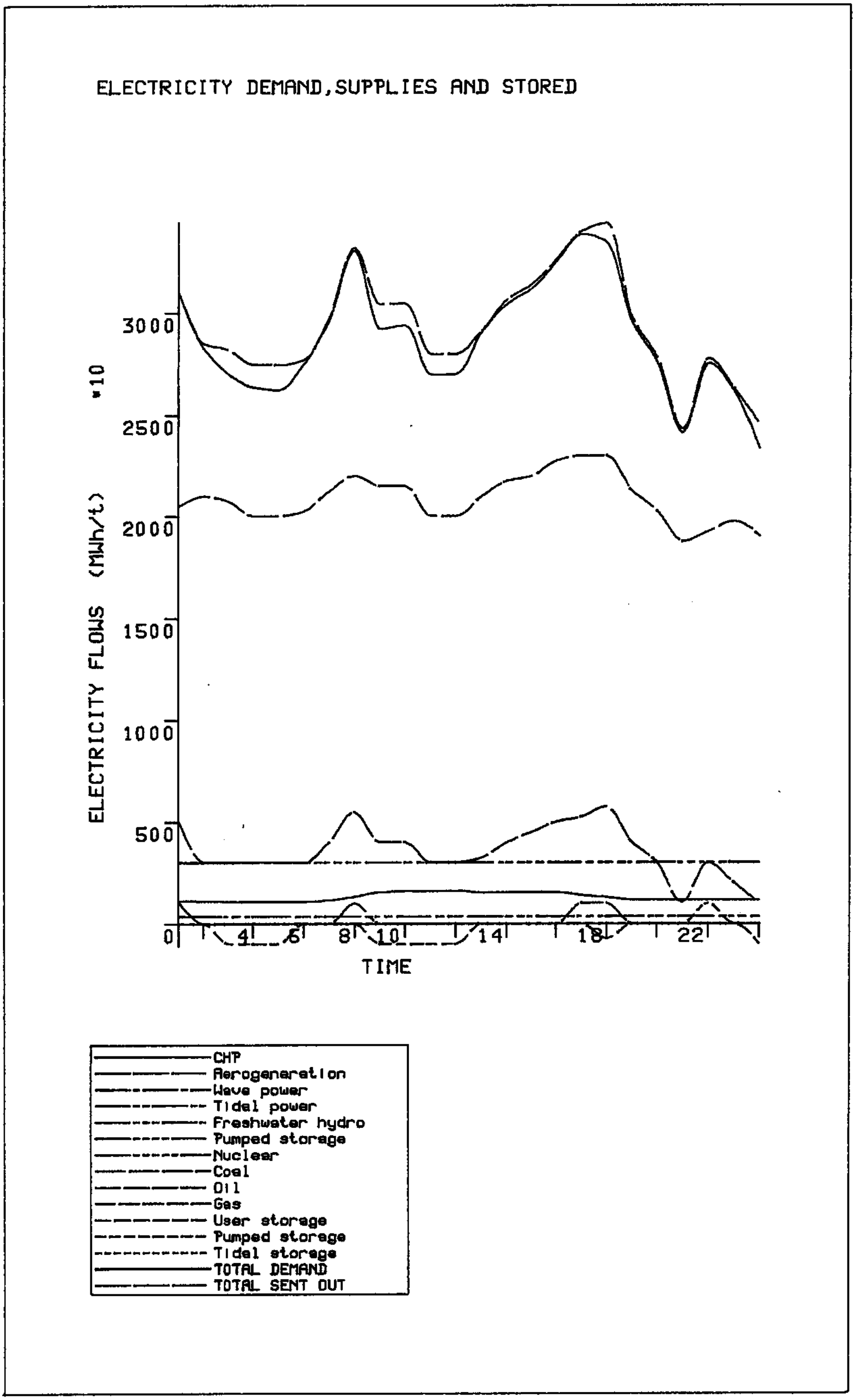

ELEC EXCEEDANCE
POWER (GW)
30
25
20
15
10
5
0
2
4
6
8
10
EXCEEDANCE
CHP
Wind
Wave
Tide
Hydro
Pump
Nucl
Coal
Oil
Gas
Store
Pump
Tide
Dem
Sent

The following two graphs show the electricity and fossil fuel flows for the system with technical conservation on a 0 degree Centigrade winter day.



ELECTRICITY DEMAND, SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t) *10
1750
1500
1250
1000
750
500
250
0
2
4
6
8
10
12
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT


FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
12000
10000
8000
6000
4000
2000
0
4
6
8
10
14
18
22
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass


ELECTRICITY DEMAND,SUPPLIES AND STORED
*10
ELECTRICITY FLOWS (MWh/t)
3000
2500
2000
1500
1000
500
0
4
6
8
10
14
18
22
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT

6. REDUCTION OF UK PRIMARY ENERGY DEMAND BY INCREASED EFFICIENCY AND REALLOCATION

6.1 Objective of system changes

6.1.1 Introduction

The present overall efficiency of converting primary energy into useful energy is around 0.35. This low figure is due to the inefficiency of individual converters (such as open coal fires) and the inefficiency due to allocation (such as the use of electric resistance heaters for space heating). Almost all existing types of converters can be made more efficient by improved design. The lifetime of converters, generally 10 to 25 years, means that a fairly rapid penetration of more efficient converters is possible without prematurely retiring existing equipment. Essentially new types of converter, such as heat pumps, are not included in this application.

6.1.2 Objective

The objective is to improve the overall efficiency of converting primary energy (including income energy) into useful energy.

The methods are varied, an attempt to summarise them is given below.

(i) Improve heat engine efficiency by higher temperatures, compression ratios.

(ii) Increase efficiency of lights by using fluorescent in place of incandescent.

(iii) Improve cooker efficiency by better design including insulation.

(iv) Improve efficiency of heaters with better heat exchangers and insulation.

(v) Change converter allocations so as to avoid inefficient conversions upstream in the system. The future scarcity of fossil/fissile fuels should be considered when reallocating.

6.2 Technical details of system

The following sections detail the assumed changes to efficiency due to improved design and allocation. Where the latter is not mentioned it is assumed to remain as for the 1976 system. All the assumed changes in allocation are due to the author.

6.3 Domestic sector

6.3.1 Light

It is assumed that the average efficiency of domestic lumieres increases from 0.13 to 0.3 because of the substitition of incandescent bulbs (efficiency 0.13) by flourescent bulbs and tubes (efficiency 0.4).

6.3.2 Cookers

The same amount of cooking can be done with 54 % less electricity if improvements are made to conventional electric cookers (p 104, IIED, 1979). Their efficiency is therefore assumed to increase from 0.2 to 0.43. [If cookers which are totally or partially microwave are introduced then the same increase again in efficiency might be possible.]

It is assumed that the the same increase in gas cooker efficiency is possible; this therefore increases from 0.11 to 0.24.

6.3.3 Hot water heaters

Improved insulation, better heat exchangers, lightweight design and controlled and/or balanced flues can improve fossil fuelled heater efficiencies to 0.8 if non-condensing, and to perhaps 0.95 if condensing.

It is assumed that all fossil heaters increase their average efficiencies to 0.8. Presently they lie in the range 0.25 to 0.7.

Electric immersion heater efficiency can be increased from 0.72 to 0.95 by improved insulation and design.

The following reallocations are assumed to occur.

2.0 mill. elec. immersion heaters -> 2.0 mill. coal C/H

6.3.4 Space heaters

The same measures as applied to fossil fuelled water heaters can be used; it is therefore assumed that the new efficiencies are the same, namely an average 0.8.

The following reallocation is assumed to occur.

1.5 mill. elec. off peak -> 1.5 mill. coal C/H

0.3 mill. elec on peak -> 0.3 mill. coal C/H

2.5 mill. oil -> 2.5 mill. coal C/H

6.3.5 Cars

The overall efficiency of car petrol internal combustion engines and transmission systems can be increased by a number of measures. These measures, and the savings assumed are listed below.

- better lubricants (p 156, IIED, 1979)	10 - 14 %
- cold start improvements (p 160, IIED, 1979)	4.5 %
- constant velocity transmission (p 161,IIED,1979)	20 - 30 %
- lean burn engines (p 161, IIED, 1979)	20 %
Total	55.5 -74.5 %

It is likely that these savings are not purely additive as assumed above, a lower estimate of 60 % savings is therefore assumed. The efficiency of cars therefore increases from 0.12 to 0.3.

6.4 Industrial sector

6.4.1 Motors

It is assumed that the efficiency of oil fuelled motors and primary transmissions can be increased from 0.17 to 0.28, this is the same improvement assumed for similar transport motors.

Smaller improvements are possible in electric motors, although losses are still considerable (about 65 %, p 41, IIED, 1979). The efficiency is assumed to increase from 0.35 to 0.65.

It is assumed that no reallocation occurs.

6.4.2 Lights

It is assumed that the majority of lights in this sector are high efficiency fluourescent lights of efficiency 0.4. However, this figure can be increased either by using existing lamp designs of higher efficiency for certain tasks or by introducing more efficient designs. It is assumed that these two measures increase the average efficiency of lights from 0.4 to 0.45.

6.4.3 Process, hot water and space heaters

It is assumed that the average efficiencies of direct and indirect fossil fired heaters increase from their present values to an average 0.8. This is achieved by the same types of measure briefly described under domestic water heaters.

The efficiency of electric heaters is assumed to remain 1.0.

CHP efficiencies for converting fuel to electricity and heat change from 0.11 to 0.2 and from 0.56 to 0.65 respectively.

It is assumed that a 50 % switch from oil, gas and electric heating to coal is made in all these subsectors of demand: this does not include a switch to CHP.

6.4.4 Transport

The average efficiency of bus/coach motor and transmission systems can be increased by 5 % by spark ignition and a further 7 - 10 % by better lubricants and transmission (p 165, IIED, 1979).

Constant velocity transmission could save 3 - 6% in lorries and improved or new engines could save a further 20 - 40 % (p 72, EP 45).

These savings, when combined to a total 40 %, result in the sectoral average efficiency of diesel motor and transmission systems increasing from 0.17 to 0.28.

6.5 Commercial sector

6.5.1 Lights

Same as industrial sector.

6.5.2 Miscellaneous electric

Nominal efficiency of 1.0 assigned anyway.

6.5.3 Cooking

It is assumed that improved design and insulation increases the efficiencies of all the cookers in this sector by 50 % (?). The efficiency changes are therefore as follows :

Gas	0.2 -> 0.3
Oil	0.2 -> 0.3
Coal	0.2 -> 0.3
tElectric	0.4 -> 0.6

6.5.4 Space and water heating

The efficiencies are assumed to increase to the same values as assumed for industrial heaters (see above).

A 35 % switch from oil and electric heaters to coal is assumed.

6.5.5 Transport

High bypass turbofan motors increase the average efficiency of aeroplane motors from 0.3 to 0.34 due to 12 % savings made by better design (p 166, IIED, 1979). The same increase is assumed to occur in ship engines and transmissions (?).

6.6 Iron and steel

The complexity of energy and material flows in this sector makes it difficult to define efficiencies and potential improvements. An increase of 15 % (?) is assumed for all converters in this sector. This gives the following efficiencies.

Gas 0.78 -> 0.92

Oil 0.54 -> 0.64

Coal 0.43 -> 0.51

Electricity 0.3 -> 0.35

6.7 Energy industry converters

For economic and other reasons an important objective of energy industries has been and is high efficiency. In general, therefore, large increases in the efficiency of existing types of plant are not possible. In fact, it is assumed that the efficiency of all energy industry converters except for oil refineries and electricity generators do not change.

6.7.1 Oil refineries

Oil refinery efficiency can be improved by insulation, heat recycling and other general improvements in design. It is assumed that these improvements increase efficiency from 0.94 to 0.96.

6.7.2 Electricity generators

The bulk of UK electricity is derived from fossil and fissile sourced heat via a heat engine utilising water as the working fluid. Material properties limit the high temperature heat input and the overall efficiency is is kept to a practical thermodynamic limit which is closely approached by modern fossil stations. [New designs of power stations incorporating thermoelectric devices which can use high temperature heat could radically increase efficiency.]

The main potential increase in the efficiency of UK power stations of conventional design is due to the substitution of obsolete, less efficient stations by modern ones. It is assumed that the efficiency ranges of stations (zero to full load for each station type) change as follows.

nuclear	0.29 - 0.23	-> 0.38 - 0.30
coal	0.35 - 0.11	-> 0.38 - 0.30
oil	0.34 - 0.18	-> 0.38 - 0.30
gas turbine	0.34 - 0.18	-> 0.38 - 0.30

It is assumed that the nuclear component of generation remains the same. All oil fired power station capacity except for 1 GW is substituted by coal stations.

Hydroelectric output is assumed to increase from 3.2 $TWh.a^{-1}$ to 10.0 $TWh.a^{-1}$.

The power and storage capacities of pumped storage increase to 3 GW and 60 GWh respectively.

DYPHEMO OUTPUT

This output is from a D ynamic PH ysical E nergy M odel
There are four main sections of output:
1. LAYOUT OF ENERGY SYSTEM COMPONENTS
2. DESCRIPTION OF ENERGY SYSTEM
3. SIMULATED PERFORMANCE OF ENERGY SYSTEM
4. ANALYSIS OF SYSTEM PERFORMANCE

1. LAYOUT OF ENERGY SYSTEM

The diagram below shows the basic arrangement of the components of the UK physical energy system and the flows of energy between them. The lists of types of each component are not exhaustive for converters and stores.
The components are numbered 1 to 7.

```
 __________     ____________      ____________      ____________
|1.DEMANDS|    |2.USER      |    |7.INCOME    |    |6.NATURAL   |
|         |    |CONVERTERS  |    |  SOURCES   |    |  STORES    |
|Work     |<--|Boiler      |<----| Solar,wind |    | Coal,oil   |
|Transport|    |Motor       |    | wave,tidal |    | gas,       |
|Light    |    |Collector   |    | hydro      |    | uranium    |
|Heat>120 |    |____________|    |____________|    |____________|
|Cooking  |        /|\    /\           |             /
|Heat<120 |         |      \           |            /
|Hot water|         |       \          |           /
|Space    |         |        \         |          /
|_________|        \|/        \       \|/        /
                ____|_____     \  _____|_____\/
               |3.USER     |    |4.ENERGY IN|    |5.ENERGY IN|
               |  STORES   |    | CONVERTERS|    |  STORES   |
               |Bunker,tank|    | Power stat|<-->|Bunker,tank|
               |H/W tank   |    | Refinery  |    |Pumped     |
               |El. storage|    | Gasifier  |    |           |
               |___________|    |___________|    |___________|
```

2. UK ENERGY SYSTEM DESCRIPTION

Increased conversion efficiency.

SYSTEM DESCRIPTION
Technical data are given; these specify the components:
DEMAND
USER CONVERTERS
USER STORES
CONVENTIONAL ELECTRICICITY GENERATION
AMBIENT ELECTRICITY GENERATION
ENERGY INDUSTRY CONVERTERS
INDUSTRY STORES
PRIMARY RESERVES
These data with climatic data determine the simulated energy flows with time.

USEFUL ENERGY DEMAND DATA

TEMPORAL USE PATTERNS
The numbers below refer to the hourly use levels for the various sectors. The first two rows of numbers for each pattern refer to the weekday pattern; the second two the weekend pattern.

Proportion houses with active occupants

0.4	0.1	0.1	0.1	0.2	0.4	0.5	0.6	0.5	0.4	0.4	0.5
0.4	0.4	0.5	0.6	0.7	0.9	0.8	0.8	0.7	0.8	0.7	0.5
0.3	0.1	0.0	0.0	0.0	0.0	0.3	0.5	0.6	0.7	0.7	0.6
0.6	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.3

Average = 0.50

Domestic cooking: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.7	0.9	1.2	1.0	0.8	1.7
2.2	1.7	1.2	1.8	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3
0.1	0.1	0.1	0.1	0.1	0.4	0.6	0.7	1.2	1.0	0.8	1.7
2.2	1.7	1.1	1.5	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3

Average = 1.00

Domestic hot water: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.7	1.6	1.4	0.8	2.0	1.6	1.2
0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.8	1.6	1.4	0.8	2.0	1.6	1.2

Average = 1.00

Domestic transport: % daily traffic

0.9	0.3	0.1	0.1	0.2	0.3	1.0	4.5	6.8	4.8	5.0	5.2
5.5	5.2	5.7	5.8	7.3	8.2	7.3	6.4	4.7	3.7	3.1	2.1
2.3	1.0	0.6	0.3	0.3	0.4	0.9	2.2	3.0	4.1	6.3	7.5
8.0	7.1	9.1	9.4	9.0	8.3	7.7	7.8	6.6	5.1	4.3	3.6

Average = 4.18

Industrial general: proportion of average demand

0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1.4	1.4	1.4	1.5
1.3	1.4	1.4	1.3	1.2	1.1	0.9	0.9	0.9	0.9	0.9	0.9
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.9	1.0	1.0	1.0
0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Average = 1.00

Industrial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

Commercial general: proportion of average demand

0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	1.2	1.6	1.7	1.7
1.7	1.7	1.7	1.7	1.6	1.3	1.1	1.0	0.9	0.9	0.9	0.9
0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.8	1.1	1.1	1.2
1.1	1.1	1.2	1.2	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.6

Average = 1.00

Commercial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

CHARACTERISTICS OF DEMANDS

DOMESTIC		
Number of occupied houses	=	19.35 mill
Miscellaneous electricity:		
Miscellaneous appliances	=	4800.0 MW
Fridges and freezers	=	897.0 MW
Light:		
Useful light per house	=	10.0 W
Cooking:		
Average useful demand per house	=	23.5 W
Hot water:		
Monthly mains temperatures (C)		
7.0 6.0 7.0 9.0 10.0 11.0 13.0 15.0 13.0 11.0 10.0 9.0		
Demand temperature (C)	=	55.0 C
Hourly demand volume	=	5.3 l.
Space heating:		
House internal temperature	=	16.0 C
House fabric loss	=	250.0 W/C
House ventilation loss	=	97.0 W/C
Incidental fudge factor	=	0.9
Transport:		
Number of cars	=	14.0 mill
Average useful power per car	=	178.3 W

INDUSTRIAL		
Number of industrial people	=	10.4 million
Kinetic:		
Average useful demand	=	2811.0 MW
Light:		
Useful light per person	=	70.0 W
Process heat > 120 C:		
Average useful demand	=	12032.0 MW
Process heat < 120 C:		
Average useful demand	=	10121.0 MW
Hot water:		
Average useful demand	=	3488.0 MW
Space heating:		
Internal temperature	=	16.5 C
Fabric loss per person	=	65.0 W/C
Ventilation loss per person	=	75.0 W/C
Incidental fudge factor	=	0.3
Transport:		
Average diesel motor demand	=	2324.0 MW

COMMERCIAL		
Number of commercial people	=	26.6 million
Miscellaneous electricity:		
Average useful demand	=	1046.0 MW
Light:		
Useful light per person	=	80.0 W
Cooking:		
Average useful demand	=	412.4 MW
Hot water:		
Average useful demand	=	2405.0 MW
Space heating:		
Internal temperature	=	17.0 C
Fabric loss per person	=	25.0 W/C
Ventilation loss per person	=	55.0 W/C
Incidental fudge factor	=	0.4
Transport:		
Average plane and ship demand	=	2511.0 MW
Average electric train demand	=	228.0 MW
IRON AND STEEL		
All energy:		
Total average demand	=	9820.0 MW
FEEDSTOCKS		
Total average demand	=	18106.0 MW

USER CONVERTERS

User converters are arranged in the sequences:

SECTOR	OUTPUT	INPUT
Domestic	Mis. Electric	Gas
Industrial	Mechanical	Liquid
Commercial	Light	Solid
Iron & Steel	Process > 120	Electricity
Feedstocks	Cooking	Solar
	Process <120	
	Hot water	
	Space	
	Transport	

A value of 9.9 means the efficiency is variable

DOMESTIC USER CONVERTERS (E) means double entry	POPULATION (millions)	EFFICIENCY
Fridges and freezers (U)	19.35	1.00
Electric appliances (U)	19.35	1.00
Incandescent lights	19.35	0.30
Gas cooker	10.70	0.24
Electric cooker	8.80	0.43
Gas individual H/W heater	4.11	0.80
Gas C/H H/W heater (E)	3.80	0.80
Gas heat pump H/W heater (E)	0.00	9.90
Oil C/H H/W heater (E)	0.20	0.80
Solid C/H H/W heater (E)	7.20	0.80
Solid CHP H/W heater (E)	0.00	0.67
Electric H/W heater	4.18	0.95
Electric heat pump H/W heater (E)	0.00	9.90
Solar individual H/W heater	0.00	9.90
Solar space & H/W heater (E)	0.00	9.90
Gas individual space heater	4.14	0.80
Gas C/H space heater	4.16	0.85
Gas heat pump space heater	0.00	9.90
Oil C/H space heater	0.90	0.85
Solid individual space heater	2.45	0.80
Solid C/H space heater	7.00	0.80
Solid CHP space heater	0.00	0.67
Electric on peak space heater	0.10	1.00
Electric off peak space heater	0.60	9.90
Electric heat pump space heater	0.00	9.90
Solar space & H/W heater	0.00	9.90
Solar passive house	0.00	9.90
Liquid fuelled car	14.00	0.30
Electric car	0.00	0.80

MISCELLANEOUS DATA ON DOMESTIC CONVERTERS		
Solar water heater:		
Area of collector	=	5.0 m2
Volume of tank	=	200.0 l.
Loss coeff. of tank	=	20.0 W/C
Active solar house:		
Area of collector	=	20.0 m2
Volume of tank	=	40.0 m3
Insulation on tank	=	28.1 cm.
Specific loss of tank	=	10.0 W/C
Passive solar house:		
Area of south glazing	=	15.0 m2
Transmittance of glazing	=	0.7
Specific loss (day)	=	150.0 W/C
Specific loss (night)	=	125.0 W/C
Ventilation loss	=	50.0 W/C

INDUSTRIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Oil fuelled motor	526.00	0.28
Electric fuelled motor	2285.00	0.65
Fluorescent lights (U)	728.00	0.45
Gas heater > 120 C	1536.00	0.80
Gas CHP heater > 120 C	691.00	0.65
Liquid heater > 120 C	1471.00	0.80
Liquid CHP heater > 120 C	1243.00	0.65
Solid heater > 120 C	5841.00	0.80
Solid CHP heater > 120 C	368.00	0.65
Electric heater > 120 C	882.00	1.00
Gas heater < 120 C	1102.00	0.80
Gas CHP heater < 120 C	907.00	0.65
Liquid heater < 120 C	1908.00	0.80
Liquid CHP heater < 120 C	1634.00	0.65
Solid heater < 120 C	4014.00	0.80
Solid CHP heater < 120 C	484.00	0.65
Electric heater < 120 C	72.00	1.00
Gas H/W heater	309.00	0.80
Gas CHP H/W heater	195.00	0.65
Liquid H/W heater	886.00	0.80
Liquid CHP H/W heater	351.00	0.65
Solid H/W heater	1595.00	0.80
Solid CHP H/W heater	104.00	0.65
Electric H/W heater	48.00	1.00
Gas space heater (U)	0.90	0.80
Gas CHP space heater (U)	0.00	0.65
Liquid space heater (U)	2.60	0.80
Liquid CHP space heater (U)	0.00	0.65
Solid space heater (U)	4.65	0.80
Solid CHP space heater (U)	2.10	0.65
Electric space heater (U)	0.15	1.00
Diesel transport motors	2324.00	0.28

COMMERCIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Miscellaneous electric	1046.00	1.00
Fluorescent lights (U)	2125.60	0.45
Gas cooker	279.00	0.30
Liquid cooker	12.70	0.30
Solid cooker	12.70	0.30
Electric cooker	108.00	0.60
Gas H/W heater	571.00	0.80
Gas CHP H/W heater	0.00	0.65
Liquid H/W heater	1300.00	0.80
Liquid CHP H/W heater	0.00	0.65
Solid H/W heater	280.00	0.80
Solid CHP H/W heater	0.00	0.65
Electric H/W heater	254.00	1.00
Gas space heater (U)	4.86	0.80
Gas CHP space heater (U)	0.00	0.65
Liquid space heater (U)	15.39	0.80
Liquid CHP space heater (U)	0.00	0.65
Solid space heater (U)	4.05	0.80
Solid CHP space heater (U)	0.00	0.65
Electric space heater (U)	2.27	1.00
Ships and aeroplanes	2511.00	0.34
Electric trains	228.00	0.80

I&S, FEEDSTOCK USER CONVERTERS	POWER (MW)	EFFICIENCY
Gas I&S process	1211.00	0.92
Liquid I&S process	2312.00	0.64
Solid I&S process	5850.00	0.51
Electric I&S process	447.00	0.35
Gas feedstock use	3076.00	1.00
Liquid feedstock use	14871.00	1.00
Solid feedstock use	159.00	1.00

USER STORES	INPUT POWER	EFF. I/O	CAPACITY /UNIT	TOTAL CAPACITY	OUTPUT POWER	POP
DOMESTIC						
House oil tanks		1.0	11194.kWh	10075.GWh		0.9
Car petrol tanks		1.0	444.kWh	6222.GWh		14.0
Coal bunkers		1.0	17056.kWh	41786.GWh		9.5
El stor. heaters	7.5 kW	1.0	85. Wh/C		4. W/C	0.6
El car batteries	10.0 kW	.8	55. kWh	0. GWh		0.0
Solar H/W tanks			200. l		20.0 W/C	0.0
Active solar houses			40.0 m3		28.1 W/C	0.0
INDUSTRY						
Liq stores				30700. GWh		
Solid stores				15800. GWh		
COMMERCE						
Liq stores				14400. GWh		
Solid stores				168. GWh		

FOSSIL/FISSILE ELECTRICITY GENERATION

FUEL AND TYPE	OUTPUT POWER	EFFICIENCY	MERIT
Domestic CHP	0.0 MW	0.25 (E)	1
Industrial CHP	3953.5 MW	0.20 (E)	1
Commercial CHP	0.0 MW	0.20 (E)	1
Pumped store	1000.0 MW	0.85	6
Nuclear	3.0 GW	0.38- 0.30	7
Solid	40.0 GW	0.38- 0.30	8
Oil	1.0 GW	0.38- 0.30	9
Gas	1.0 GW	0.38- 0.30	10
Gas turbine	2.0 GW	0.38- 0.30	11

Peaking plant (gas turbine and pumped storage) used if d(NET LOAD)/dt > 1000.0 MW/hr

Merit order of conventional stations:
nuclear (1),coal (2),oil (3),gas (4)

1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 3 2
3 2 3 2 3 2 4 3 2 3 2 3 2 3 2 3 2 3 2 3 2 2 2 2 2 2
3 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AMBIENT ELECTRICITY GENERATION			
AMBIENT SOURCE	MAX OUTPUT	SIZE	MERIT
Aerogeneration Dispersed in UK Vcut= 3.0 ms-1 Vrat= 20.0 (ms-1) Radius=23 m.	0.00 GW	0. num	2
Wave power NW of Scotland Max. mech. (kWm-1)= 100.0 Max height(m.) 4.2	0.00 GW	0.0 km	3
Tidal power Severn estuary	0.0 + 0.0 GW	0.0+ 0.0 km2	4
Fresh hydro Dispersed in UK 10.0 TWhe/annum 24. hrs average= 1142. MWe	1165.0 MW		5

ENERGY INDUSTRY CONVERTERS	POWER (GW)	EFFICIENCY
Gas extraction	85.	0.96
Gas from coal converter	0.	0.70
Gas transmission	102.	0.97
Oil extraction	120.	0.96
Oil from coal converter	0.	0.70
Oil refinery	144.	0.94
Oil distribution	144.	0.99
Coal mines	180.	0.95
Coal distribution	216.	0.97
Nuclear reprocessor	30.	0.50
Nuclear waste disposal	0.	9.90
Electricity transmission	56.	0.92

ENERGY INDUSTRY STORES	POWER (GW)	CAPACITY
Gas stores	85.0	228.0 GWh
Oil stores	120.0	262000.0 GWh
Solid stores	180.0	260000.0 GWh
Nuclear stores	30.0	1000.0 GWh
Pumped storage	1.0	29.1 GWhm
In at power 1000.0 MW		
Out if d(LOAD)/dt > 1000.0 MW/hr		
Biomass area	0.0 km2	
Efficiency biomass to gas 0.55		
Efficiency biomass to oil 0.50		

PRIMARY RESERVES	SIZE (TWh)
Gas reserves	15332.
Oil reserves	17279.
Coal reserves	563889.
Uranium reserves	50000.

SUMMARIES FOR ONE YEAR
ENERGY IN GWh

SUMMARY OF USEFUL ENERGY DEMANDS

	Dom	Ind	Com	I&S	Feed	TOTAL
Work	0.	24518.	0.	0.	0.	24518.
Miscellane	28770.	0.	9162.	0.	0.	37932.
Transport	21750.	20358.	21996.	0.	0.	64105.
Light	684.	3383.	8005.	0.	0.	12072.
High Temp	0.	104946.	0.	86023.	0.	190969.
Cooking	3995.	0.	3612.	0.	0.	7607.
Low temp	0.	88278.	0.	0.	0.	88278.
Hot water	46536.	30701.	21065.	0.	0.	98302.
Space	141717.	29177.	65262.	0.	0.	236156.
Feedstocks	0.	0.	0.	0.	158609.	158609.
TOTAL	243453.	301361.	129103.	86023.	158609.	918548.

SUMMARY OF FUEL DELIVERIES

	Dom	Ind	Com	I&S	Feed	TOTAL
Gas	127204.	59377.	29319.	11531.	26946.	254377.
Liquid	11898.	115406.	61856.	31646.	130270.	351076.
Solid	108158.	163278.	15871.	100482.	1393.	389182.
Electricit	52512.	47344.	36328.	11188.	0.	147371.
CHP (heat)	0.	58080.	0.	0.	0.	58080.
Solar (hea	0.	0.	0.	0.	0.	0.
Transport	72501.	72708.	64695.	0.	0.	209904.
Transport	0.	0.	1997.	0.	0.	1997.
TOTAL	372274.	516193.	210066.	154846.	158609.	1411988.

SUMMARY OF ELECTRICITY PRODUCTION

	Electricity	Fuel used	Effic.	Load factor
CHP	17870.9			0.52
Aero	0.0			0.00
Wave	0.0			0.00
Tide	0.0			0.00
Hydro	9998.8			0.98
Pumped	944.0			0.11
Nuclear	26280.0	72400.3	0.36	1.00
Coal	108896.3	288068.1	0.38	0.31
Oil	791.5	2112.9	0.37	0.09
Gas	0.0	0.0	0.00	0.00
Other storage	0.0			0.00
Pumped storage	-1329.3			0.00
Tidal storage	0.0			0.00
Total demand	162357.0			0.33
TOTAL SENT OUT	164781.5			0.30

SUMMARY OF PRIMARY FUEL FLOWS	
Gas	254376.7
Oil	572290.7
Coal	680652.4
Nuclear (heat)	72400.3
Coal for gas	0.0
Coal for oil	0.0
Biomass	0.0

GROSS PRIMARY FUEL EXTRACTED	
Gas	273192.4
Oil	665404.0
Coal	763515.6
Nuclear	144982.6
TOTAL FOSS/FISS	1847094.5

4. PERFORMANCE ANALYSIS
This section of output gives some analysis of the performance of the energy system over the simulated time period.

GAS
Maximum flow rate of gas delivery was
63.70 GW
Minimum storage requirement between component 2 and 6 was 0.0 in interval 12

LIQUID
Maximum flow rate of liquid delivery was
64.87 GW
Minimum storage requirement between component 2 and 6 was 0.0 in interval 12

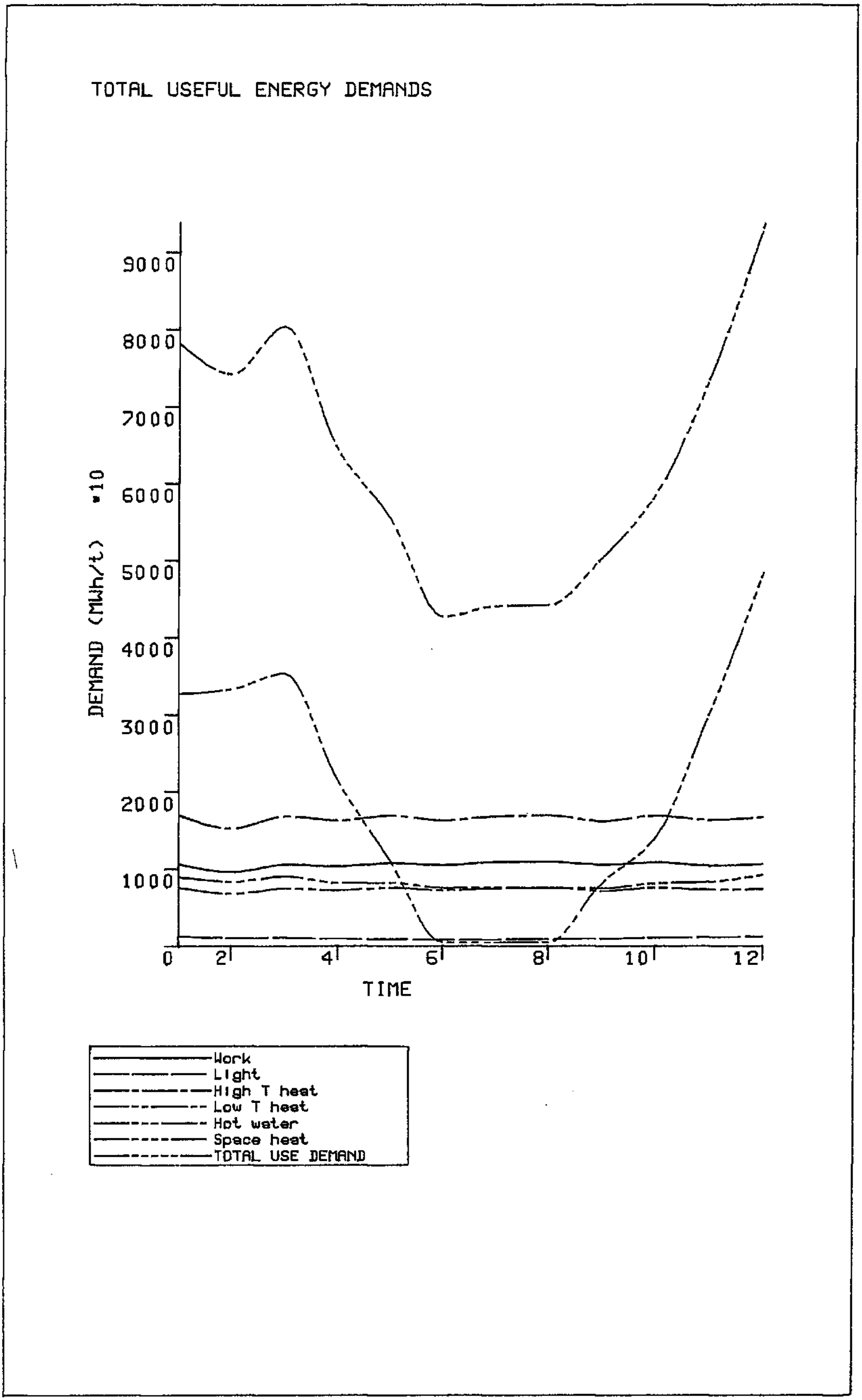
SOLID
Maximum flow rate of solid delivery was
88.98 GW
Minimum storage requirement between component 2 and 6 was 0.0 in interval 12

ELECTRICITY

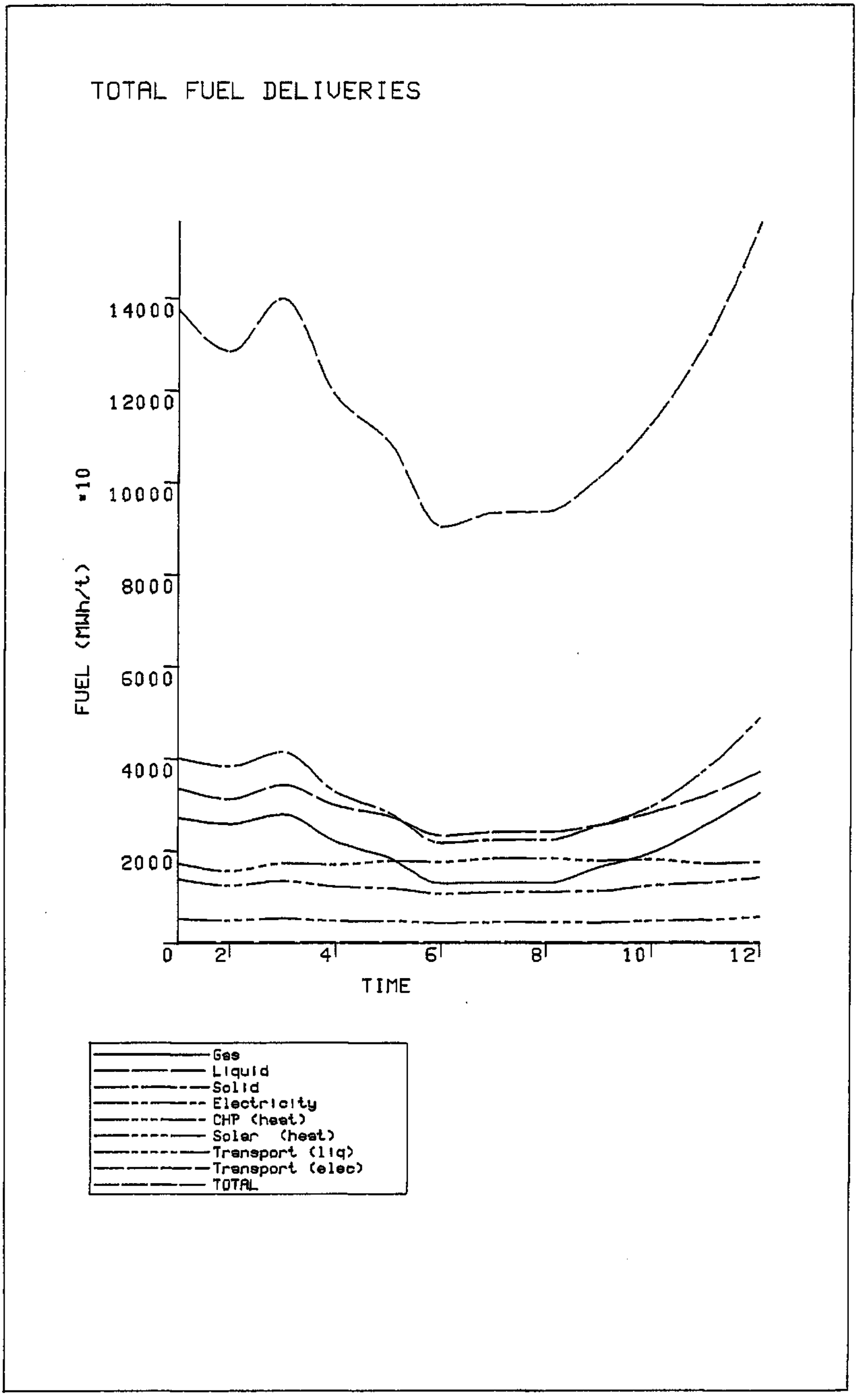
FLOW DURATION CURVES
Numbers are powers (GW)
Columns are percentage of time flow exceeded.

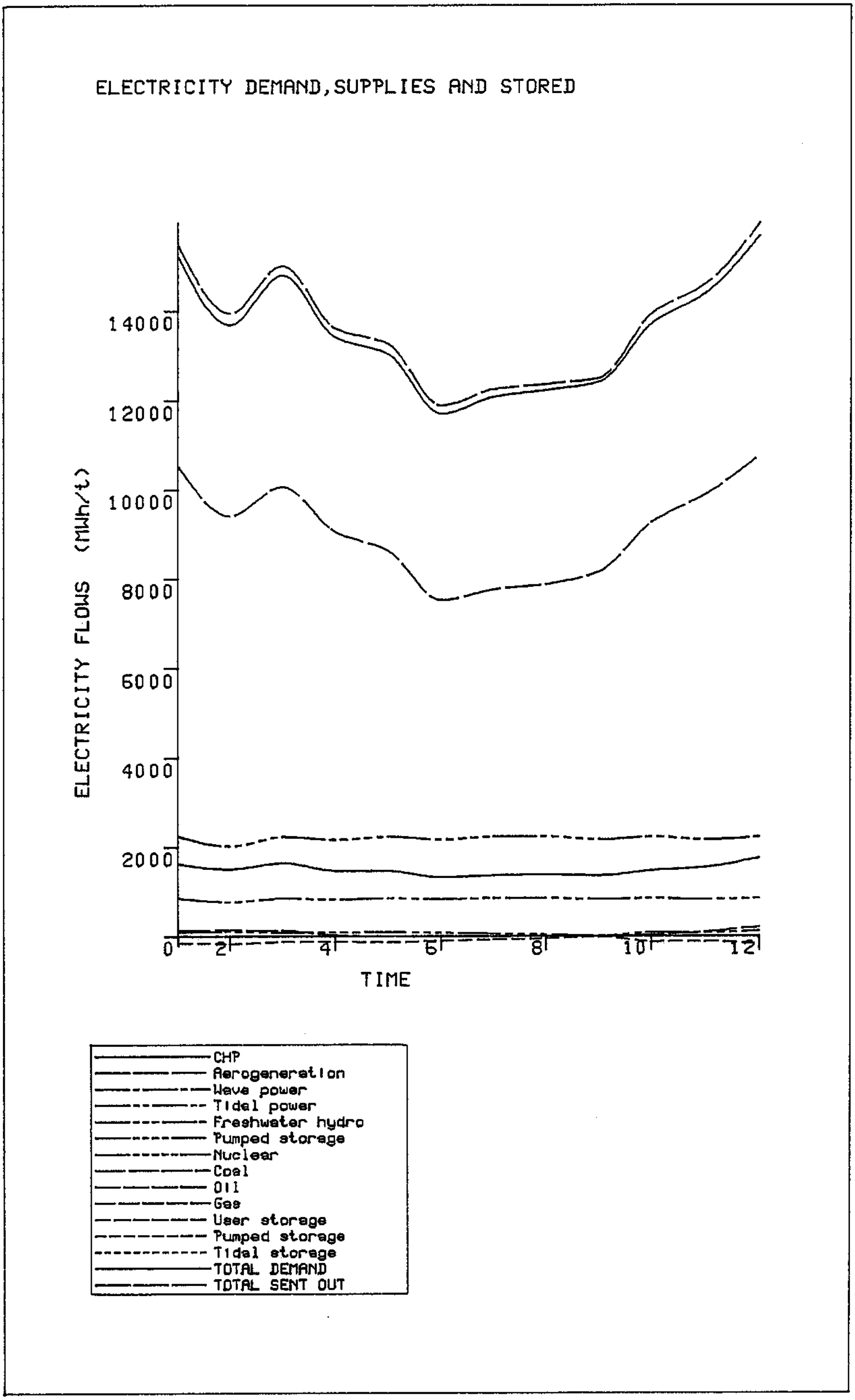
	0	10	20	30	40	50	60	70	80	90	100
CHP	3.3	2.5	2.3	2.3	2.0	2.0	1.8	1.5	1.5	1.3	1.0
Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wave	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydro	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pump	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nucl	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Coal	20.0	17.5	16.0	14.8	13.5	12.5	11.5	10.5	9.0	7.3	3.5
Oil	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Store	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pump	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dem	28.8	24.0	22.0	20.5	19.5	18.5	17.3	16.3	15.0	12.8	8.5
Sent	29.3	24.5	22.5	21.0	19.8	18.8	17.8	16.5	15.0	12.8	8.5

Maximum electrical power sent out was 29433.9 MW
in the 18 th hour of the 365 th day of the year.

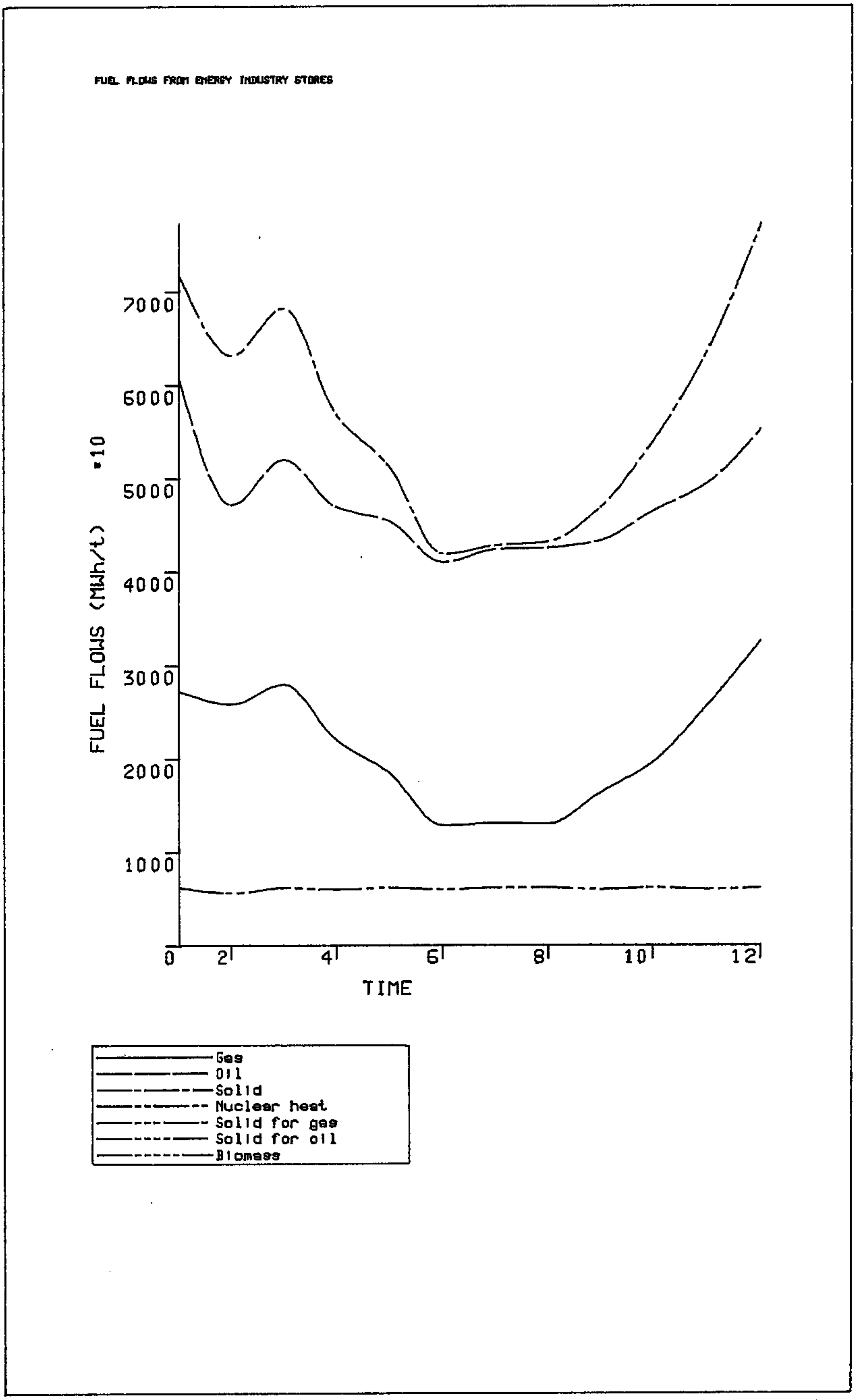


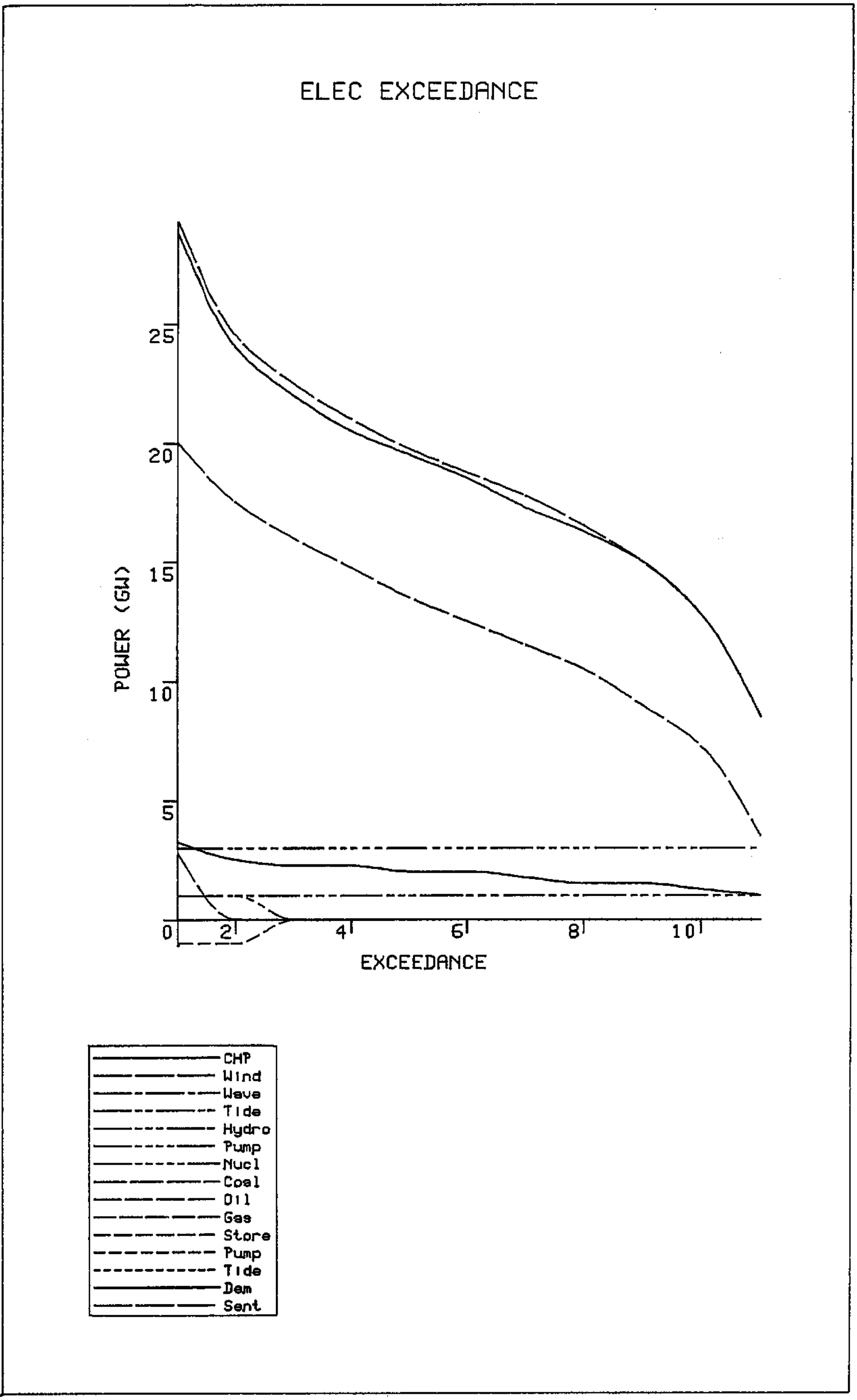
TOTAL USEFUL ENERGY DEMANDS
9000
8000
7000
6000
5000
4000
3000
2000
1000
DEMAND (MWh/t) *10
0
2
4
6
8
10
12
TIME
Work
Light
High T heat
Low T heat
Hot water
Space heat
TOTAL USE DEMAND


TOTAL FUEL DELIVERIES
14000
12000
10000
8000
6000
4000
2000
FUEL (MWh/t) *10
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL

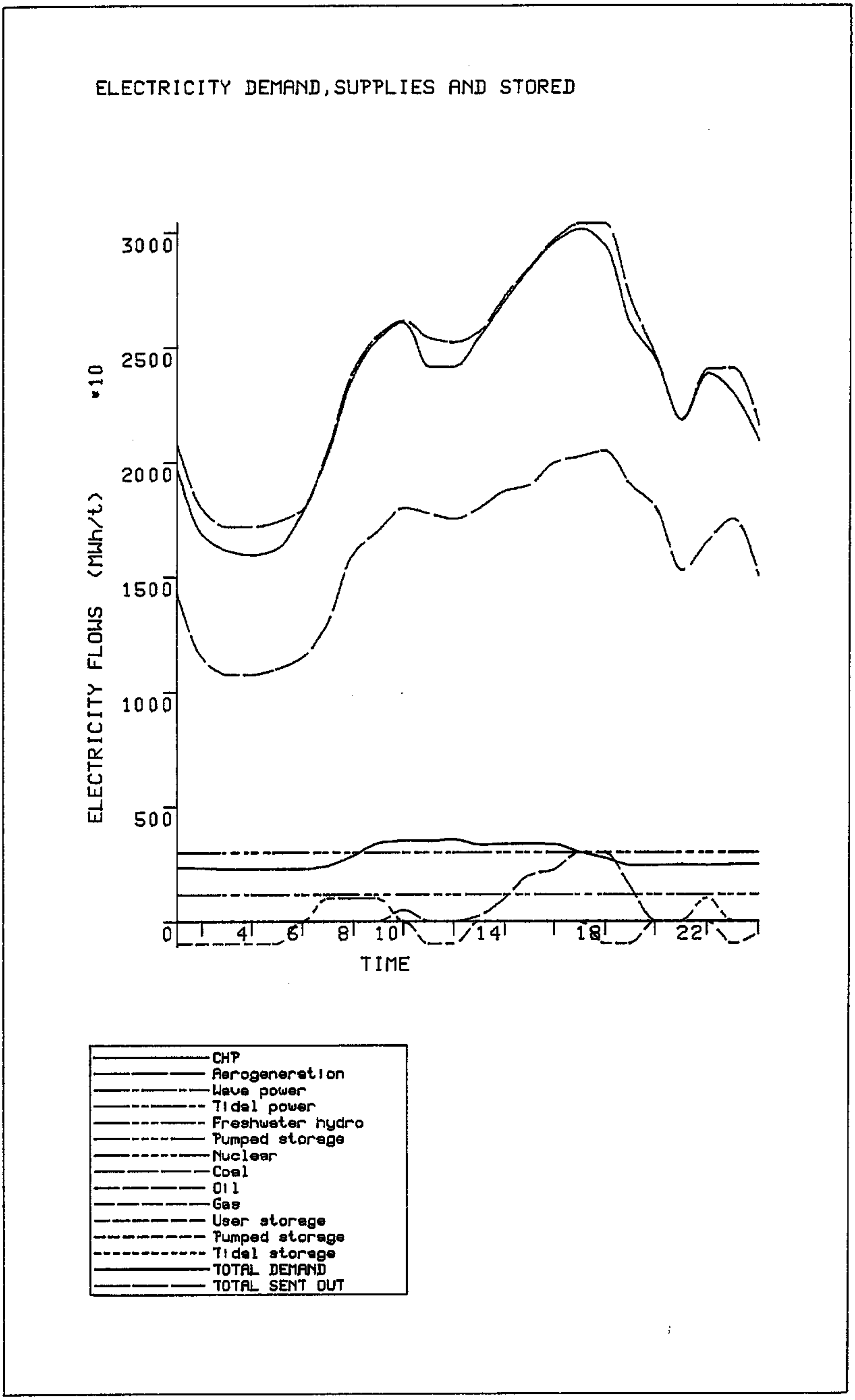


ELECTRICITY DEMAND, SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t)
14000
12000
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT

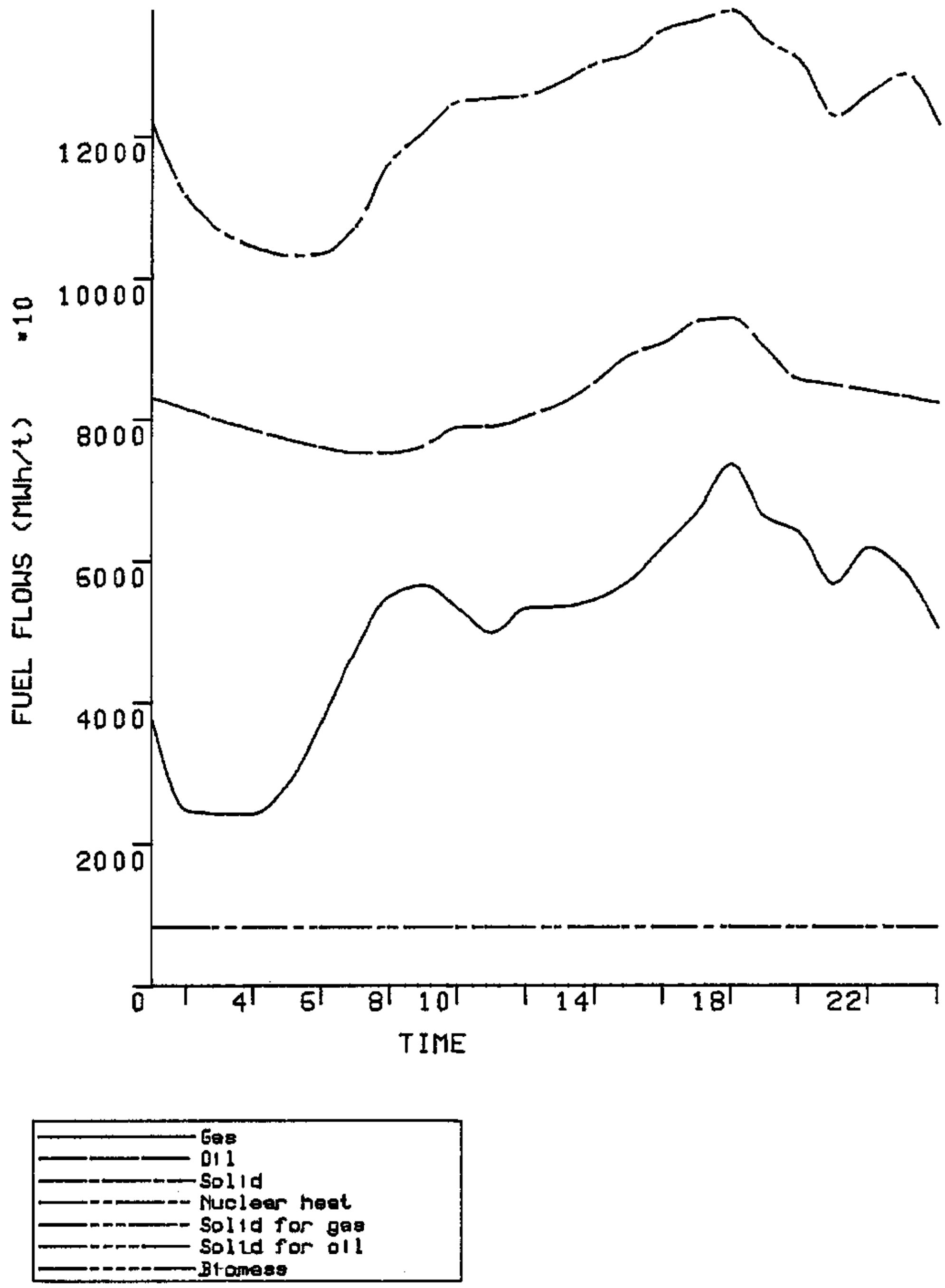

FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass


ELEC EXCEEDANCE
POWER (GW)
25
20
15
10
5
0
2
4
6
8
10
EXCEEDANCE
CHP
Wind
Wave
Tide
Hydro
Pump
Nucl
Coal
Oil
Gas
Store
Pump
Tide
Dem
Sent

The two following graphs show the flows of electricity and fossil fuels for the system with increased efficiency for a 0 degree Centigrade winter's day.


ELECTRICITY DEMAND, SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t) *10
3000
2500
2000
1500
1000
500
0
4
6
8
10
14
18
22
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT

FUEL FLOWS FROM ENERGY INDUSTRY STORES



7. REDUCTION OF UK PRIMARY ENERGY DEMAND WITH NEW CONVERTERS

7.1 Objective of system changes

7.1.1 Introduction

Fossil and fissile fuels are finite. To secure medium and long term future supplies of primary energy it is therefore necessary to extend finite resources by conservation and efficient use as a first measure. It is also necessary, ultimately, to use income energy rather than those supplies derived from finite, natural energy stores. To do this new energy conversion and storage devices are required.

The uncertainties and the costs and lead times of many new conversion technologies makes them the least reliable and proven component of a future energy system. This is especially so for the larger technologies proposed for the energy supply industries. It is because of these uncertainties that new technologies are considered after improvements in conservation and efficiency.

In addition to the new technologies assumed, the system described below assumes that many of the reductions in energy flow due to conservation (behavioural and technical) and increased efficiency take place. This is because the author considers it unlikely that these new technologies will be implemented to any large extent before the simpler, cheaper conservation methods.

7.2 Objective

The objective is to reduce the primary fossil/fissile energy consumption by increasing efficiency and utilising income energy with new converters.

The general methods are:

(i) the increased implementation of CHP

(ii) the introduction of electric cars

(iii) the use of ambient energy sources (atmospheric heat, solar, wind, wave, tidal, hydro)

7.3 Technical details of new system

The sections below give brief technical details of the hypothesised system. As for all the previous systems, the starting point is the 1976 system. However, this system incorporates several kinds of change; demands and efficiencies are changed as well new technologies being introduced.

The demands for this system are estimated by taking 1976 demands and then reducing them according to the combined effects of behavioural and technical conservation. In general it is assumed that the savings due to behaviour and technical conservation are multiplicative, not additive. For example; if 10 % savings were made with each measure separately, then the overall saving would be 19 %, not 20 %.

[overall savings = $100\ (1 - (1-10/100)^2)$ %]

The assumptions conerning the introduction of new technologies are solely due to the author.

7.4 Domestic sector

7.4.1 Miscellaneous electric appliances

Combined savings reduce this demand by 55 %, from 4800 MW to 2160 MW.

7.4.2 Fridges and freezers

Total savings of 65 % change the demand from 897 MW to 314 MW.

7.4.3 Light

Demand reduced by 7 %; from 10 W to 9.3 W per house.

7.4.4 Cooking

Demand reduced by 5 %; from 23.5 W to 22.3 W per house.

7.4.5 Hot water

It is assumed that the demand temperature is reduced from 55 C to 52 C and the demand volume from 127 l. to 108 l. per day per house.

7.4.6 Space heating

Same as for technical conservation.

7.4.7 Cars

As for the behavioural case, switching to from cars and better use reduce demand from 178.3 W to 99.8 W. It is assumed that technical conservation further reduces this demand by 15 % (?) to 84.8 W.

Heat pumps, solar collections systems and electric cars are introduced to the domestic sector as follows.

Hot water

1 mill. gas individual -> 1 mill. gas heat pump
3 mill. coal -> 3 mill. CHP

3.5 mill. electric -> 1mill. electric heat pump
-> 2 mill. individual solar
-> 0.5 mill. solar space & water

Space heaters

1 mill. gas ->1 mill. gas heat pumps
0.5 mill. gas -> 0.5 mill. solar space & water
2 mill. gas -> 2 mill. passive solar

2.5 mill. oil	-> 2.5 mill. CHP
0.5 mill. coal	-> 0.5 mill. CHP
1 mill. elec. off peak	-> 1 mill. electric heat pumps
0.5 mill. elec. on peak	-> 0.5 mill. electric heat pumps

Electric cars

It is assumed that 3 million petrol cars are substituted by electric vehicles.

7.5 Industrial sector

7.5.1 Motive power

15 % savings reduce demand from 2811 MW to 2403 MW.

7.5.2 Light

19 % savings reduce demand from 70 W to 56 W per person.

7.5.3 Process and hot water

Combined savings of 19 % cause the following changes to demand :

HT process	120209 -> 9743 MW
LT process	10122 -> 8199 MW
Hot water	3488 -> 2825 MW

It is assumed that 70 %, 20 %, 5 % and 5 % of half of these demands are met by coal, gas, oil and electricity respectively. It is assumed that the other half of these demands are met by CHP. The CHP component is split into 70 % coal, 20 % gas and 10 % oil.

7.5.4 Space

Same assumptions as for technical conservation.

Space heating is accomplished by the same mix of fuels and CHP as process and water heating.

7.5.5 Transport

Behavioural change causes this demand to become 2437 MW. Technical conservation reduces this demand of 2437 MW by 15 % to 2071 MW.

7.6 Commercial sector

7.6.1 Miscellaneous electric

Combined measures reduce demand by 37 %; from 1046 MW to 659 MW.

7.6.2 Light

Savings of 23 % reduce light demand from 80 W to 61 W per person.

7.6.3 Cooking

Savings of 19 % reduce demand from 412 MW to 334 MW.

7.6.4 Hot water

19 % savings reduce demand from 2405 MW to 1948 MW.

7.6.5 Space

Same assumptions as under technical conservation.

Reallocation of heaters for commercial hot water and space heating is assumed to be as follows. It is assumed that 70 %, 20 %, 5 % and 5 % of half of these demands are met by coal, gas, oil and electricity respectively. It is assumed that the other half of these demands are met by CHP. The CHP component is split into 70 % coal, 20 % gas and 10 % oil.

7.6.6 Transport

Transport demand for ships and planes is assumed to decrease from 2511 MW to 2448 MW because of behavioural change.

Electric train demand changes from 303 MW to 273 MW through technology switch and behavioural change, and then to 137 MW because of the 50 % savings assumed possible by technical conservation.

7.7 Iron and steel

A combined 20 % saving reduces demand from 9820 MW to 7856 MW. No new technologies are introduced in this sector.

7.8 Energy industries

Several new technologies are assumed to be implemented in this sector.

7.8.1 Gas

It is assumed that 10 GW of coal to gas conversion plant are installed, the power is the output power.

7.8.2 Oil

It is assumed that 10 GW of coal to oil conversion plant are installed.

7.8.3 Biomass

It is assumed that 1000 km.^{2} (or the equivalent in waste) of biomass area is implemented.

7.8.4 Electricity generation

Apart from CHP, which is detailed in the demand sectors, several other new technologies are assumed.

Wind

2000 aerogenerators are installed, with a maximum electrical output of 1.3 GW.

Wave

15 km. of wave machines with a maximum electrical output of 0.9 GW are installed.

Tide

A Severn estuary scheme with the following characteristics is assumed. The high and low reservoirs are of areas 400 $km.^2$ and 200 $km.^2$ respectively. The electrical power of the pumps/turbines is 4.5 GW for the sea to high reservoir sets and 2.5 GW for the low reservoir to sea sets.

DYPHEMO OUTPUT

This output is from a D ynamic PH ysical E nergy M odel
There are four main sections of output:

1. LAYOUT OF ENERGY SYSTEM COMPONENTS
2. DESCRIPTION OF ENERGY SYSTEM
3. SIMULATED PERFORMANCE OF ENERGY SYSTEM
4. ANALYSIS OF SYSTEM PERFORMANCE

1. LAYOUT OF ENERGY SYSTEM

The diagram below shows the basic arrangement of the components of the UK physical energy system and the flows of energy between them. The lists of types of each component are not exhaustive for converters and stores.
The components are numbered 1 to 7.

```
 __________    ____________      _____________     ____________
|1.DEMANDS|   |2.USER      |    |7.INCOME     |   |6.NATURAL   |
|         |   |CONVERTERS  |    |  SOURCES    |   |  STORES    |
|Work     |<--|Boiler      |<---| Solar,wind  |   | Coal,oil   |
|Transport|   |Motor       |    | wave,tidal  |   | gas,       |
|Light    |   |Collector   |    | hydro       |   | uranium    |
|Heat>120 |   |____________|    |_____________|   |____________|
|Cooking  |      /!\    /\            |              /
|Heat<120 |       |       \           |             /
|Hot water|       |        \          |            /
|Space    |       |         \         |           /
|_________|      \|/         \       \|/         /
                  !           \_______!______\/_
 ____________                 ______________      ____________
|3.USER      |               |4.ENERGY IN   |    |5.ENERGY IN |
|  STORES    |               | CONVERTERS   |    |  STORES    |
|Bunker,tank |               | Power stat   |<-->|Bunker,tank |
|H/W tank    |               | Refinery     |    |Pumped      |
|El. storage |               | Gasifier     |    |            |
|____________|               |______________|    |____________|
```

2. UK ENERGY SYSTEM DESCRIPTION

Reduced demand and nw technolgies.

SYSTEM DESCRIPTION

Technical data are given; these specify the components:

DEMAND
USER CONVERTERS
USER STORES
CONVENTIONAL ELECTRICICITY GENERATION
AMBIENT ELECTRICITY GENERATION
ENERGY INDUSTRY CONVERTERS
INDUSTRY STORES
PRIMARY RESERVES

These data with climatic data determine the simulated energy flows with time.

USEFUL ENERGY DEMAND DATA

TEMPORAL USE PATTERNS

The numbers below refer to the hourly use levels for the various sectors. The first two rows of numbers for each pattern refer to the weekday pattern; the second two the weekend pattern.

Proportion houses with active occupants

0.4	0.1	0.1	0.1	0.2	0.4	0.5	0.6	0.5	0.4	0.4	0.5
0.4	0.4	0.5	0.6	0.7	0.9	0.8	0.8	0.7	0.8	0.7	0.5
0.3	0.1	0.0	0.0	0.0	0.0	0.3	0.5	0.6	0.7	0.7	0.6
0.6	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.7	0.6	0.3

Average = 0.50

Domestic cooking: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.7	0.9	1.2	1.0	0.8	1.7
2.2	1.7	1.2	1.8	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3
0.1	0.1	0.1	0.1	0.1	0.4	0.6	0.7	1.2	1.0	0.8	1.7
2.2	1.7	1.1	1.5	2.4	2.3	2.1	1.1	0.5	0.7	0.5	0.3

Average = 1.00

Domestic hot water: proportion of average demand

0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.7	1.6	1.4	0.8	2.0	1.6	1.2
0.1	0.1	0.1	0.1	0.2	0.4	0.6	0.8	1.5	1.1	0.9	0.8
1.4	1.4	1.3	1.2	1.8	1.8	1.6	1.4	0.8	2.0	1.6	1.2

Average = 1.00

Domestic transport: % daily traffic

0.9	0.3	0.1	0.1	0.2	0.3	1.0	4.5	6.8	4.8	5.0	5.2
5.5	5.2	5.7	5.8	7.3	8.2	7.3	6.4	4.7	3.7	3.1	2.1
2.3	1.0	0.6	0.3	0.3	0.4	0.9	2.2	3.0	4.1	6.3	7.5
8.0	7.1	9.1	9.4	9.0	8.3	7.7	7.8	6.6	5.1	4.3	3.6

Average = 4.18

Industrial general: proportion of average demand

0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1.4	1.4	1.4	1.5
1.3	1.4	1.4	1.3	1.2	1.1	0.9	0.9	0.9	0.9	0.9	0.9
0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.9	1.0	1.0	1.0
0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6

Average = 1.00

Industrial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

Commercial general: proportion of average demand

0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	1.2	1.6	1.7	1.7
1.7	1.7	1.7	1.7	1.6	1.3	1.1	1.0	0.9	0.9	0.9	0.9
0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.8	1.1	1.1	1.2
1.1	1.1	1.2	1.2	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.6

Average = 1.00

Commercial transport: proportion of average demand

1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Average = 1.00

CHARACTERISTICS OF DEMANDS

DOMESTIC

Number of occupied houses	=	19.52 mill
Miscellaneous electricity:		
Miscellaneous appliances	=	2160.0 MW
Fridges and freezers	=	314.0 MW
Light:		
Useful light per house	=	9.3 W
Cooking:		
Average useful demand per house	=	22.3 W
Hot water:		
Monthly mains temperatures (C)		
7.0 6.0 7.0 9.0 10.0 11.0 13.0 15.0 13.0 11.0 10.0 9.0		
Demand temperature (C)	=	52.0 C
Hourly demand volume	=	4.5 l.
Space heating:		
House internal temperature	=	16.0 C
House fabric loss	=	163.0 W/C
House ventilation loss	=	50.0 W/C
Incidental fudge factor	=	0.9
Transport:		
Number of cars	=	14.0 mill
Average useful power per car	=	84.8 W

INDUSTRIAL

Number of industrial people	=	10.6 million
Kinetic:		
Average useful demand	=	2389.0 MW
Light:		
Useful light per person	=	56.0 W
Process heat > 120 C:		
Average useful demand	=	9744.0 MW
Process heat < 120 C:		
Average useful demand	=	8210.0 MW
Hot water:		
Average useful demand	=	2828.0 MW
Space heating:		
Internal temperature	=	16.5 C
Fabric loss per person	=	46.0 W/C
Ventilation loss per person	=	38.0 W/C
Incidental fudge factor	=	0.4
Transport:		
Average diesel motor demand	=	2071.0 MW

```
COMMERCIAL
Number of commercial people  =          26.6 million
Miscellaneous electricity:
     Average useful demand   =         659.0  MW
Light:
     Useful light per person =          61.0  W
Cooking:
     Average useful demand   =         371.0 MW
Hot water:
     Average useful demand   =        1949.0  MW
Space heating:
     Internal temperature        =          16.0  C
     Fabric loss per person      =          10.0  W/C
     Ventilation loss per person =          39.0 W/C
     Incidental fudge factor     =           0.6
Transport:
     Average plane and ship demand =        2448.0  MW
     Average electric train demand =         137.0  MW
IRON AND STEEL
All energy:
     Total average demand =       8345.0  MW
FEEDSTOCKS
     Total average demand =      18106.0  MW
```

USER CONVERTERS

User converters are arranged in the sequences:

SECTOR	OUTPUT	INPUT
Domestic	Mis. Electric	Gas
Industrial	Mechanical	Liquid
Commercial	Light	Solid
Iron & Steel	Process > 120	Electricity
Feedstocks	Cooking	Solar
	Process <120	
	Hot water	
	Space	
	Transport	

A value of 9.9 means the efficiency is variable

DOMESTIC USER CONVERTERS (E) means double entry	POPULATION (millions)	EFFICIENCY
Fridges and freezers (U)	19.52	1.00
Electric appliances (U)	19.52	1.00
Incandescent lights	19.52	0.30
Gas cooker	10.70	0.24
Electric cooker	8.80	0.43
Gas individual H/W heater	3.11	0.80
Gas C/H H/W heater (E)	3.80	0.80
Gas heat pump H/W heater (E)	1.00	9.90
Oil C/H H/W heater (E)	0.20	0.80
Solid C/H H/W heater (E)	2.20	0.80
Solid CHP H/W heater (E)	3.00	0.67
Electric H/W heater	2.70	0.95
Electric heat pump H/W heater (E)	1.00	9.90
Solar individual H/W heater	2.00	9.90
Solar space & H/W heater (E)	0.50	9.90
Gas individual space heater	0.64	0.80
Gas C/H space heater	4.16	0.85
Gas heat pump space heater	1.00	9.90
Oil C/H space heater	1.45	0.85
Solid individual space heater	1.45	0.80
Solid C/H space heater	2.72	0.80
Solid CHP space heater	3.00	0.67
Electric on peak space heater	0.10	1.00
Electric off peak space heater	1.00	9.90
Electric heat pump space heater	1.50	9.90
Solar space & H/W heater	0.50	9.90
Solar passive house	2.00	9.90
Liquid fuelled car	11.00	0.30
Electric car	3.00	0.80

MISCELLANEOUS DATA ON DOMESTIC CONVERTERS		
Solar water heater:		
Area of collector	=	5.0 m2
Volume of tank	=	200.0 l.
Loss coeff. of tank	=	2.5 W/C
Active solar house:		
Area of collector	=	20.0 m2
Volume of tank	=	3.0 m3
Insulation on tank	=	10.0 cm.
Specific loss of tank	=	5.0 W/C
Passive solar house:		
Area of south glazing	=	20.0 m2
Transmittance of glazing	=	0.7
Specific loss (day)	=	150.0 W/C
Specific loss (night)	=	125.0 W/C
Ventilation loss	=	50.0 W/C

INDUSTRIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Oil fuelled motor	447.00	0.28
Electric fuelled motor	1942.00	0.65
Fluorescent lights (U)	591.36	0.45
Gas heater > 120 C	974.00	0.80
Gas CHP heater > 120 C	974.00	0.65
Liquid heater > 120 C	244.00	0.80
Liquid CHP heater > 120 C	488.00	0.65
Solid heater > 120 C	3410.00	0.80
Solid CHP heater > 120 C	3410.00	0.65
Electric heater > 120 C	244.00	1.00
Gas heater < 120 C	820.00	0.80
Gas CHP heater < 120 C	820.00	0.65
Liquid heater < 120 C	205.00	0.80
Liquid CHP heater < 120 C	420.00	0.65
Solid heater < 120 C	2870.00	0.80
Solid CHP heater < 120 C	2870.00	0.65
Electric heater < 120 C	205.00	1.00
Gas H/W heater	283.00	0.80
Gas CHP H/W heater	283.00	0.65
Liquid H/W heater	71.00	0.80
Liquid CHP H/W heater	142.00	0.65
Solid H/W heater	989.00	0.80
Solid CHP H/W heater	989.00	0.65
Electric H/W heater	71.00	1.00
Gas space heater (U)	1.10	0.80
Gas CHP space heater (U)	1.10	0.65
Liquid space heater (U)	0.43	0.80
Liquid CHP space heater (U)	0.43	0.65
Solid space heater (U)	3.70	0.80
Solid CHP space heater (U)	3.70	0.65
Electric space heater (U)	0.10	1.00
Diesel transport motors	2071.00	0.28

COMMERCIAL USER CONVERTERS	POWER (MW)	EFFICIENCY
Miscellaneous electric	659.00	1.00
Fluorescent lights (U)	1622.60	0.45
Gas cooker	251.00	0.30
Liquid cooker	11.40	0.30
Solid cooker	11.40	0.30
Electric cooker	97.20	0.60
Gas H/W heater	195.00	0.80
Gas CHP H/W heater	195.00	0.65
Liquid H/W heater	49.00	0.80
Liquid CHP H/W heater	97.00	0.65
Solid H/W heater	682.00	0.80
Solid CHP H/W heater	682.00	0.65
Electric H/W heater	49.00	1.00
Gas space heater (U)	2.70	0.80
Gas CHP space heater (U)	2.70	0.65
Liquid space heater (U)	1.00	0.80
Liquid CHP space heater (U)	1.30	0.65
Solid space heater (U)	9.30	0.80
Solid CHP space heater (U)	9.30	0.65
Electric space heater (U)	0.30	1.00
Ships and aeroplanes	2448.00	0.34
Electric trains	137.00	0.80

I&S, FEEDSTOCK USER CONVERTERS	POWER (MW)	EFFICIENCY
Gas I&S process	1029.00	0.92
Liquid I&S process	1965.00	0.64
Solid I&S process	4972.00	0.51
Electric I&S process	379.00	0.35
Gas feedstock use	3076.00	1.00
Liquid feedstock use	14871.00	1.00
Solid feedstock use	159.00	1.00

USER STORES	INPUT POWER	EFF. I/O	CAPACITY /UNIT	TOTAL CAPACITY	OUTPUT POWER	POP
DOMESTIC						
House oil tanks		1.0	11194.kWh	16232.GWh		1.5
Car petrol tanks		1.0	444.kWh	4888.GWh		11.0
Coal bunkers		1.0	17056.kWh	24731.GWh		4.2
El stor. heaters	7.5 kW	1.0	85. Wh/C		4. W/C	1.0
El car batteries	10.0 kW	.8	55. kWh	165. GWh		3.0
Solar H/W tanks			200. l		2.5 W/C	2.0
Active solar houses			3.0 m3		10.0 W/C	0.5
INDUSTRY						
Liq stores				30700. GWh		
Solid stores				15800. GWh		
COMMERCE						
Liq stores				3000. GWh		
Solid stores				168. GWh		

FOSSIL/FISSILE ELECTRICITY GENERATION FUEL AND TYPE	OUTPUT POWER	EFFICIENCY	MERIT
Domestic CHP	4733.3 MW	0.25 (E)	1
Industrial CHP	6760.2 MW	0.20 (E)	1
Commercial CHP	3412.6 MW	0.20 (E)	1
Pumped store	3000.0 MW	0.85	6
Nuclear	1.0 GW	0.38- 0.30	7
Solid	15.0 GW	0.38- 0.30	8
Oil	1.0 GW	0.38- 0.30	9
Gas	1.0 GW	0.38- 0.30	10
Gas turbine	3.0 GW	0.38- 0.30	11

Peaking plant (gas turbine and pumped storage) used if d(NET LOAD)/dt > 1000.0 MW/hr

Merit order of conventional stations:
nuclear (1),coal (2),oil (3),gas (4)

1 2 2 2 2 2 2 2 4 2 3 2 2 2 2 2 2 2 3 3 3 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

AMBIENT ELECTRICITY GENERATION			
AMBIENT SOURCE	MAX OUTPUT	SIZE	MERIT
Aerogeneration Dispersed in UK Vcut= 3.0 ms-1 Vrat= 12.0 (ms-1) Radius=23 m.	1.32 GW	2000. num	2
Wave power NW of Scotland Max. mech. (kWm-1)= 100.0 Max height(m.) 4.2	0.90 GW	15.0 km	3
Tidal power Severn estuary	2.5 + 4.5 GW	200.0+400.0 km2	4
Fresh hydro Dispersed in UK 10.0 TWhe/annum 24. hrs average= 1142. MWe	1500.0 MW		5

ENERGY INDUSTRY CONVERTERS	POWER (GW)	EFFICIENCY
Gas extraction	45.	0.96
Gas from coal converter	10.	0.70
Gas transmission	54.	0.97
Oil extraction	40.	0.96
Oil from coal converter	10.	0.70
Oil refinery	48.	0.94
Oil distribution	48.	0.99
Coal mines	60.	0.95
Coal distribution	72.	0.97
Nuclear reprocessor	30.	0.50
Nuclear waste disposal	0.	9.90
Electricity transmission	25.	0.92

ENERGY INDUSTRY STORES	POWER (GW)	CAPACITY
Gas stores	45.0	228.0 GWh
Oil stores	40.0	150000.0 GWh
Solid stores	60.0	200000.0 GWh
Nuclear stores	30.0	1000.0 GWh
Pumped storage	3.0	60.0 GWhm
In at power 1500.0 MW		
Out if d(LOAD)/dt > 1000.0 MW/hr		
Biomass area	1000.0 km2	
Efficiency biomass to gas 0.55		
Efficiency biomass to oil 0.50		

PRIMARY RESERVES	SIZE (TWh)
Gas reserves	15332.
Oil reserves	17279.
Coal reserves	563889.
Uranium reserves	50000.

SUMMARIES FOR ONE YEAR
ENERGY IN GWh

SUMMARY OF USEFUL ENERGY DEMANDS

	Dom	Ind	Com	I&S	Feed	TOTAL
Work	0.	20837.	0.	0.	0.	20837.
Miscellane	12161.	0.	5772.	0.	0.	17933.
Transport	10345.	18142.	21444.	0.	0.	49931.
Light	642.	2748.	6111.	0.	0.	9501.
High Temp	0.	84989.	0.	73102.	0.	158092.
Cooking	3791.	0.	3249.	0.	0.	7040.
Low temp	0.	71610.	0.	0.	0.	71610.
Hot water	37549.	18156.	17071.	0.	0.	72776.
Space	80009.	18267.	33911.	0.	0.	132187.
Feedstocks	0.	0.	0.	0.	158609.	158609.
TOTAL	144497.	234750.	87558.	73102.	158609.	698516.

SUMMARY OF FUEL DELIVERIES

	Dom	Ind	Com	I&S	Feed	TOTAL
Gas	82735.	53931.	21689.	9798.	26946.	195098.
Liquid	13610.	35019.	6320.	26896.	130270.	212114.
Solid	27075.	188281.	43487.	85401.	1393.	345637.
Electricit	35486.	36813.	21582.	9486.	0.	103367.
CHP (heat)	18309.	96499.	21221.	0.	0.	136029.
Solar (hea	11446.	0.	0.	0.	0.	11446.
Transport	27093.	64793.	63072.	0.	0.	154958.
Transport	3472.	0.	1200.	0.	0.	4672.
TOTAL	219224.	475335.	178570.	131581.	158609.	1163320.

SUMMARY OF ELECTRICITY PRODUCTION

	Electricity	Fuel used	Effic.	Load factor
CHP	43002.6			0.33
Aero	3685.2			0.32
Wave	2140.7			0.27
Tide	13917.8			0.23
Hydro	9898.3			0.75
Pumped	3621.8			0.14
Nuclear	8498.0	23483.0	0.36	0.97
Coal	37631.3	126744.8	0.30	0.29
Oil	338.0	897.2	0.38	0.04
Gas	835.0	2288.7	0.36	0.10
Other storage	-3471.7			0.00
Pumped storage	-5046.5			0.00
Tidal storage	0.0			0.00
Total demand	117433.2			0.53
TOTAL SENT OUT	123568.6			0.51

SUMMARY OF PRIMARY FUEL FLOWS	
Gas	197386.8
Oil	375961.0
Coal	474912.7
Nuclear (heat)	23483.0
Coal for gas	125142.9
Coal for oil	125142.9
Biomass	9596.3

GROSS PRIMARY FUEL EXTRACTED	
Gas	120742.0
Oil	338788.5
Coal	524642.3
Nuclear	47147.8
TOTAL FOSS/FISS	1031320.6

```
4. PERFORMANCE ANALYSIS
This section of output gives some analysis
of the performance of the energy system  over
the simulated time period.
```

```
     GAS
Maximum flow rate of gas delivery was
       40.58 GW
Minimum storage requirement between component 2 and 6
was            0.0 in interval  12
```

```
     LIQUID
Maximum flow rate of liquid delivery was
       29.51 GW
Minimum storage requirement between component 2 and 6
was            0.0 in interval  12
```

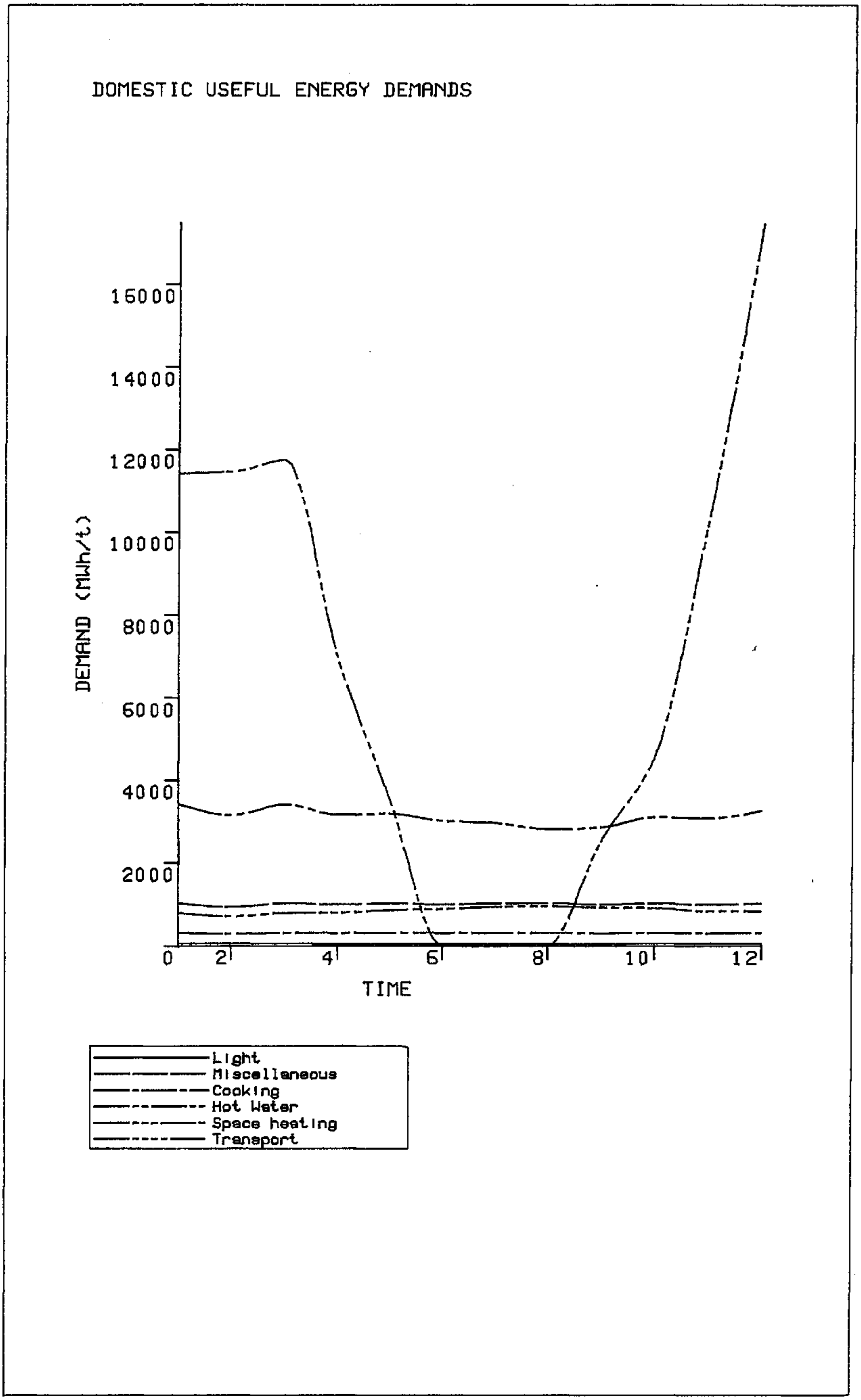
```
     SOLID
Maximum flow rate of solid delivery was
       65.29 GW
Minimum storage requirement between component 2 and 6
was            0.0 in interval  12
```

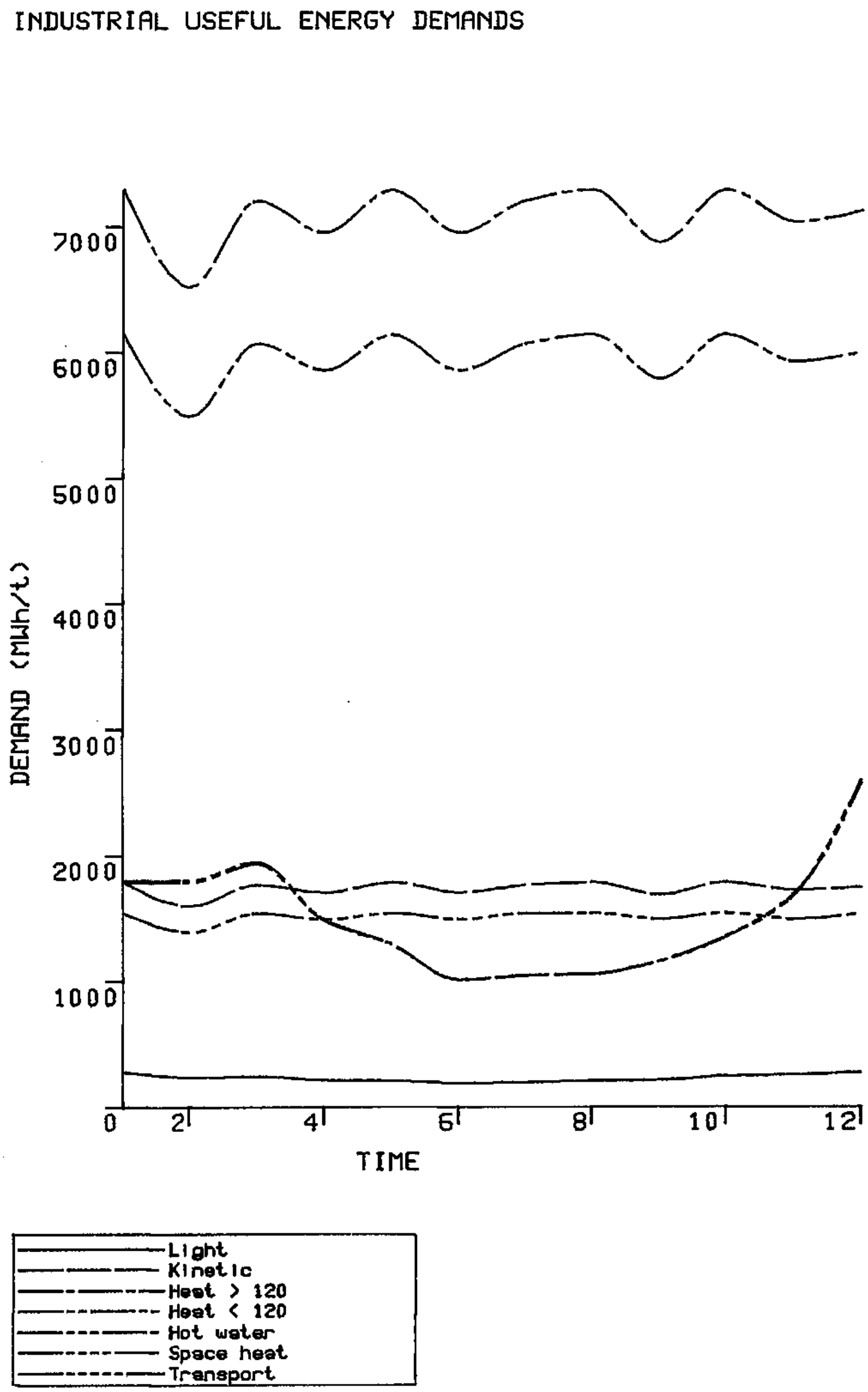
ELECTRICITY

FLOW DURATION CURVES
Numbers are powers (GW)
Columns are percentage of time flow exceeded.

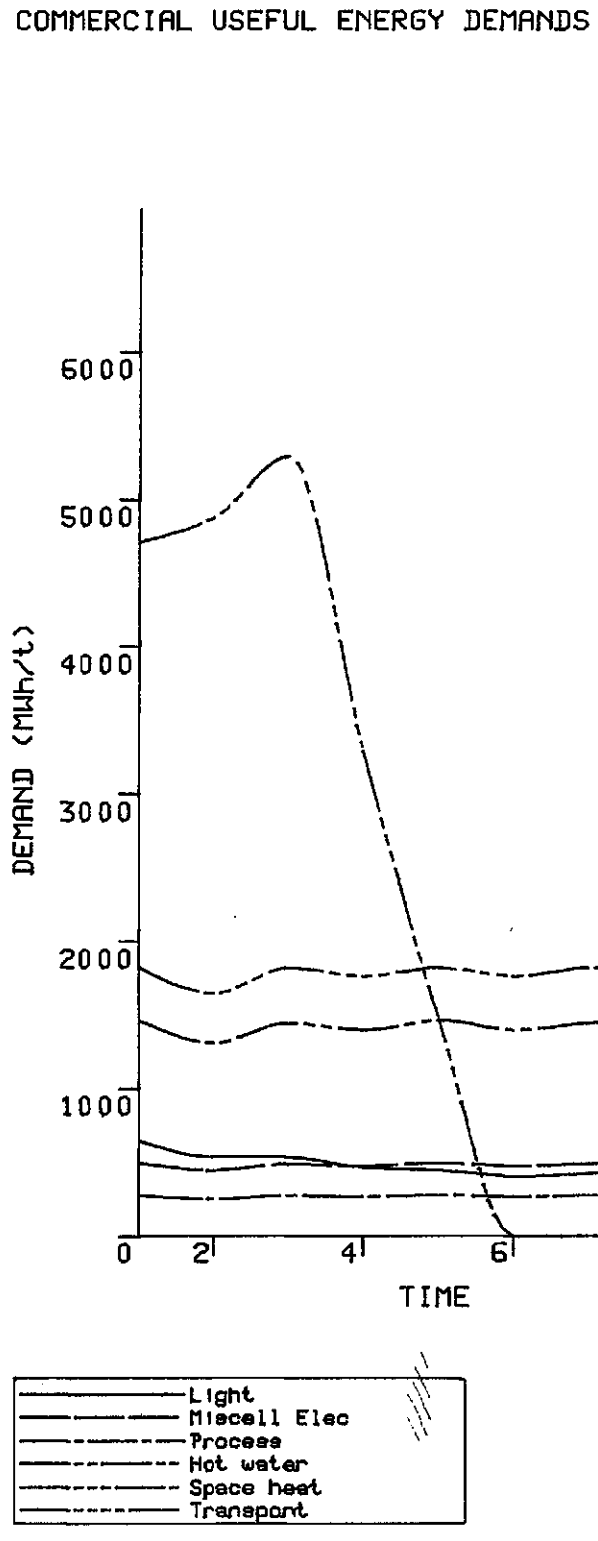
	0	10	20	30	40	50	60	70	80	90	100
CHP	9.3	6.8	6.3	5.5	5.0	4.8	4.3	3.8	3.3	2.8	1.8
Wind	1.0	1.0	0.8	0.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Wave	0.3	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Tide	7.0	5.3	3.8	2.0	1.3	0.5	0.3	0.0	0.0	0.0	0.0
Hydro	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Pump	3.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nucl	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Coal	8.8	7.0	6.5	5.8	5.0	4.5	4.0	3.3	2.3	1.0	0.0
Oil	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Store	-2.5	-1.3	-0.8	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pump	-3.0	-3.0	-1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tide	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dem	19.5	16.5	15.5	14.8	14.0	13.3	12.5	12.0	11.3	10.0	7.3
Sent	22.8	17.5	16.3	15.5	14.8	14.0	13.3	12.5	11.5	10.5	7.5

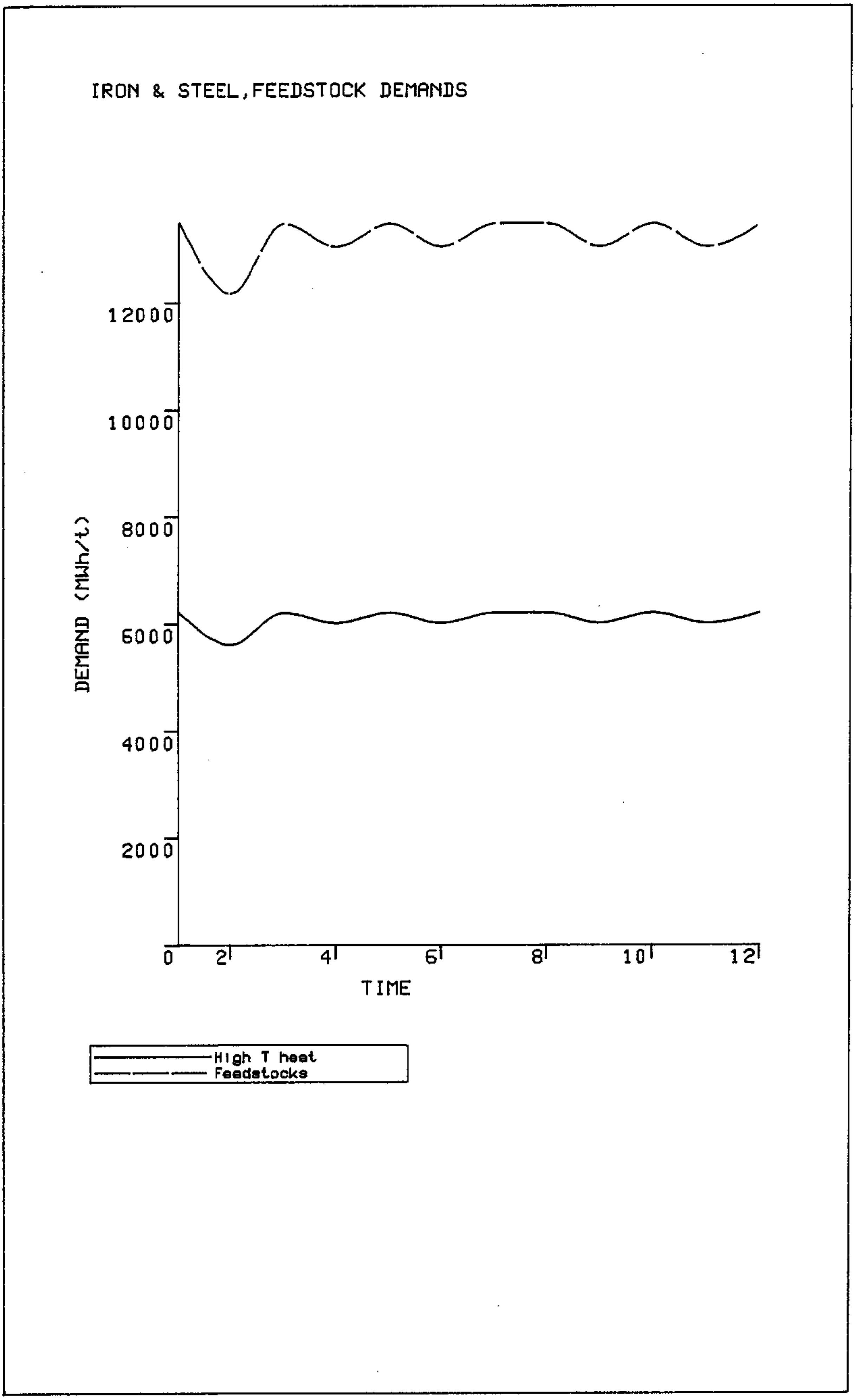
Maximum electrical power sent out was 22947.2 MW
in the 1 th hour of the 1 th day of the year.

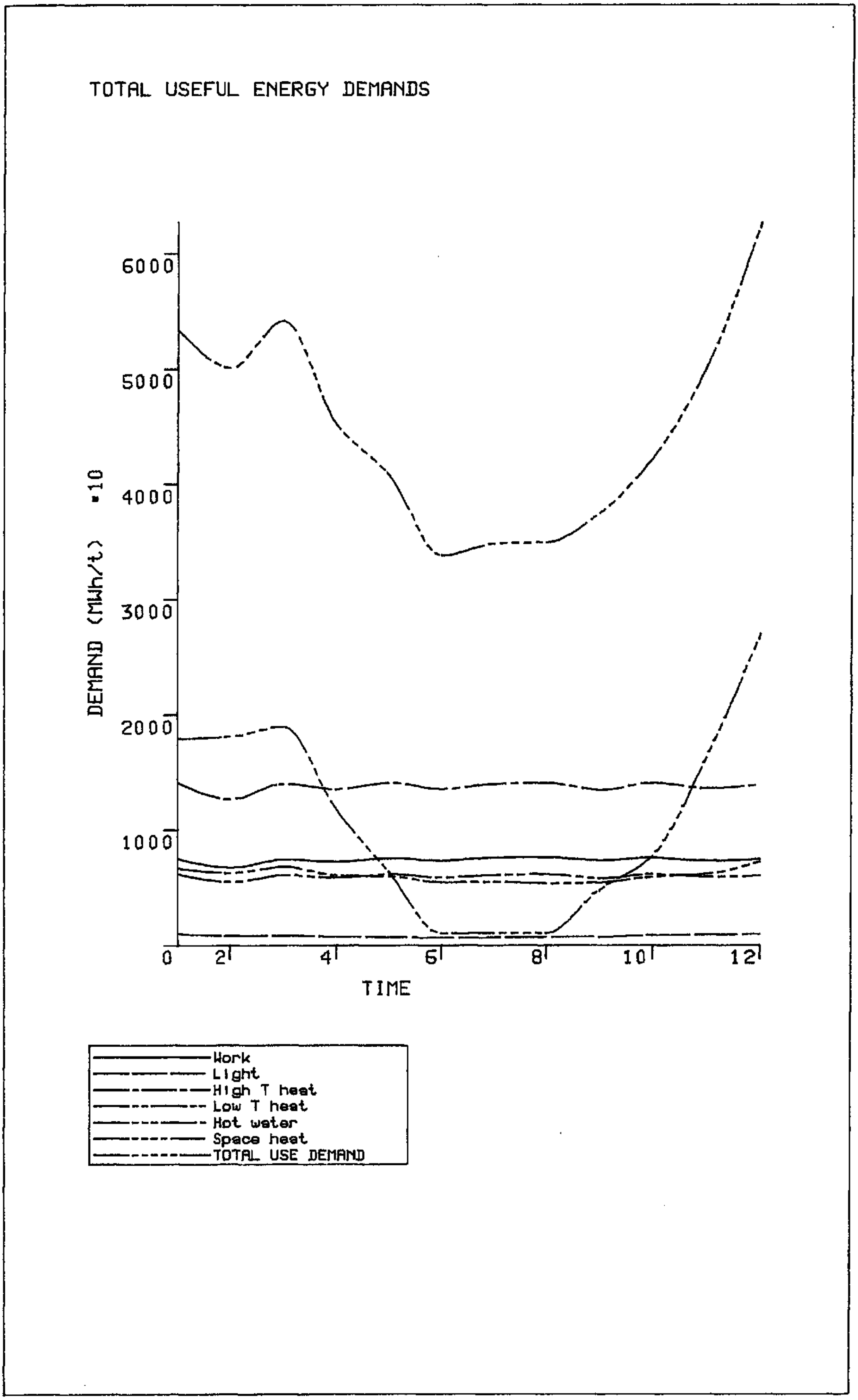

DOMESTIC USEFUL ENERGY DEMANDS
DEMAND (MWh/t)
16000
14000
12000
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
Light
Miscellaneous
Cooking
Hot Water
Space heating
Transport

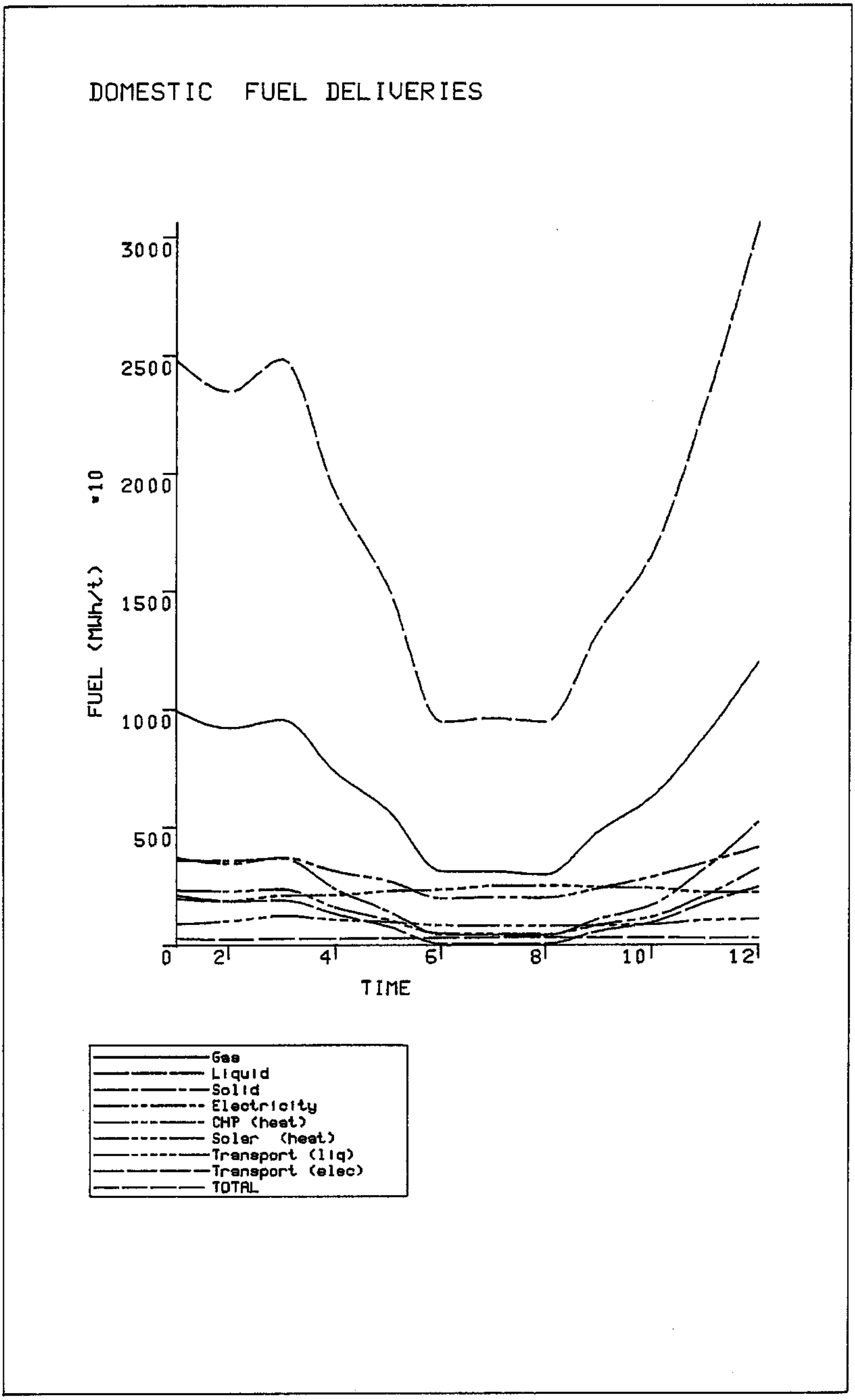


INDUSTRIAL USEFUL ENERGY DEMANDS
DEMAND (MWh/t)
7000
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Light
Kinetic
Heat > 120
Heat < 120
Hot water
Space heat
Transport

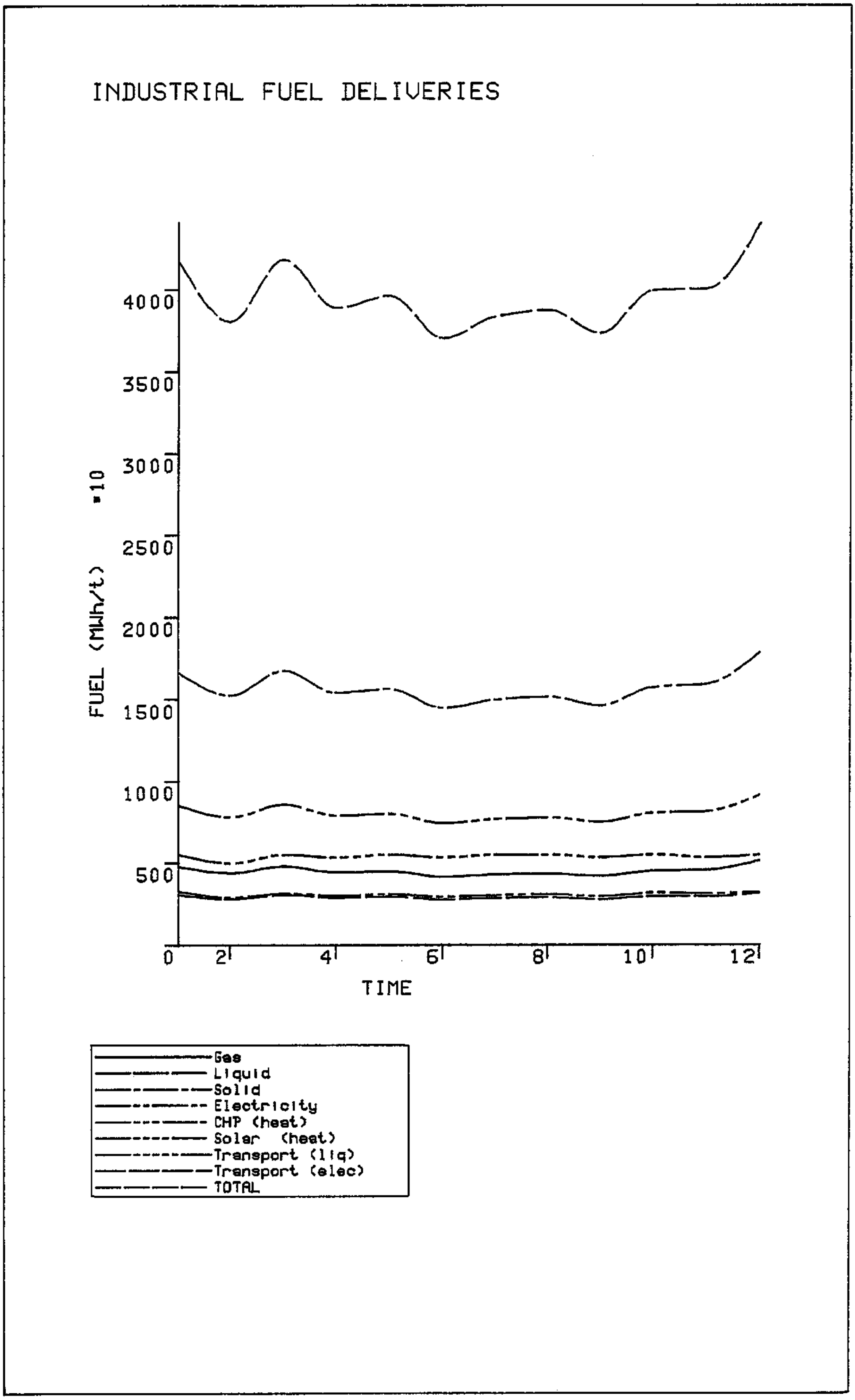

COMMERCIAL USEFUL ENERGY DEMANDS
DEMAND (MWh/t)
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Light
Miscell Elec
Process
Hot water
Space heat
Transport

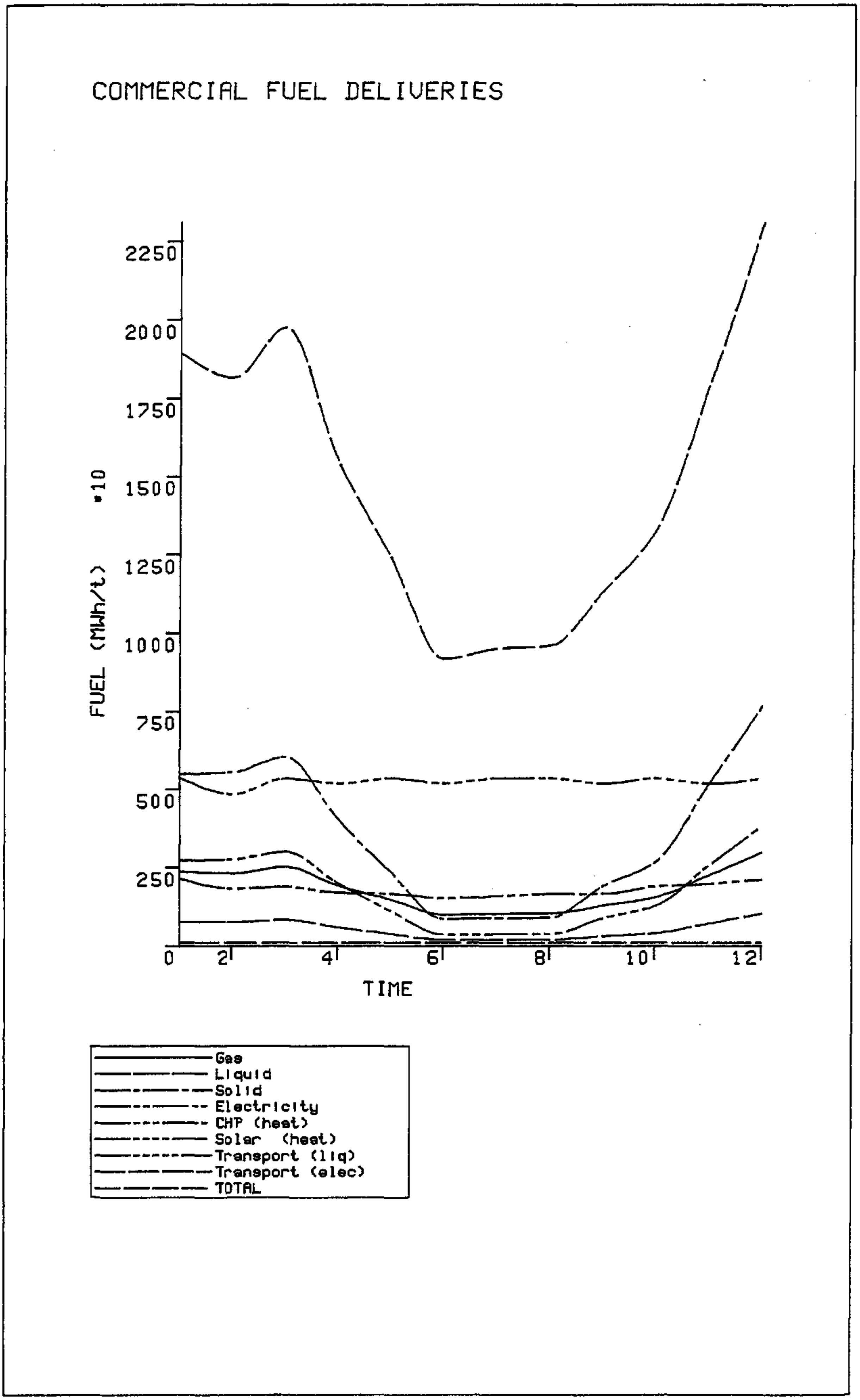

IRON & STEEL,FEEDSTOCK DEMANDS
DEMAND (MWh/t)
12000
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
High T heat
Feedstocks

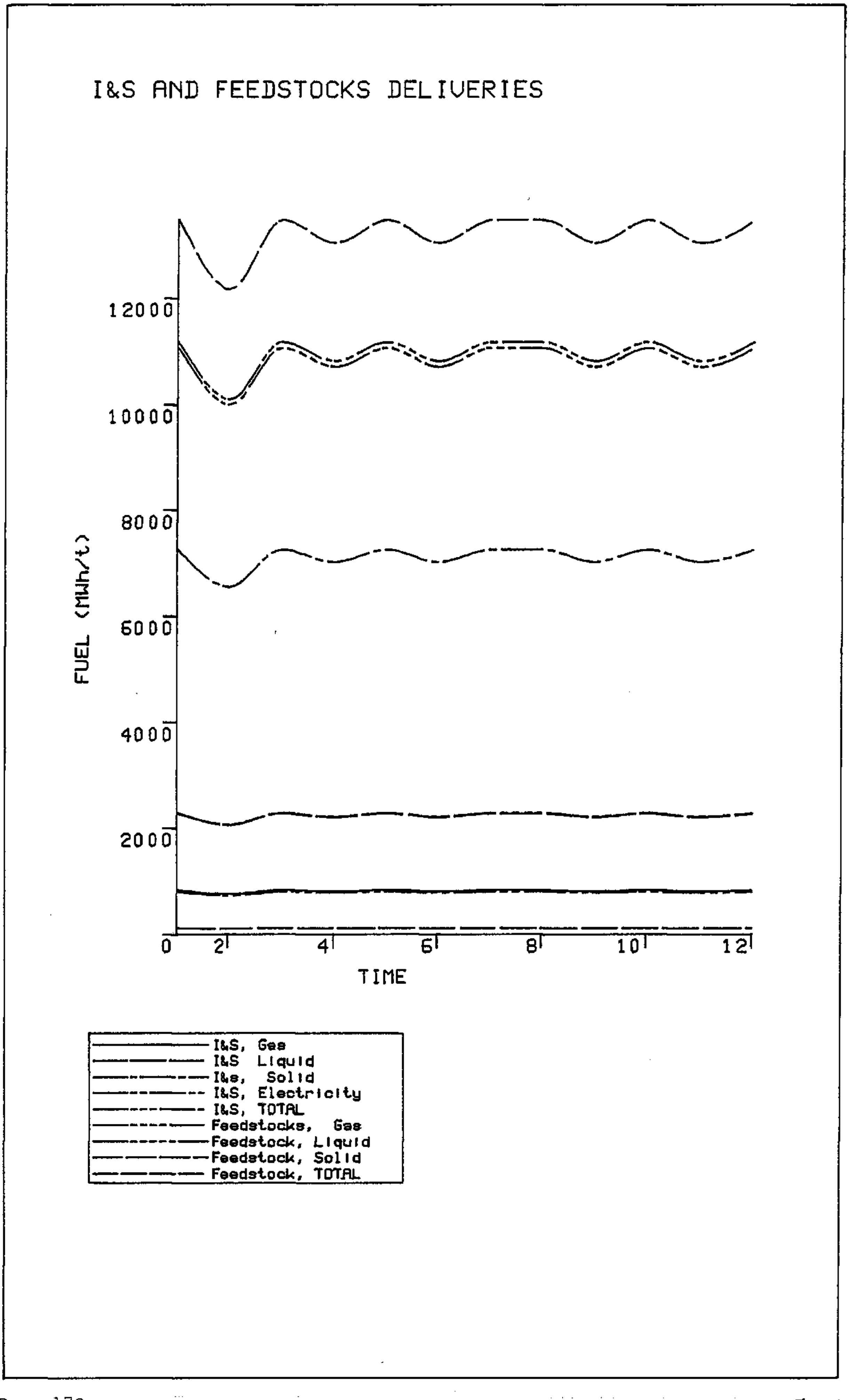

TOTAL USEFUL ENERGY DEMANDS
DEMAND (MWh/t) *10
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Work
Light
High T heat
Low T heat
Hot water
Space heat
TOTAL USE DEMAND



DOMESTIC FUEL DELIVERIES
FUEL (MWh/t) *10
3000
2500
2000
1500
1000
500
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL

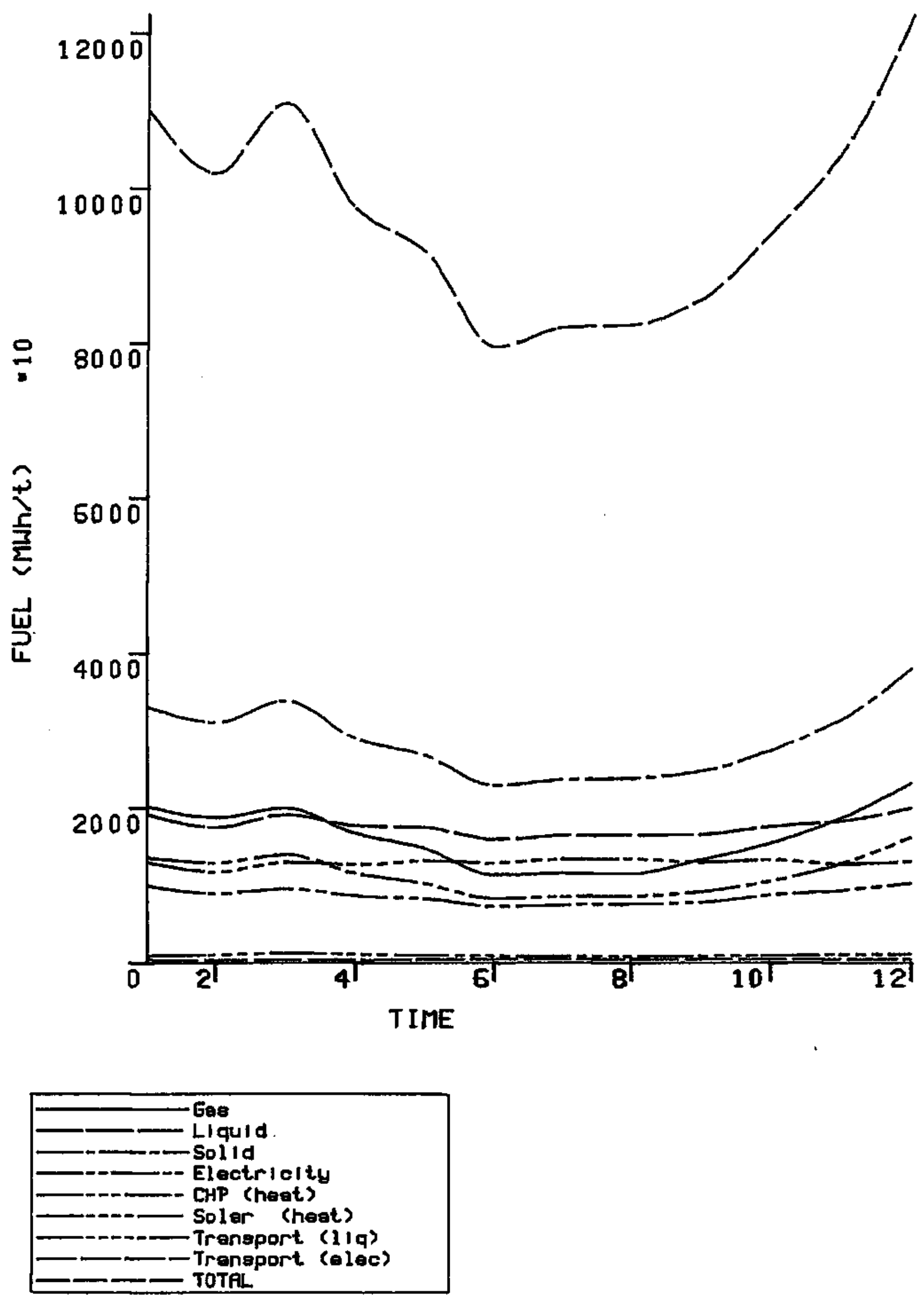

INDUSTRIAL FUEL DELIVERIES
FUEL (MWh/t) *10
4000
3500
3000
2500
2000
1500
1000
500
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL

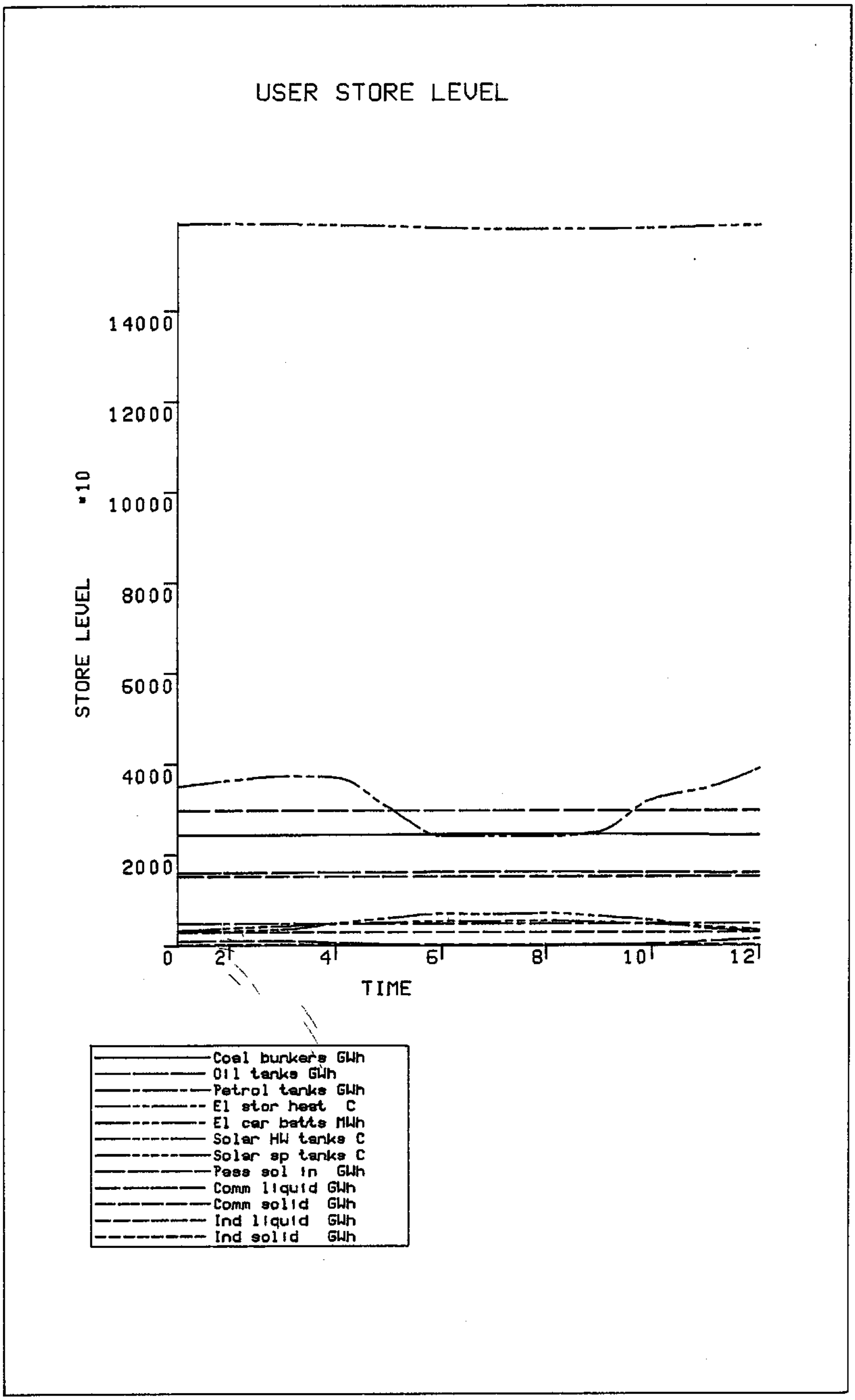

COMMERCIAL FUEL DELIVERIES
FUEL (MWh/t) *10
2250
2000
1750
1500
1250
1000
750
500
250
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Electricity
CHP (heat)
Solar (heat)
Transport (liq)
Transport (elec)
TOTAL

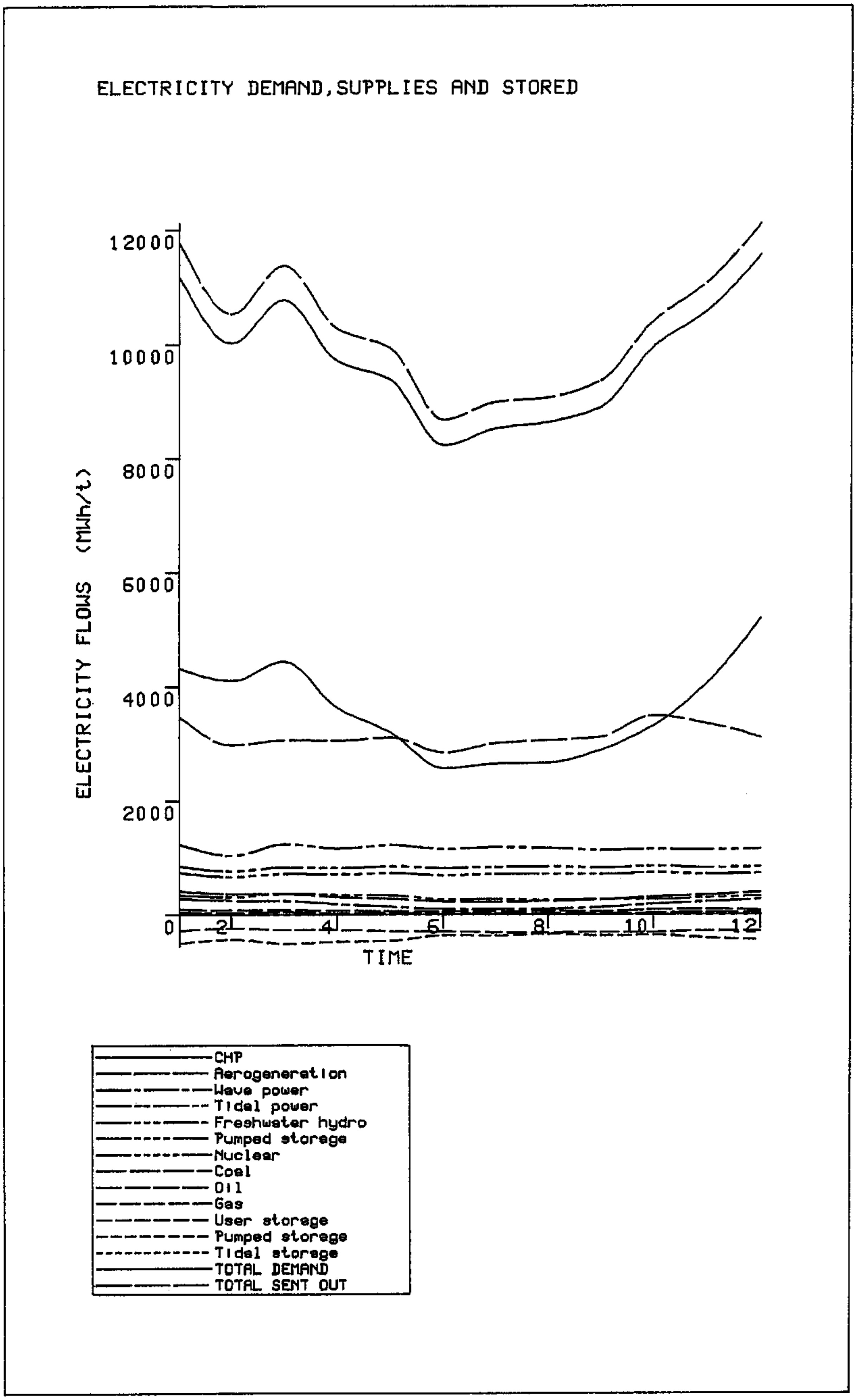


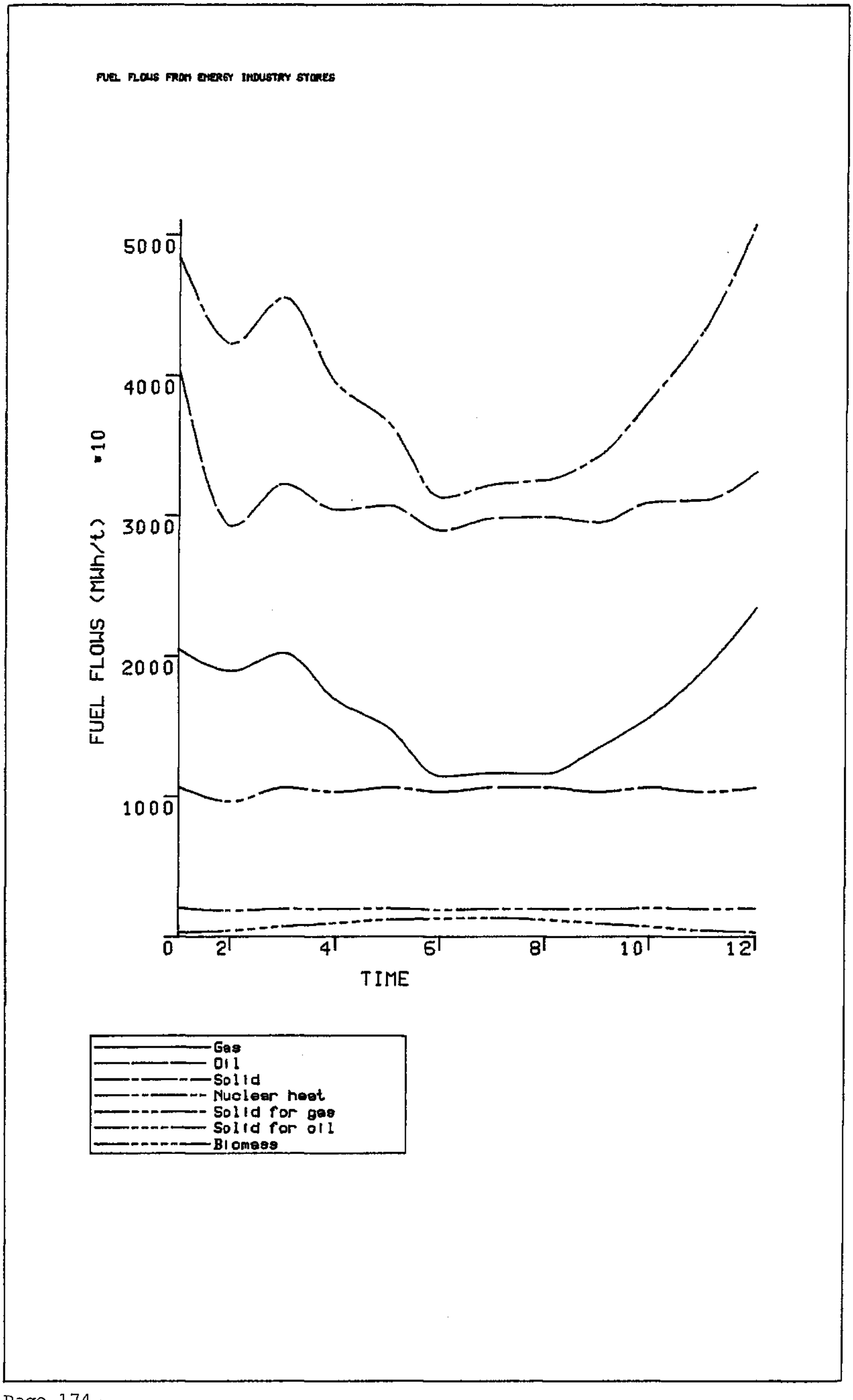
I&S AND FEEDSTOCKS DELIVERIES
12000
10000
8000
6000
4000
2000
FUEL (MWh/t)
0
2
4
6
8
10
12
TIME
I&S, Gas
I&S Liquid
I&s, Solid
I&S, Electricity
I&S, TOTAL
Feedstocks, Gas
Feedstock, Liquid
Feedstock, Solid
Feedstock, TOTAL

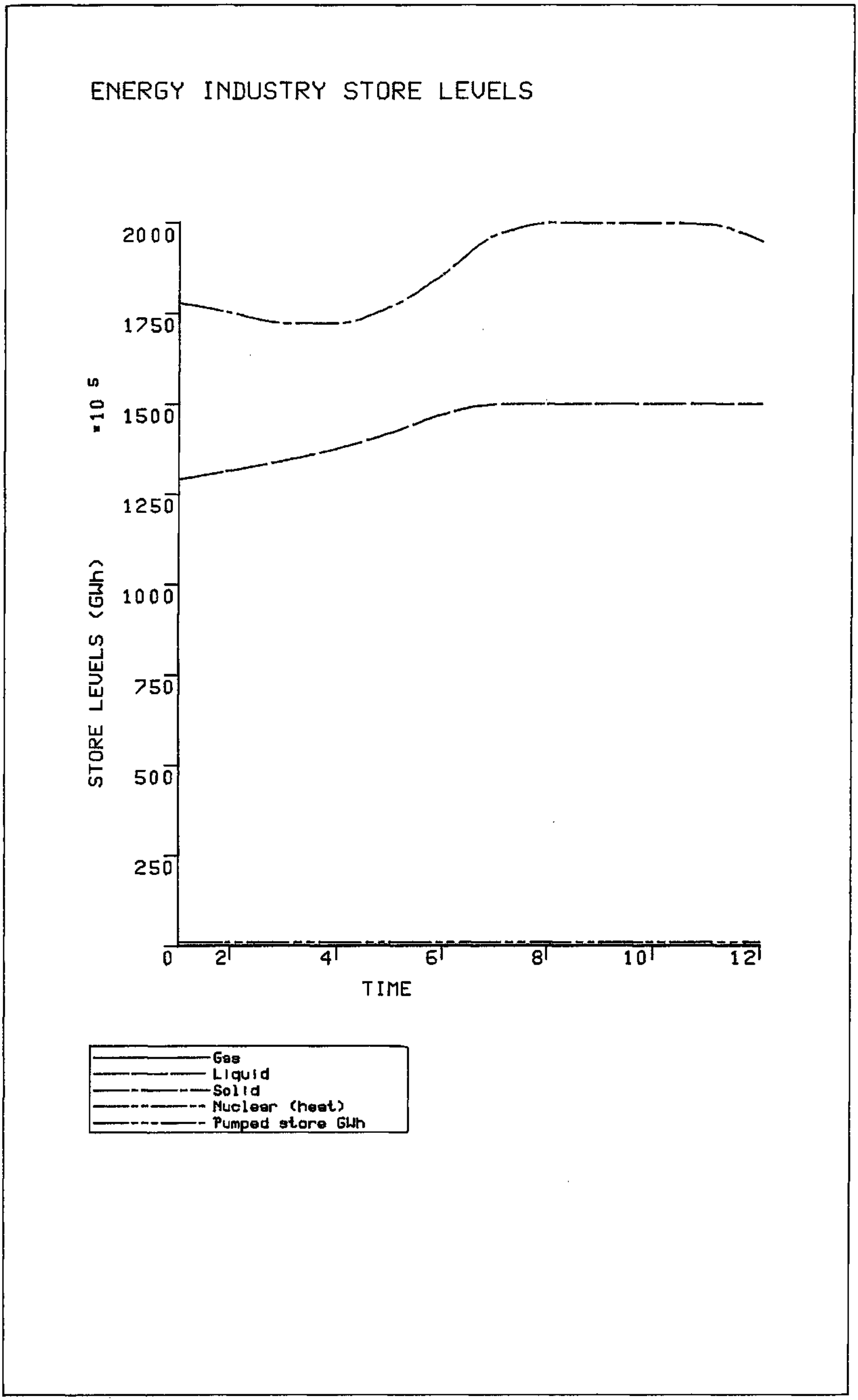
TOTAL FUEL DELIVERIES



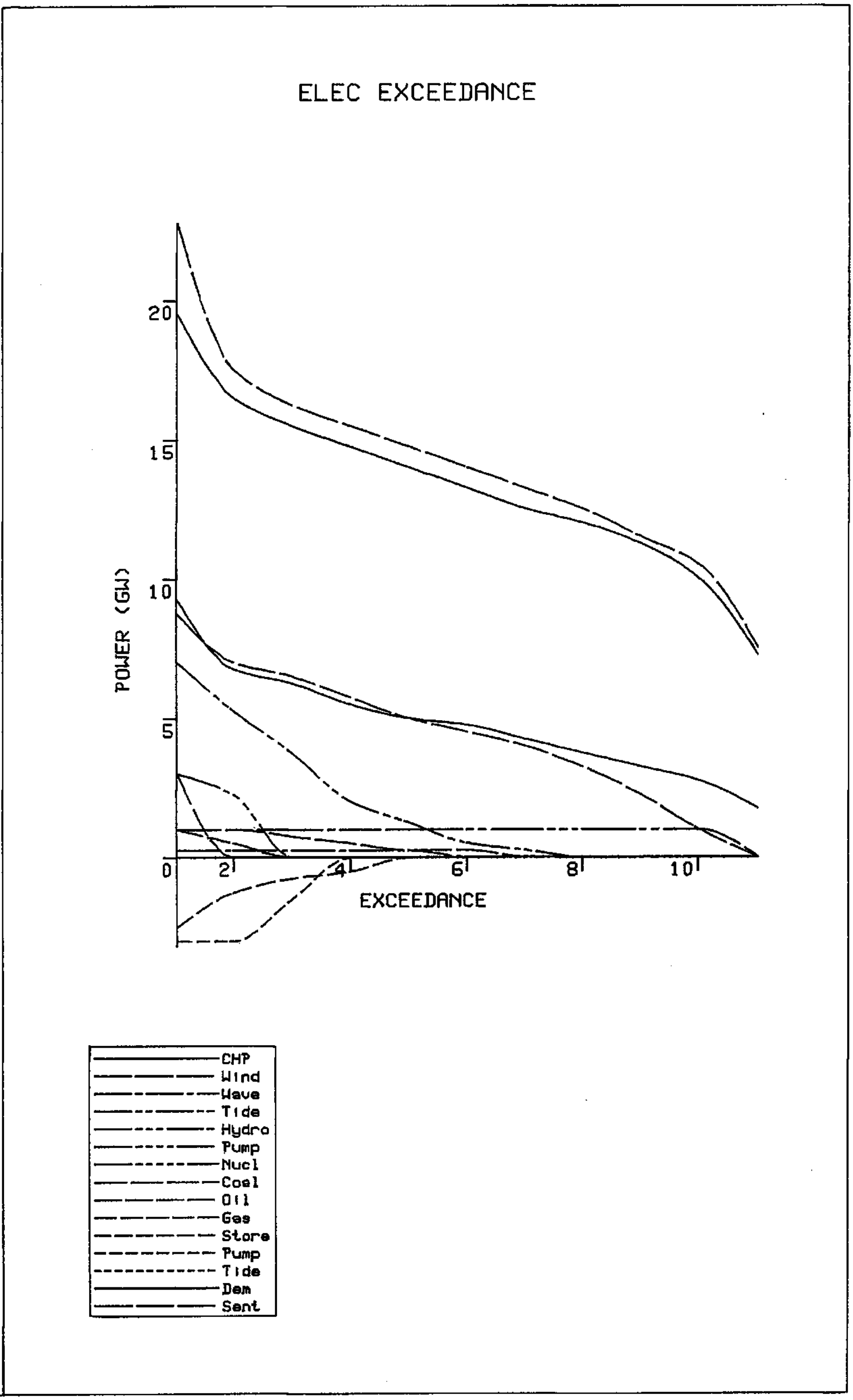

USER STORE LEVEL
STORE LEVEL *10
14000
12000
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
Coal bunkers GWh
Oil tanks GWh
Petrol tanks GWh
El stor heat C
El car batts MWh
Solar HW tanks C
Solar sp tanks C
Pass sol in GWh
Comm liquid GWh
Comm solid GWh
Ind liquid GWh
Ind solid GWh


ELECTRICITY DEMAND, SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t)
12000
10000
8000
6000
4000
2000
0
2
4
6
8
10
12
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT


FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass

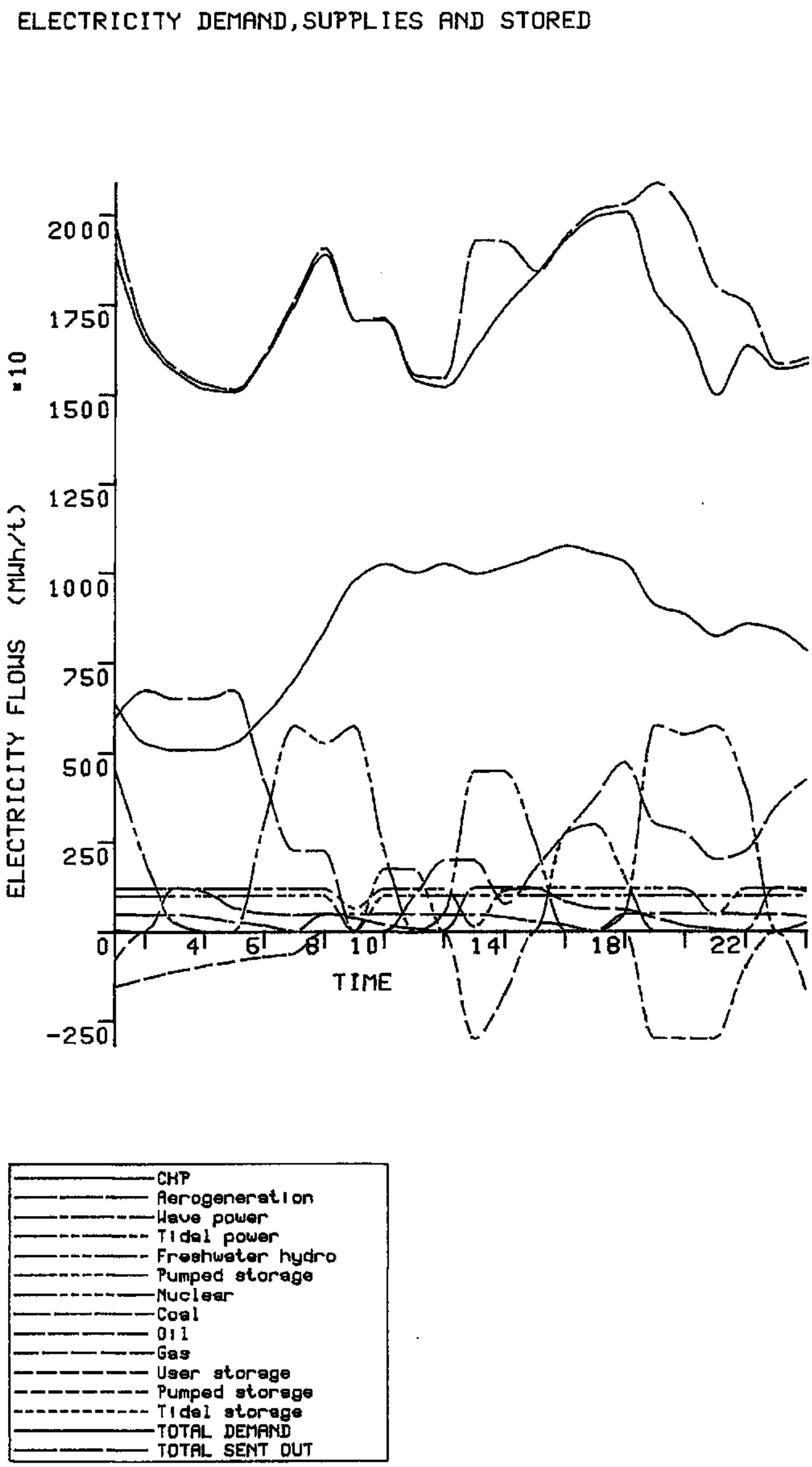


ENERGY INDUSTRY STORE LEVELS
STORE LEVELS (GWh)
*10 5
2000
1750
1500
1250
1000
750
500
250
0
2
4
6
8
10
12
TIME
Gas
Liquid
Solid
Nuclear (heat)
Pumped store GWh

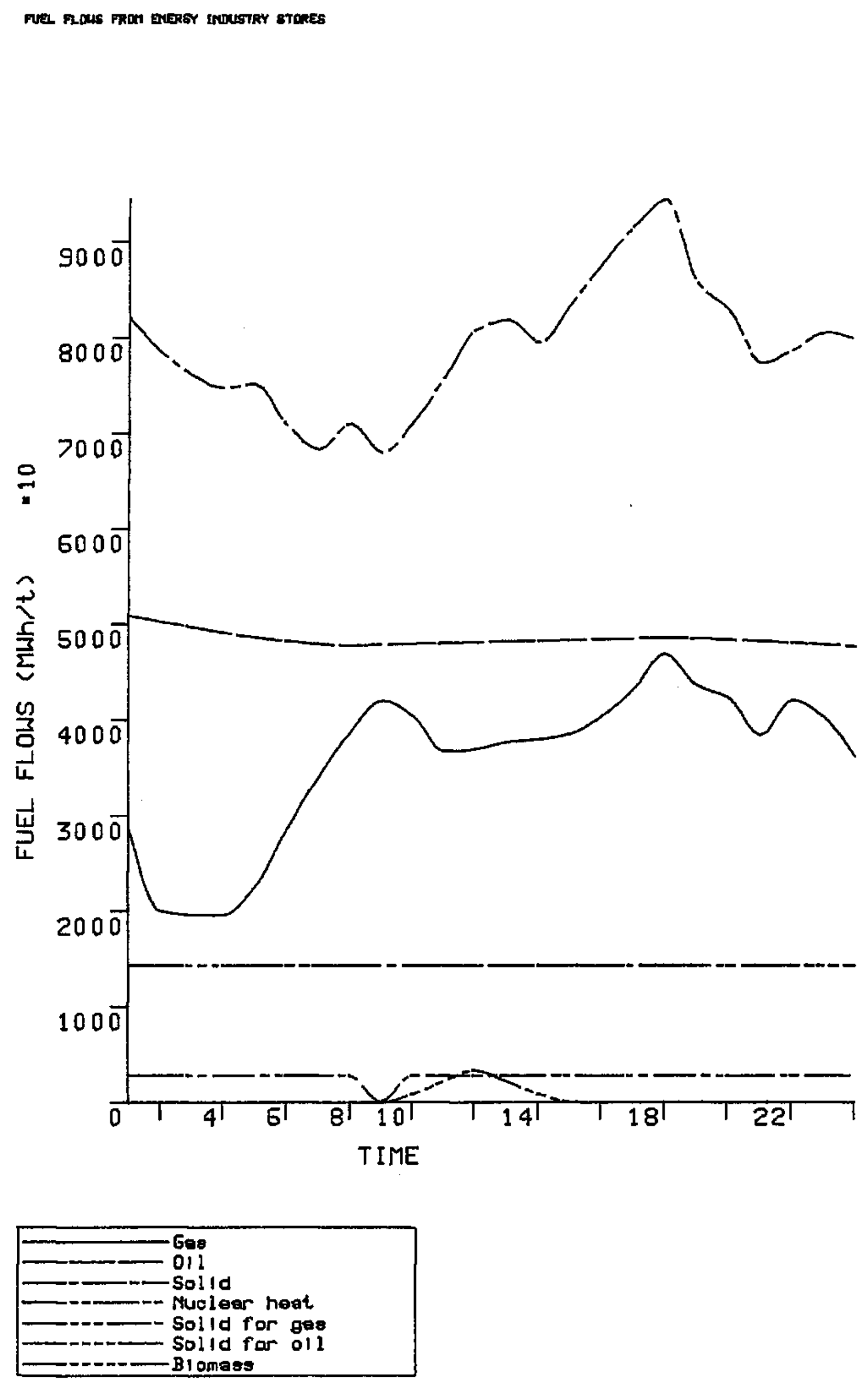


ELEC EXCEEDANCE
POWER (GW)
20
15
10
5
0
2
4
6
8
10
EXCEEDANCE
CHP
Wind
Wave
Tide
Hydro
Pump
Nucl
Coal
Oil
Gas
Store
Pump
Tide
Dem
Sent

The following two graphs show the flows of electricity and fossil fuels on a 0 degree Centigrade winter's day through the system with conservation and alternative supply technologies.



ELECTRICITY DEMAND,SUPPLIES AND STORED
ELECTRICITY FLOWS (MWh/t) *10
2000
1750
1500
1250
1000
750
500
250
0
-250
4
6
8
10
14
18
22
TIME
CHP
Aerogeneration
Wave power
Tidal power
Freshwater hydro
Pumped storage
Nuclear
Coal
Oil
Gas
User storage
Pumped storage
Tidal storage
TOTAL DEMAND
TOTAL SENT OUT


FUEL FLOWS FROM ENERGY INDUSTRY STORES
FUEL FLOWS (MWh/t) *10
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
4
6
8
10
14
18
22
TIME
Gas
Oil
Solid
Nuclear heat
Solid for gas
Solid for oil
Biomass

REFERENCES

BARRETT M. A., 1982, "A dynamic physical energy model of the UK", ERG 044, Energy Research Group, Open University.

ENERGY PAPER 45 (EP 45), 1981, "Prospects for improved fuel economy and fuel flexibility in road vehicles", HMSO.

ENERGY PAPER 48 (EP 48), 1981, "Energy Conservation in the production of domestic hot water", HMSO.

IIED (LEACH G., ROMIG R., BUREN A., LEWIS C., FOLEY G.), "A low energy strategy for the UK", Science Reviews, London.

LAKER I.B., 1981 ,"Fuel economy- some effects of driver characteristics and vehicle type", TRRL Laboratory Report 1025, Transport and Road Research Laboratory, Crowthorne, Berkshire.