Technical University of Denmark

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Halsnæs, Kirsten; Sørensen, H.

Publication date:
1989

Document Version
Publisher's PDF, also known as Version of record

Risø-M-2798

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Kirsten Halsnæs
Henrik Sørensen

Risø National Laboratory, DK-4000 Roskilde, Denmark
June 1989

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Simulation of the Italian Energy System with the DESS-Model

By Kirsten Halsnæs, Henrik Sørensen

Abstract. This report describes a simulation of the Italian energy system for the period 1980 to 2000 with the energy simulation model DESS (Detailed Energy Simulation System). The Italian model comprises a detailed database for the most important part of the energy demand and conversion system. This database is split into the following five parts: the building stock, district heating, power system, the process sector, and the transport sector. As a result of the simulation a total gross energy balance for Italy is generated. The actual simulation referred to in this report is made according to some main assumptions in the National Italian Energy Plan where nuclear power production is kept constant and all new constructed power plants are coal fired.

Risø National Laboratory, DK-4000 Roskilde, Denmark
June 1989

ISBN-87-550-1542-5
ISSN-0418-6435

Printing: Grafisk Service, Risø
June 1989

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1. INTRODUCTION

By the end of 1985 the work of developing an Italian version of the DESS-model (Detailed Energy Simulation System) was started under a contract with the Commission of European Communities.

The DESS-model is a further development of the Danish Energy System model DES which has been used for several years in Danish national energy planning.

The overall purpose of the DESS-model is to provide a flexible and easily understandable tool for translating sector-specific demands for electricity, heat and transport into fuel requirements and economic consequences in different parts of the conservation system, see Grohnheit, 1986 for a detailed description of the model.

The DESS-model contains five sub-modules, namely:

- the building stock module, where the fuel requirements for space heating and water heating is simulated,
- the district heating module where the fuel requirement for different types of district heating plants is simulated,
- the power system module, where the electricity and combined heat and power system are simulated,
- the process module, where the process energy demands are transformed to fuel requirements,
- the transport module where different kinds of traffic are transformed to fuel requirements.

The Italian energy system is simulated for the period 1980 to 2000. Emphasis has been put on establishing a database on the Italian energy system representing the current state of the system. On this basis a scenario for the development of the different parts of the energy system is simulated.

2. THE BUILDING STOCK MODULE

In the building stock module the total energy demand for space heating and hot water purposes is simulated and the resulting fuel consumption is calculated. The module is structured after a "bottom-up principle" which means that the building heat demand is simulated on the basis of relatively detailed building and climatic data for different geographical parts of Italy.

The net heat demand for space heating in houses and other buildings is calculated as the product of building area, unit heat demand per m^3 and degree days for a specific geographical area. In the same way the net energy demand for water heating is calculated as a product of building area and unit heat demand. The result of these calculations is the total net energy demand for space heating and hot water purposes for Italy as a whole and disaggregated over different building types and relevant geographical regions.

Subsequently the total heat demand for space heating and water heating is distributed over different kinds of hot-water installations and space-heating installations, specified according to type of combustion and fuel. Finally the fuel consumption for space heating and water heating is calculated using efficiencies and heat contents for the different installations and fuels.

2.1. The climatic factor

In the Italian law no. 373 of 30.04.76 on energy conservation in connection to space heating in buildings, it is stated that the number of degree days is calculated on the basis of a mean indoor temperature of 20°C.

In table 2.1 the average number of degree days for the nineteen Italian regions are shown (Graziani, 1983).

Table 2.1. Average degree days for the 19 regions of Italy.

	Average degree days for the region
Piemonte	appr. 2600
Val d'Aosta	2579
Leguria	1241
Lombardia	2389
Trentino-Alto Adige	2575
Friuli-Venezia Giulia	2182
Veneto	2261
Emilia Romagna	2210
Toscana	1690
Marche	1866
Umbria	2055
Lazio	1547
Abruzzi	2018
Modese	2080
Campania	1180
Puglia-Calabria	1031
Basilicata	2101
Sicilia	809
Sardegna	1059

As table 2.1 shows there are such great differences in climatic conditions for different parts of Italy that it is necessary to split the space heating demand into different climatic regions.

Following a desire to combine the climatic division with a geographical division showing essential differences in state of the development of different parts of Italy the following division is chosen: Italy is divided into three subregions namely:

Northern Italy comprising Piemonte, Valle d'Aosta, Lombardia, Liguria, Trentino Alto Adige, Veneto, Friuli-Venezia Giulia and Emilia Romagna.
Central Italy comprising Toscana, Umbria, Marche and Lazio.
Southern Italy comprising Abruzzi, Molese, Campania, Puglia, Basilicata, Calabria, Sicilia, and Sandegna.

Table 2.2 shows the number of degree days assumed for the three regions calculated on the basis of the simple mean.

Table 2.2. Average number of degree days for different regions in Italy.

	Average degree days per year
Northern	2300
Central	1800
Southern	1500

Compared with a weighted mean for degree days based on the distribution of the building area in different climatic zones one must expect some error on the results. However this error seems to be acceptable for the aggregation level in the building stock module. A more detailed "weighted" number of degree day method is used in the Banal-model, (Graziani, 1983).

2.2. The unit heat demand

An analysis of differences in unit heat demand depending on different heat conductivity in buildings is an important element in a valuation of the heat conservation potential in the building stock and for an evaluation of appropriate methods.

Unfortunately there has only been poor data available about unit demand for space heating. The only source has been a survey of the unit heat demand in 1000 Italian buildings by Boffa, 1984. Supplemented with own estimates the unit heat demand used in the model is determined as shown in Table 2.3.

Table 2.3. Unit heat demand for space heating in Italy.

	Unit heat demand kJ/m^3/degree-day
One and two family dwellings:	
Of which constructed	
- before 1945	68.4
- between 1945 and 1975	72.2
- after 1975	61.4
Multi family dwellings:	
Of which constructed	
- before 1945	53.1
- between 1945 and 1975	56.0
- after 1975	47.6
Other buildings:	58.0

The unit heat demand for space heating is assumed constant for the period 1980-2000 in the simulation.

It should be noticed that Table 2.3 shows an increase in unit heat demand from the construction period before 1945 to the construction period between 1945 and 1975. This can be explained by the massive post-war building up process, where the building sector was so busy that the resulting quality of the buildings was lower than in the earlier construction period.

For other buildings than houses only very poor data is available and therefore a single assumption about unit heat demand for space heating is used. This assumption is a unit demand for hot water on 12.0 TJ per million houses (Keetoff, 1980) kept constant for the period 1980-2000.

2.3. The building stock

On the basis of an evaluation of the characteristic factors which are relevant for a disaggregation of the space heating demand for houses and other buildings the following building stock vector was formulated:

1. One and two family houses without electrical heating.
2. One and two family houses with electrical heating
3. Multi family houses
4. Service buildings
5. Production buildings
6. Hospitals
7. Summercottages

This vector is constructed separately for the three geographical regions. Northern- Central and Southern Italy and for the following three construction periods:

- buildings constructed before 1945
- buildings constructed between 1945 and 1975
- buildings constructed after 1975

As a result nine building vectors are constructed.

The input data for the building stock are shown in Table 2.4.

Table 2.4. The building stock data for houses in Italy used in the DESS simulation (building volume in occupied buildings 1980 in million m^3).

	Construction year:		
	before 1945	between 1946-1975	after 1975
Northern Italy:			
One and two family houses without elec. heating	306.000	613.000	105.000
One and two family houses with elec. heating	3.000	6.000	1.000
Multi-family houses	360.000	720.000	124.000
Central Italy			
One and two family houses without elec. heating	111.000	248.000	38.000
One and two family houses with elec. heating	2.000	5.000	800
Multi-family houses	132.000	294.000	45.000
Southern Italy			
One and two family houses	178.000	330.000	66.000
One and two family houses with elec. heating	24.000	45.000	9.000
Multi-family houses	235.000	436.000	88.000

Source: Estimated on the basis of data on the number of houses for different construction years and geographical areas from the Italian census 1981 (ISTAT, 1985). These data are transformed to building estimates using the general assumption that the mean volumene for one and two family houses is 285 m^3 and for multi-family dwellings 240 m^3.

The development in the housing stock in the simulation period 1980 to 2000 is extrapolated on the general assumption that the total net growth in the building stock (new construction minus demolition) will be 200,000 houses per year. It is assumed that this increment will be distributed over the different types of houses and geographical areas proportionally to the building stock in 1980.

The building stock for buildings not used for housing purposes is estimated to 1100 million m^3 in 1980 in Northern Italy, 420 million m^3 in Central Italy and 680 million m^3 in Southern Italy. An annual growth of 0.45% is assumed for the building stock in the simulation period 1980-2000. The sources for the estimation are the annual construction statistics from United Nations (UN, 1985 and ISTAT, 1987).

2.4. The heat installations

In connection with the heat simulation structure in the DESSmodel it would be ideal to combine information about building construction period, type of heat installation and fuels in a single vector. This is not possible because of missing data. The above mentioned information is, however, separately available so it is possible to get a rough impression of the uncertainty in the data used in the model.

Table 2.5 below gives some information about the relation between construction year for the building and the type of heat installation.

Table 2.5. Building construction year and type of heat installation in Italy 1981. (mill. dwellings).

	Central heat instal.	Autonomous heat instal.	No heat instal.	Total
Construction year:				
Until 1945	1.3	2.9	0.6	4.8
Between 1946-1960	1.7	1.1	0.2	3.0
Between 1961-1975	4.6	1.2	0.4	6.2
After 1976	1.1	0.3	0.1	1.5
Total	8.7	5.5	1.3	15.5

Source: ISTAT, 1985, table 53.

The general impression of the data shown in Table 2.5 is that the share of dwellings without heating installation is highest for the earlier construction years, while the share of dwellings with central heat installation is increasing for the newer construction years.

The input data of the heat installation vector in the DESS simulation is shown in Table 2.6.

Table 2.6. Distribution of heat installations in Northern, Central and Southern Italy in 1980 (pct. of the dwelling stock with the specific heat installation).

	Northern	Central	Southern
Central installation:			
Liquid fuels	42.0	44.7	22.0
Solid fuels	2.0	2.0	1.0
Natural gas	25.9	18.0	3.6
Electricity	0.2	0.3	0.4
Other fuels	0.5	1.0	1.0
Total	70.6	66.0	28.0
Autonomous installation:			
Liquid fuels	4.0	5.0	4.0
Solid fuels	12.0	17.0	26.0
Gas	11.0	5.0	4.0
Electricity	1.0	2.0	11.0
Other fuels	0.4	1.0	2.0
Total	28.4	30.0	47.0
No heat installation:	1.0	4.0	25.0

Source: ISTAT, 1985, table 32.

Central installations are defined as heat installations placed outside the dwelling covering the heat delivery for one or more dwellings.

Autonomous installations are defined as heat installations placed inside the dwelling managed by the inhabitants of the dwelling.

As Table 2.6 shows there are very important differences in the distribution of heat installations for Northern, Central, and Southern Italy. At first one can notice that more than 95 per cent of the dwellings in Northern and Central Italy have a heat installation while only about 75 per cent have a heat installation in Southern Italy. Furthermore the central heat installations are the most dominating installations in Central and especially in Northern Italy while autonomous heat installations are most common in Southern Italy, especially heat installations with solid fuels are common there.

It was the general impression from our study tour to Italy in October 1987, that there would be the following trend in the distribution of the types of heat installations in the simulation period:

- there would be an increasing share of dwellings in Southern Italy with heat installations because of an expected general growth in welfare and building standard. This tendency will probably also indicate a development towards more advanced heat installations,
- there will be a general tendency towards substituting central heat installations with autonomous installations because "people" want to manage their own heat system,
- there will be a relatively big increase in the heat installations using natural gas as fuel and in district heating.

It is difficult to give a precise forecast for the distribution of heat installations on this basis in the three parts of Italy. Therefore the heat installation vector is kept constant in the basic simulation with the exception that the share of district heat installations grows according to development plans by the Italian District Heat Organisation, Assoziazione Italiana Riscaldamento Urbano, (Olesen,1987). The development assumption for district heat systems is shown in Table 2.7.

Table 2.7. Expected number of dwellings heated with district heat in 1980, 1987 and 2000 (in 1000).

	1980	1987	2000
Northern Italy	0	114	340
Central Italy	0	2	15
Southern Italy	0	7	7

Table 2.7 shows that the greatest expansion of the district heating systems is planned in Northern Italy, which also is the absolutely most promising area for such heating systems because of the relatively high space heating demand and the high population and industrial density. Following the development plan described in the table the share of dwellings with district heating installation in Northern Italy will be about 5 per cent. For futher information about the district heating systems in Italy see chapter 3.

2.5. The installations for water heating

In 1980 approximately 45% of the Italian buildings had an installation for water heating. The distribution among different types of water heating installations was according to an American study in 1980 (Keetoff, 1980) as shown in Table 2.8.

Table 2.8. Types of water heating installations in Italy (per cent).

Oil-fired installations	28
Gas-fired installations	36
Coal, coke or wood-fired installations	4
Electrical installations	32
Total	100

The shares of the installations are calculated on the basis of data about their fuel consumption assuming the same efficiencies for all.

Due to lack of better information the distribution of installations is kept constant until 2000. At the same time the share of dwellings with water heating installation is expected to growth from 45% in 1980 to 65% in 2000.

2.6. Simulation results

The results of the heat simulation for Italy as a whole and split into Northern, Central and Southern Italy are shown in the following figure 2 using the DESS plot-program.

It is seen from Figure 2 that the total national demand for space heating increases from a level about 540 PJ to about 640 PJ in 2000 in this simulation. About 50 per cent of the

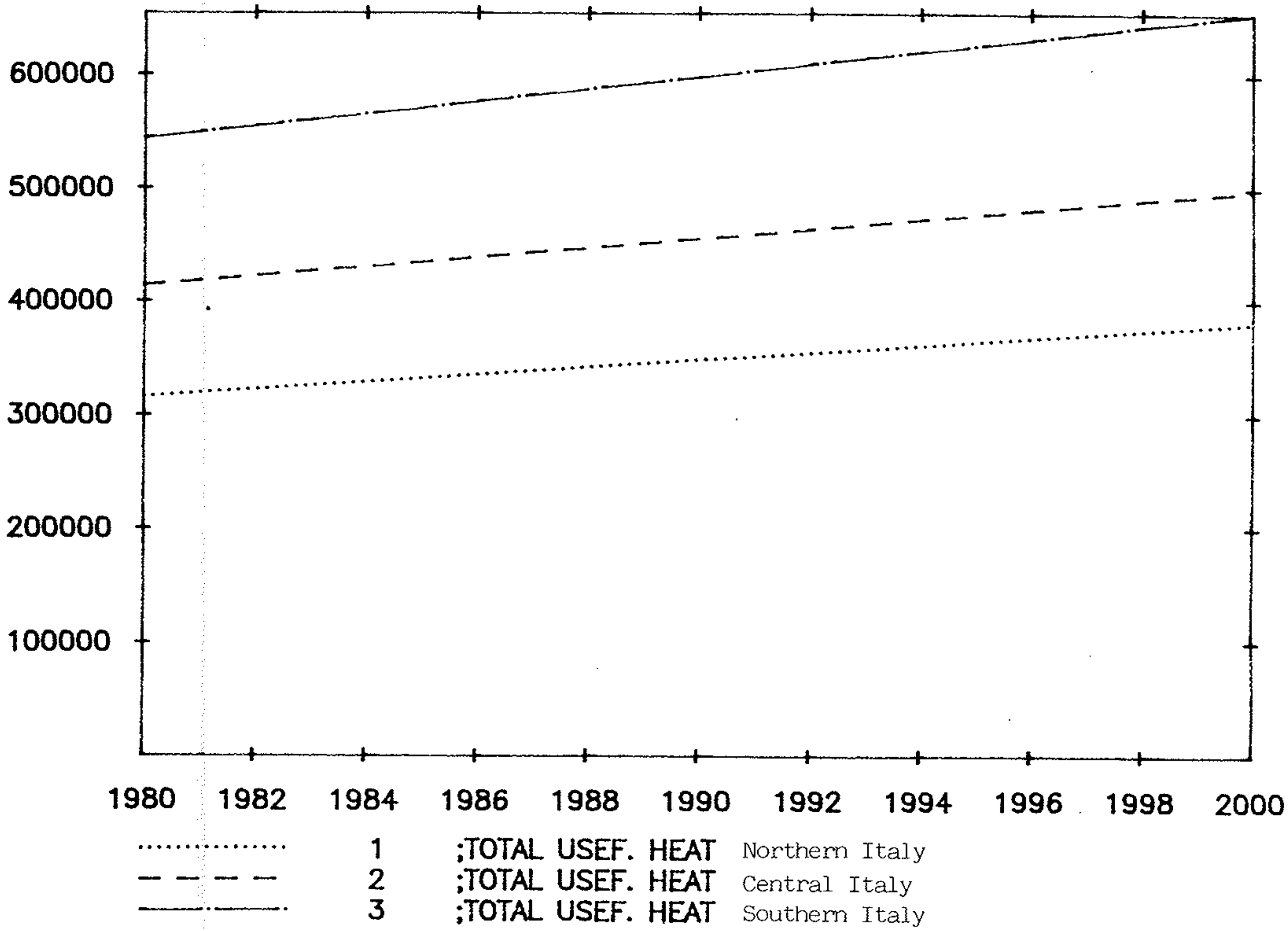


Fig. 2. Space heating demand in Northern, Central, and Southern Italy 1980 to 2000 in TJ.

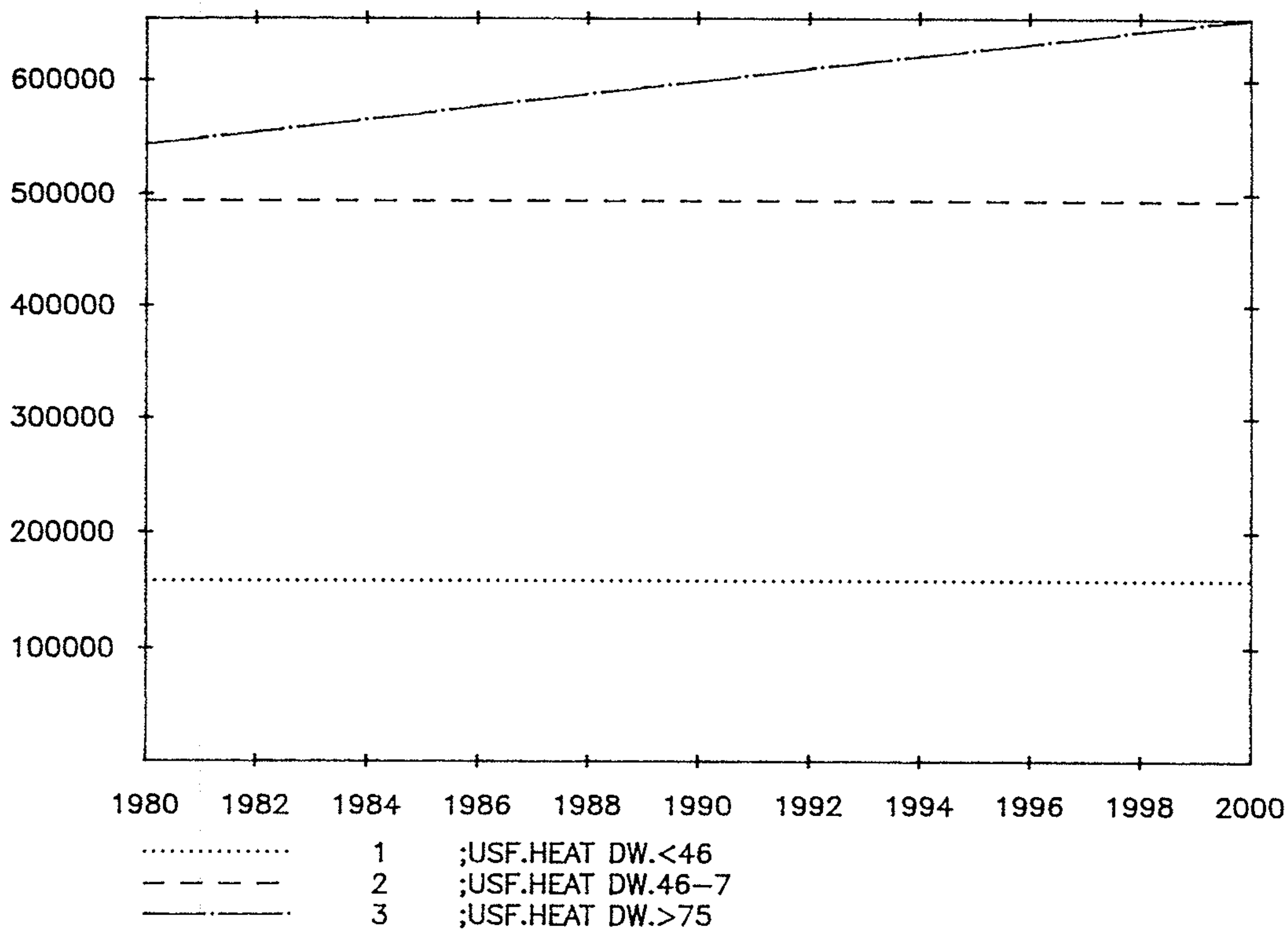


Fig. 3. Space heating in Italy for buildings constructed before 1946, between 1946 and 1975 and after 1975 in TJ.

space heating demand is from Northern Italian buildings, about 20 per cent on buildings in Central Italy and the rest 30 per cent in Southern Italian buildings.

The linearity of the simulation for 1980-2000 depends on the assumptions described already: constant yearly increase in building stock and constant unit heat consumption per m^3 building area.

Figure 3 shows the total demand for space heating split into buildings constructed before 1946, between 1946 and 1975 and after 1975 for Italy as a whole. More than 60% of the total space heating demand is from buildings constructed between 1946 and 1975-1980 the period which as earlier mentioned earlier was characterized by relatively low quality buildings and relatively high unit heat demand per m^3. This result could suggest a special energy conservation programme for such buildings.

The detailed simulation data are shown in Table 2.9.

Similarly the total water heating demand is shown in Table 2.10.

Table 2.9. Total heat demand for different building types.

			1980	1987	1990	1995	2000
BY71:	1;N USEF.HEAT BUIL.<1945	TJ	48140	48140	48140	48140	48140
BY71:	2;N USEF.HEAT BUIL.<1945	TJ	472	472	472	472	472
BY71:	3;N USEF.HEAT BUIL.<1945	TJ	43967	43967	43967	43967	43967
BY71:	4;N USEF.HEAT BUIL.<1945	TJ	147	151	153	157	161
BY71:	5;N USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY71:	6;N USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY71:	7;N USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY72:	1;N USEF.HEAT BUIL.45-76	TJ	101795	101795	101795	101795	101795
BY72:	2;N USEF.HEAT BUIL.45-76	TJ	996	996	996	996	996
BY72:	3;N USEF.HEAT BUIL.45-76	TJ	92736	92736	92736	92736	92736
BY72:	4;N USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY72:	5;N USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY72:	6;N USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY72:	7;N USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY73:	1;N USEF.HEAT BUIL.>1976	TJ	14828	27505	32938	41983	51048
BY73:	2;N USEF.HEAT BUIL.>1976	TJ	141	262	314	400	486
BY73:	3;N USEF.HEAT BUIL.>1976	TJ	13576	23349	27538	34518	41499
BY73:	4;N USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY73:	5;N USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY73:	6;N USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY73:	7;N USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY74:	1;C USEF.HEAT BUIL.<1945	TJ	13666	13666	13666	13666	13666
BY74:	2;C USEF.HEAT BUIL.<1945	TJ	246	246	246	246	246
BY74:	3;C USEF.HEAT BUIL.<1945	TJ	12617	12617	12617	12617	12617
BY74:	4;C USEF.HEAT BUIL.<1945	TJ	44	45	46	47	48
BY74:	5;C USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY74:	6;C USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY74:	7;C USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY75:	1;C USEF.HEAT BUIL.45-76	TJ	32230	32230	32230	32230	32230
BY75:	2;C USEF.HEAT BUIL.45-76	TJ	650	650	650	650	650
BY75:	3;C USEF.HEAT BUIL.45-76	TJ	29635	29635	29635	29635	29635
BY75:	4;C USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY75:	5;C USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY75:	6;C USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY75:	7;C USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY76:	1;C USEF.HEAT BUIL.>1976	TJ	4200	8051	9701	12452	15203
BY76:	2;C USEF.HEAT BUIL.>1976	TJ	88	169	203	261	319
BY76:	3;C USEF.HEAT BUIL.>1976	TJ	3856	6833	8109	10235	12362
BY76:	4;C USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY76:	5;C USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY76:	6;C USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY76:	7;C USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY77:	1;S USEF.HEAT BUIL.<1945	TJ	18263	18263	18263	18263	18263
BY77:	2;S USEF.HEAT BUIL.<1945	TJ	2462	2462	2462	2462	2462
BY77:	3;S USEF.HEAT BUIL.<1945	TJ	18718	18718	18718	18718	18718
BY77:	4;S USEF.HEAT BUIL.<1945	TJ	59	61	62	63	65
BY77:	5;S USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY77:	6;S USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY77:	7;S USEF.HEAT BUIL.<1945	TJ	0	0	0	0	0
BY78:	1;S USEF.HEAT BUIL.45-76	TJ	35739	35739	35739	35739	35739
BY78:	2;S USEF.HEAT BUIL.45-76	TJ	4874	4874	4974	4874	4874
BY78:	3;S USEF.HEAT BUIL.45-76	TJ	36624	36624	36624	36624	36624
BY78:	4;S USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY78:	5;S USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY78:	6;S USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY78:	7;S USEF.HEAT BUIL.45-76	TJ	0	0	0	0	0
BY79:	1;S USEF.HEAT BUIL.>1976	TJ	6079	10742	12740	16071	19402
BY79:	2;S USEF.HEAT BUIL.>1976	TJ	829	1465	1737	2191	2645
BY79:	3;S USEF.HEAT BUIL.>1976	TJ	6283	10342	12082	14981	17880
BY79:	4;S USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY79:	5;S USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY79:	6;S USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY79:	7;S USEF.HEAT BUIL.>1976	TJ	0	0	0	0	0
BY84	;N USEFUL HEAT DEM. TOT	TJ	316451	339222	348895	365017	381139
BY85	;C USEFUL HEAT DEM. TOT	TJ	97188	104097	107058	111993	116929
BY86	;S USEFUL HEAT DEM. TOT	TJ	129970	139228	143239	149922	156606
BY80:	1;TOTAL USEF. HEATDEMAND	TJ	274939	296131	305213	320349	335486
BY80:	2;TOTAL USEF. HEATDEMAND	TJ	10769	11596	11954	12552	13149
BY80:	3;TOTAL USEF. HEATDEMAND	TJ	258011	274820	282024	294031	306039
BY80:	4;TOTAL USEF. HEATDEMAND	TJ	250	258	262	268	274
BY80:	5;TOTAL USEF. HEATDEMAND	TJ	1	1	1	1	1
BY80:	6;TOTAL USEF. HEATDEMAND	TJ	1	1	1	1	1
BY80:	7;TOTAL USEF. HEATDEMAND	TJ	1	1	1	1	1
BY87	;N USEF.HEAT INC.HOT.W	TJ	362255	386156	411034	436297	462141
BY88	;C USEF.HEAT INC.HOT.W	TJ	115634	126375	131372	139892	148620
BY89	;S USEF.HEAT INC.HOT.W	TJ	158623	175146	182450	194918	207757

Table 2.10. Total water heating demand.

	1980	1981	1984	1985	1986	1987	1990	1995	2000
Hot water u.dem. TJ/mill.B.	12	12	12	12	12	12	12	12	12
Hot water tot. demand TJ	45605	47153	51939	53581	55246	56935	62139	71280	81002
Hot water tot. demand TJ	17846	18452	20324	20967	21618	22278	24314	27890	31692
Hot water tot. demand TJ	28752	29732	32758	33797	34850	35918	39211	44996	51150

The demand for hot water is simulated to a level about 115 PJ in 1987 and about 164 PJ in 2000. This demand is only calculated on the basis of demand for hot water in housing buildings. Further the other part of the building stock for instance public service buildings such as hospitals, also has a great energy consumption for water heating purposes which however not is simulated because of the lack of data.

In the following Table 2.11 the fuel consumption simulation by different space heating installations is shown.

Furthermore the results are illustrated in Figure 4-7.

The simulation shows remarkable differences in the relative shares of different fuels in Northern, Central, and Southern Italy. In Northern Italy fuel oil and gas oil contribute to nearly half of the total fuel consumption and natural gas to nearly about a third. Solid fuels cover almost the rest of the fuel consumption. In Central Italy fuel oil and gas oil covers a little more than 50 per cent, while solid fuels are the next important fuel with a share about 20 per cent and thereafter natural gas with a shortly less importance. The picture is somewhat different in Southern Italy. There the dominating fuel is solid fuels with a share about 50 per cent of the total fuel consumption, fuel oil and gas oil amounts about 30 per cent and both electrical heat and natural gas to a share about 10 per cent.

In the same way the fuel consumption by water heating installations is shown in Table 2.12. The simulation results shown that both oil, gas and electricity are important fuels for water heating purposes.

Table 2.11. Simulation of fuel consumption by different space heating installations in Northern, Central, and Southern Italy. (TJ).

FUELCONSUMPTION
INSTALLATIONS.

IA31: 1:N ELEC. AB PLANT	2111	2133	2197	2218	2240	2261	2326	2433	2541
IA31: 2:N FUEL OIL	181546	183395	188941	190770	192638	194487	200033	209276	218520
IA31: 3:N NATURAL GAS	102911	103959	107103	108151	109199	110247	113391	118631	123870
IA31: 4:N DIST.HEAT AB PLANT	0	1	3	4	4	5	8	12	16
IA31: 5:N GASOIL	16888	17060	17576	17748	17920	18092	18608	19468	20327
IA31: 6:N NATURAL GAS INDIVID.	53587	54133	55770	56315	56861	57407	59044	61772	64500
IA31: 7:N SOLID FUELS	63330	63975	65910	66555	67199	67844	69779	73003	76228
IA31: 8:N OTHER DELIV. HEAT.	10766	10876	11205	11314	11424	11534	11862	12411	12959
IA32: 1:C ELEC. AB PLANT	2484	2509	2585	2610	2635	2660	2736	2862	2988
IA32: 2:C FUEL OIL	58313	58905	60682	61274	61866	62458	64235	67196	70157
IA32: 3:C NATURAL GAS	21867	22089	22756	22978	23200	23422	24088	25198	26309
IA32: 4:C DIST.HEAT AB PLANT	0	0	0	0	0	0	0	0	1
IA32: 5:C GASOIL	6479	6545	6742	6808	6874	6940	7137	7466	7795
IA32: 6:C NATURAL GAS INDIVID.	7476	7552	7780	7856	7932	8007	8235	8615	8994
IA32: 7:C SOLID FUELS	27537	27816	28655	28935	29214	29494	30333	31731	33129
IA32: 8:C OTHER DELIV. HEAT.	7483	7559	7787	7863	7939	8015	8243	8623	9003
IA33: 1:S ELEC. AB PLANT	17893	18077	18630	18814	18998	19182	19735	20656	21577
IA33: 2:S FUEL OIL	43290	43736	45072	45518	45964	46409	47746	49974	52202
IA33: 3:S NATURAL GAS	6494	6560	6761	6828	6895	6961	7162	7496	7830
IA33: 4:S DIST.HEAT AB PLANT	0	0	0	0	0	0	0	0	0
IA33: 5:S GASOIL	6926	6998	7212	7283	7354	7425	7639	7996	8352
IA33: 6:S NATURAL GAS INDIVID.	9990	10093	10401	10504	10607	10710	11018	11532	12047
IA33: 7:S SOLID FUELS	60606	61230	63101	63725	64349	54973	66845	69964	73083
IA33: 8:S OTHER DELIV. HEAT.	28052	28341	29207	29496	29784	30073	30939	32383	33827
IA30: 1:T ELEC. AB PLANT	22488	22719	23412	23642	23873	24104	24797	25951	27106
IA30: 2:T FUEL OIL	283149	286036	294695	297582	300468	303354	312014	326446	340879
IA30: 3:T NATURAL GAS	131272	132609	136620	137957	139293	140630	144641	151325	158009
IA30: 4:T DIST.HEAT AB PLANT	0	1	3	4	5	6	8	12	16
IA30: 5:T GASOIL	30294	30603	31530	31839	32148	32457	33384	34930	36475
IA30: 6:T NATURAL GAS INDIVID.	71053	71777	73951	74675	75400	76124	78297	81919	85542
IA30: 7:T SOLID FUELS	151473	153021	157666	159215	150763	162311	166957	174698	182440
IA30: 8:T OTHER DELIV. HEAT.	46302	46776	48199	48673	49148	49622	51045	53417	55789

Table 2.12. Fuel consumption by water heating installations in Italy (TJ).

	1980	1981	1984	1985	1986	1987	1990	1995	2000
H.W. from oil install.	25817	26694	29406	30337	31280	32237	35186	40366	45876
H.W. from gas install.	33193	34321	37808	39004	40217	41447	45239	51899	58984
H.W. from solid.f.inst.	3688	3813	4201	4334	4469	4605	5027	5767	6554
H.W. from electric.inst.	29505	30508	33607	34670	35749	36842	40213	46133	52430
H.W. Oil consump.	34423	35593	39208	40449	41707	42982	46915	53822	61168
H.W. Gas consump.	44258	45762	50411	52005	53623	55263	60319	69199	78645
H.W. Solid fuels	4918	5085	5601	5778	5958	6140	6702	7689	8738
H.W. Electricity	39340	40677	44809	46227	47665	49123	53617	61510	69907

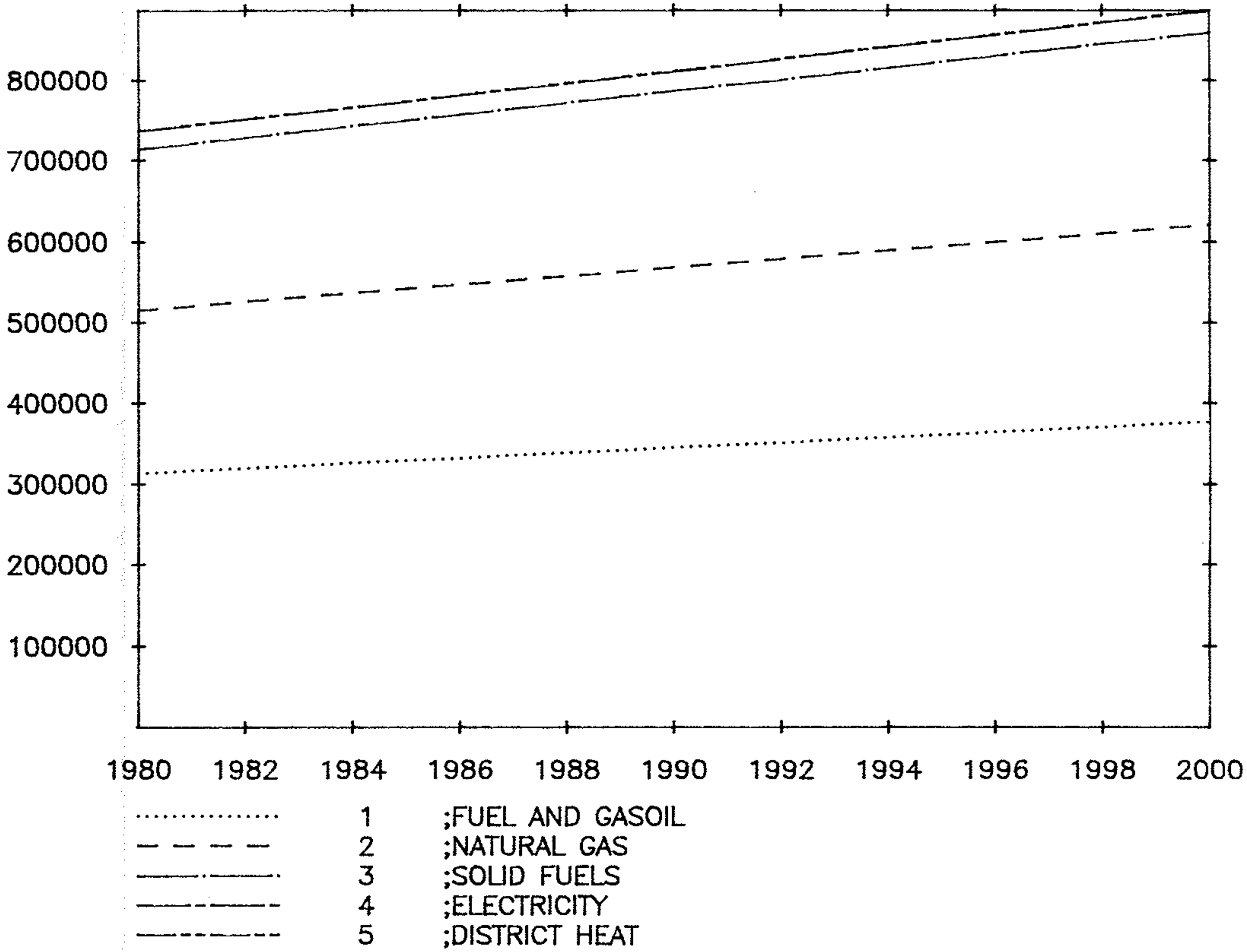


Fig. 4. Fuel consumption for space heating in Italy in TJ.

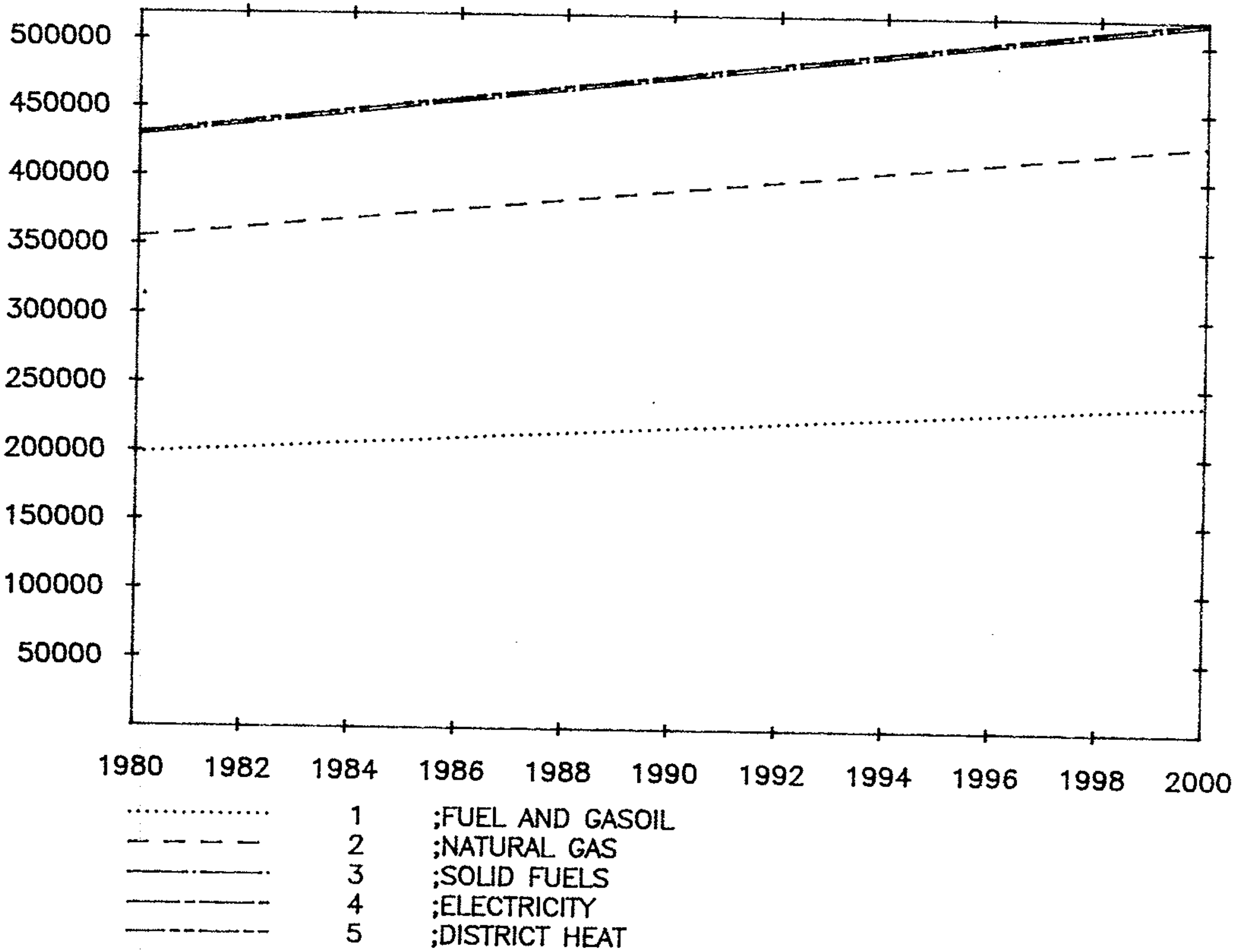


Fig. 5. Fuel consumption for space heating in Northern Italy in TJ.

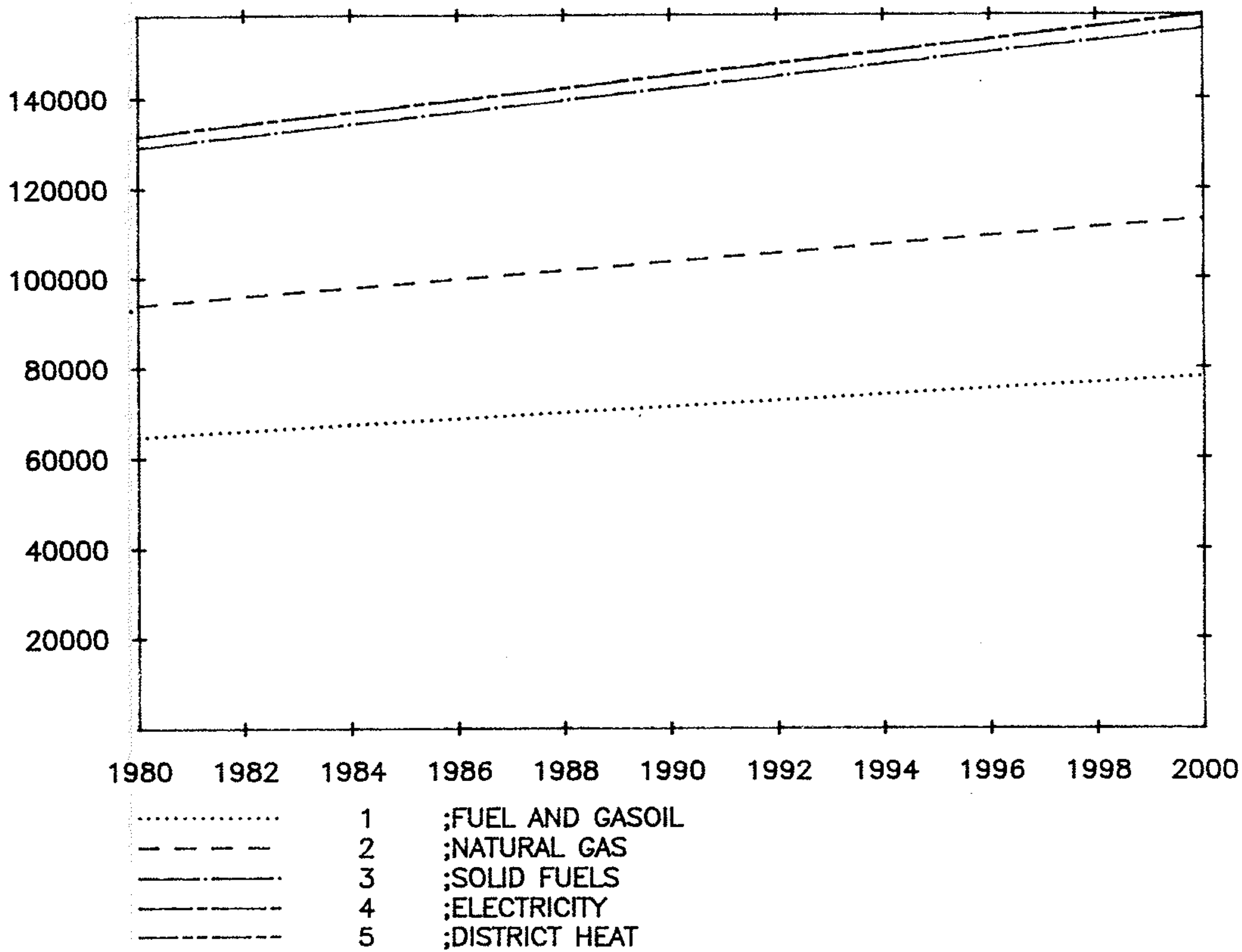


Fig. 6. Fuel consumption for space heating in Central Italy in TJ.

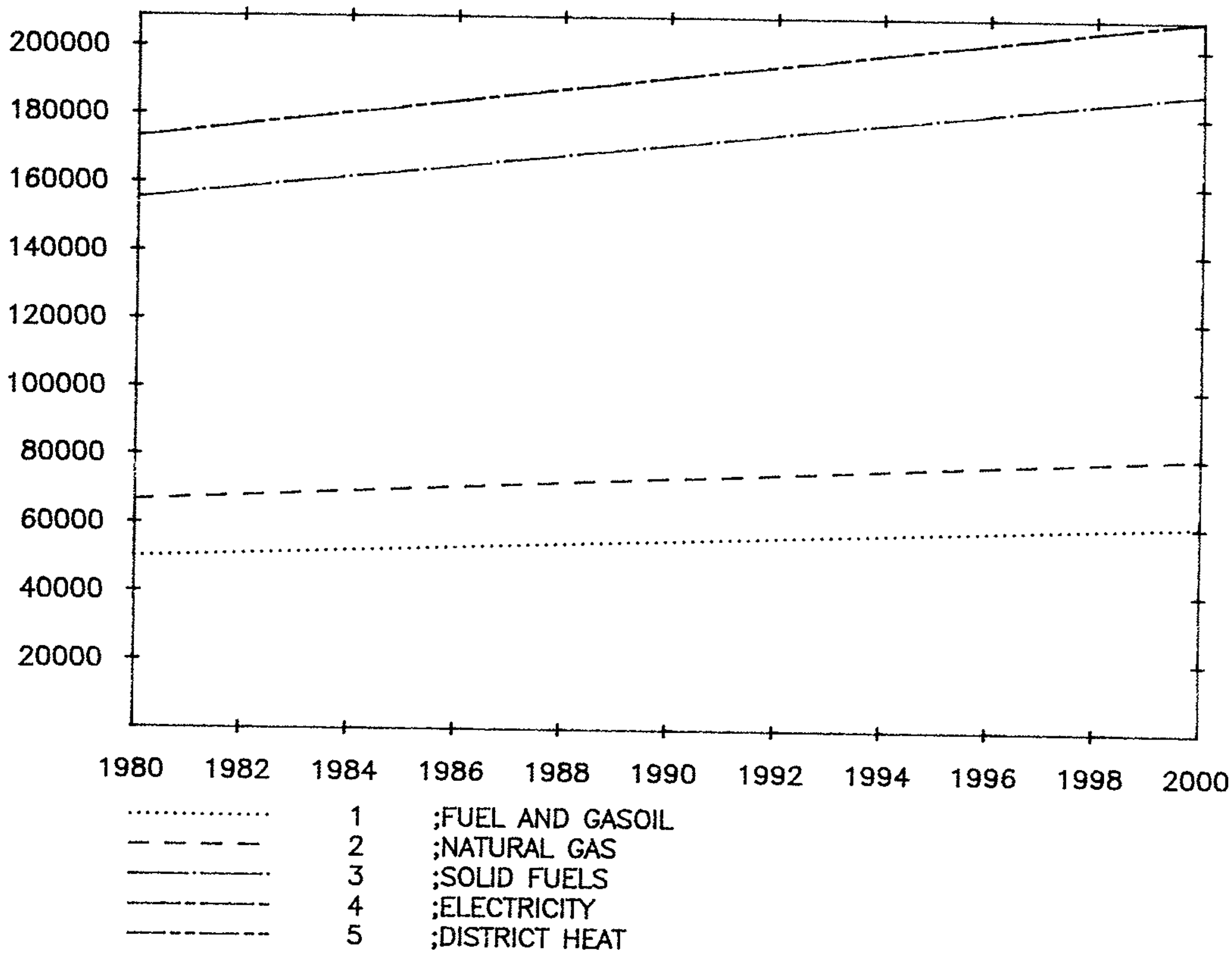


Fig. 7. Fuel consumption for space heating in Southern Italy in TJ.

3. THE DISTRICT HEATING MODULE

The district heating module in the DESS-Model computes the primary energy requirements for district heating.

The calculation is done in three steps:

- The total demands for district heat in the Northern, Central and Southern regions are calculated on basis of heat demand forecasts.

- The requirements for different fuel types are calculated according to a priority list for these fuel types and the maximum load of the different district heating plants.

- The primary energy demands are summarized, and the investment and operation cost are calculated.

3.1. The Italian district heating system

Italy is divided into three regions according to Table 3.1 below.

The most interesting area as far as district heating is concerned the Northern Region, especially the municipalities located in climatic zones with more than 2100 degree-days. According to this definition, more than 90% of the Northern municipalities are potential district heating customers.

Table 3.1 Regions in the Italian district heating system.

Region	Province	Town
North	Lombardia	Brescia
"	"	Cremona
"	"	Mantova
"	"	San Donato Milanese (Milano)
"	Emillia Rom.	Imola
"	"	Modena
"	"	Reggio Emilia
"	Trentino Alto	Rovereto
"	Piemonte	Torino
"	Veneto	Verona
"	"	Vicenza
Central	Toscana	Castel Nuovo Val Cecina
"	Camp. di Roma	Roma

Source: A.I.R.U 1986

NOTE: Current version for the Italian district heat module includes no district heating in the Southern region.

The development of the district heating systems is regulated by the 1982-law on energy conservation and development of alternative sources of energy. According to this law district heating plants are allowed to produce electricity subject to the constraint that the total power of the plant must not exceed 3 MW. The construction of these plants is subsidized by the state, and the development of the district heating systems is administrated by local authorities.

An overview of the heat produced in the Italian district heating systems is given in Table 3.2.

Table 3.2 Italian district heating, total heat produced in 1986. (TJ)

Town	Heat from CHP	Conventional Dist. Heat	Total
Northern region			
Brescia	1449.0	1093.0	2542.0
Cremona	0	5.5	5.5
Mantova	10.0	40.2	50.2
Milano	290.4	201.8	492.2
Modena	0	163.0	163.0
Reggio Emilia	13.4	178.6	192.0
Rovereto	4.3	9.2	13.5
Torino	96.2	288.7	384.9
Verona	44.9	110.0	154.9
Vicenza	0.5	11.5	12.0
Italy, North tot.	908.7	2101.5	4010.2
Central region			
C. N. V. Cecina	0	22.4	22.4
Roma	11.0	11.4	22.4
Italy, Central tot.	11.0	33.8	44.8
Italy, Total	1919.7	2135.3	4055.0

Source: A.I.R.U. 1986

As mentioned above the most attractive area for district heating is the Northern region. From Table 3.2 it can be seen that over 98 per cent of the heat produced in the district heating systems is actually produced in the Northern region. Of this heat nearly 50 per cent is produced at combined heat and power plants.

3.2. Combined heat and power

The simulation of combined production of heat and power is processed in the power simulation module, described in chapter 5. In this simulation the heat demands in each region are split into 12 periods in order to represent the seasonal variations in district heat demand. No detailed information about these variations has been available for Italy and therefore a standard curve based on Danish data (ELSAM,1978) has been used. In Fig. 3.1 the correction factors are shown for each month.

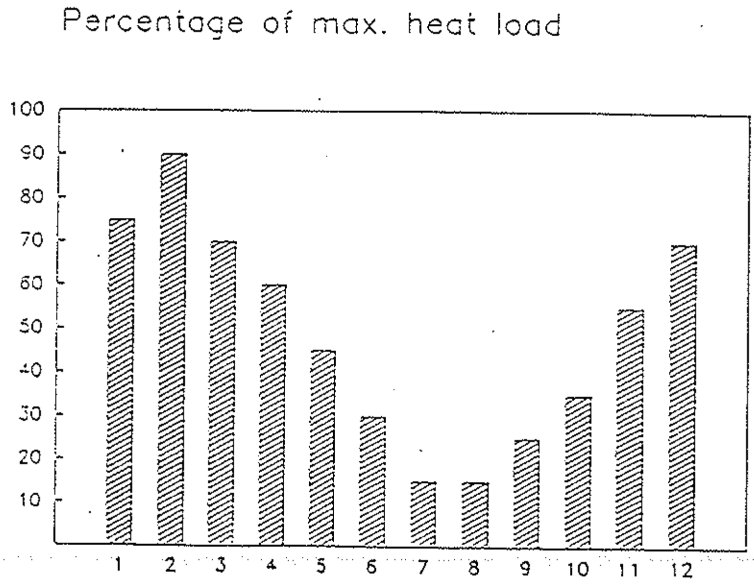


Fig. 3.1. Seasonal variations in district heat demand.

3.3. Conventional district heating

The simulation routine for conventional district heating does not use the detailed heat load curve as shown in Fig. 3.1 but uses aggregate annual data. The routine obtains the heat demand for district heating from the heat demand simulation in the building stock module.

The fuel requirement for district heating is simulated using a fuel priority list. The priority list for the fuels used in the Italian district heat module consists of 4 elements:

1. Industrial waste heat
2. Heat from combined heat and power plants
3. Natural gas
4. Fuel oil

- where fuel oil is considered as a residual. Other fuels, such as straw and other biomass, can be added to the list in order to obtain more detailed analysis. Heat from combined heat and power production is included in the list to simulate district heating with both combined heat and power and with conventional district heating.

In 1983 the total installed capacity of district heating in the Northern Region was about 680 MW heat output and the total heat production was nearly 3400 TJ. In conjunction with this about 360 GWh electricity was produced according to the Italian District Heating Organisation (Olesen, 1986).

In Table 3.3 the primary energy demand for district heating in 1986 is shown as a function of fuel type and region. The table includes fuel for electricity produced at combined heat and power plants.

In 1986, the proportion of the total fuel consumption in district heating plants covered by fuel oil was 22 per cent and 64 per cent for Northern and Central Italy, respectively.

3.4. National district heating programme

The development programme until 1995 forecasts a total installed heat production capacity of 6700 MW and an electricity generation capacity of 3500 MW. According to this programme the annual heat production in 1995 will be nearly 49000 TJ. Included in the national energy plan is an increased use of natural gas in district heating plants.

Table 3.3 Primary energy consumed in the Italian district heat producing units including fuel for electricity at combined heat and power plants. (TJ).

Town	Fuel oil	Natural gas	Total
Northern region			
Brescia	784	3096	3880
Cremona	-	-	-
Imola	0	18	18
Mantova	2	56	58
Milano	0	1043	1043
Modena	15	177	192
Reggio Emilia	15	158	*) 243
Rovereto	0	18	18
Torino	667	234	901
Verona	0	453	453
Vicenza	0	20	20
Italy, North tot.	1483	5273	*) 6826
Central region			
C. N. V. Cecina	-	-	-
Roma	145	82	227
Italy, Central tot.	145	82	227
Italy, Total	1628	5355	7053

Source: A.I.R.U. 1986

*) 70 TJ additional heat produced for district heating in Reggio Emilia is based on industrial waste heat.

The capacity is forecasted by linear extrapolation. On the basis of the average heat demands described in Section 2.6, it is calculated that about 20% of the dwelling stock in the Northern Region will have district heating in 1955.

3.5. Simulation results

Data concerning investment, operation and maintenance costs for Italian district heating plants have not been available. Only very aggregated data concerning the future development programmes for the Italian district heating systems have been found.

The priority lists of the fuels are exogenous but in most district heating areas fuel oil becomes the residual fuel in conventional district heating plants. This means that the order of the fuels in the priority list is less important but typically the cheapest fuels have the highest priority. The maximum loads for each fuel are more important because they directly affect the amount of residual fuel consumed in the district heating area in question.

A forecast of district heat demand until the year 2000 is shown in Table 3.4.

Table 3.4. District heat demand forecast.

	Area heated by district heating, 1986 (10^6m^3	Annual growth in the area heated by district heat until year 2000
Northern italy	27.35	8.8%
Central Italy	0.29	16.6%
Southern Italy	0	0 %
Total, Italy	27.64	

Source (AIRU 1986, and Table 2.6).

In Table 3.5 the simulated primary energy consumption for disstrict heating is listed. The model assumes that 75% of the annual growth in primary energy requirement for district heating will be covered by natural gas according to the general trends in Italian energy planning.

From Table 3.5 it is seen that the annual growth in primary energy for district heating is around 9% for the whole of Italy.

The electricity produced at minor combined heat and power plants with an installed capacity less than 30 MW is treated in the DESS-model as a simple reduction in the electricity demand.

Table 3.5. Primary energy demand for district heating (TJ)

		1986	1990	1995	2000
Northern Italy	Fuel oil	1.483	2.367	3.608	5.501
	Nat. gas	5.273	7.100	10.825	16.503
	Total	6.756	9.467	14.433	22.004
Central Italy	Fuel oil	145	105	226	487
	Nat. gas	82	315	678	1.462
	Total	227	420	904	1.949
Total fuel oil		1.628	2.472	3.834	5.988
Total nat. gas		5.355	7.415	11.503	17.965
Italy total		6.983	9.887	15.337	23.953

4. THE POWER SYSTEM MODULE

In the power system module the total electricity production, split into different power systems and fuels, is simulated. Priority has been given to an analysis of the coordination between hydropower and thermal electricity production.

4.1. The general structure of the power system

The general structure of the Italian power system is shown in Table 4.1 and 4.2.

Table 4.1. The structure of the Italian power system, max. capacity 1986 (MW)

		Max. capacity
Hydropower plants		18047
Thermal power plants:		40215
- fossil	38438	
- geothermal	465	
- nuclear	1312	
Total		58262

Source: ENEL, 1987 (Table 4)

The hydropower capacity amounted to about 30 per cent of the total in 1986. The rest of the thermal capacity was split into traditional fossil production with about 66 per cent of the total power and geothermal and nuclear plants with respectively about 1 and 2 per cent.

Table 4.2. Generation structure for Italy 1986 (GWh)

	1986
Hydropower production	44.531
Traditional thermal production	136.281
Geothermal production	2.760
Nuclear production	8.758
Electricity used for power production[2)]	-9.724
Electricity used for pumping	-4.786
Import-export balance	+22.114
Net production[1)]	199.934

Source: ENEL, 1987 (Table 2)
ENEL, 1982 (Table 2)

1) Corresponding to total useful electricity for consumption plus transmission losses.
2) In connection to reservoirs.

It is seen from Table 4.2 that thermal production contributed to about 68 per cent of the total generation in 1986 and hydropower to about 22 per cent. A net electricity import covered the remainder of the requirements.

The situation is further illustrated in Table 4.3 which shows the fuels used in the plants in 1985 together with estimates for 1990 and 1995.

In the period 1985 to 1995 the total fuel requirements for electricity generation are planned to increase by 22 per cent. (Commissione Industria della Camera, 1984).

Table 4.3. Share of fuels for electricity generation in 1985 and the goals of the national energy plan for 1990 and 1995.

	1985	1990	1995
Coal	14,0	21,4	38,5
Gas	11,8	8,9	6,1
Oil products	38,7	33,9	16,2
Hydro-geo	22,6	19,7	19,2
Nuclear	3,2	7,2	12,3
Import	9,7	8,9	7,7
Total	100,0	100,0	100,0

Source: Commissione Industria della Camera, 1984

In 1985 oil products were a dominating fuel covering about 60 per cent of the fuels in fossil fired thermal production, while coal and gas each covered about 20 per cent.

In the period up to 1995 coal is planned to have a rising share. By 1995 its share will be even greater than that of oil products.

This development is different from the tendency of the power system structure in the last 20 years which is shown in Table 4.4.

Table 4.4. Electricity generation in Italy 1965-1985 (TWh)

	1965	1970	1974	1980	1985
Hydropower	43,0	41,3	39,3	47,5	44,6
Traditional thermal power	33,9	70,2	103,7	133,4	131,4
Geothermal power	2,6	2,7	2,5	2,7	2,7
Nuclear power	3,5	3,2	3,4	2,2	7,0
Power for production and pumping	-2,9	-5,9	-8,9	-11,6	-14,4
Import-export balance	0,3	4,0	2,3	6,1	23,7
Total	80,4	115,5	142,3	180,3	195,0

Source: ENEL, 1977
ENEL, 1982
ENEL, 1987

The development of the power system was in the period 1965 to 1985 characterized by that almost the total increment in power production was covered by an enlargement of the traditional thermal production. At the same time nuclear power production only increased sligthly. The hydropower production was relatively stable in the period.

4.2. The Italian electricity legislation

It is stated in the Italian energy legislation that the government electricity generation company Ente Nazionale Per L'Energia Elettrica (ENEL) is the main producer of electricity. In addition, autoproducers of combined heat and power are permitted to deliver electricity to ENEL under the constraint that capacity of each producer is less than 3 MW. Further some municipal power plants are excepted from this constraint.

Following that ENEL contributed more than 80 per cent to the total electricity production in Italy in 1986 while the shares of autoproducers and municipalities was about 13 and 4 per cent respectively (ENEL, 1987).

Power stations established by municipalities, other local authorities or public organisations are dimensioned according to the heat requirements in the area. Surplus electricity is sold to ENEL at a price given by the Ministry of Industry and Commerce. With ENEL being responsible for the establishment of the necessary connections to the distribution systems. In recent years the contribution from industrial producers has been decreasing.

4.3. The power system optimization principle

As mentioned above the power system module simulates the electricity generation split into different types of plants. In this simulation an advanced optimization method is necessary to describe the variation in durability and marginal and total costs for the different production systems.

The DESS-Model contains a database with technical and economic information about the production systems. The information may be very detailed, covering every single existing or planned power plant, or can be typical data for a specific production system. In the Italian DESS simulation, priority has been given to the analysis of the interaction between thermal power production and hydropower production and therefore the production is represented on an average level.

The optimization problem is fundamentally different for the two cases of thermal power and hydropower simulation. In the thermal power simulation the marginal costs of production must be minimized for every single time step. This means that the base load must be covered by plants with relatively low variable costs (i.e. operation and maintenance costs) and high start-up costs. At the same time, the peak load must be covered by smaller flexible plants with relatively high marginal costs.

Typical base load plants are nuclear power plants and fossil-fired condensing plants. Peak load plants may be diesel engines gas turbines etc. This systemisation method used in the DESSModel has been further described in specific reports (Grohnheit 1986, Larsen 1981).

The hydropower production may be used most efficiently observing two constraints:

- as much as possible of the peak load demand must be covered
- the available amount of water - representing potential energy - must be used in accordance to the reservoir dimensions and the expected amount of water in a given period.

In relation to this it is necessary to manage the hydropower production using models which according to the actual long forecast horizon used in the DESS-model are able to make a relatively precise forecast of the electricity demand and the water amount in the reservoirs.

A miscalculation of the hydropower load can have the consequence that very expensive peak load production from thermal power plants must substitute the peak-load hydropower production. The latter has, in principle, a near zero marginal cost when the water is available.

It is typical for the hydropower simulation problem that the available amount of water varies substantially during the year In some periods of the year, for example in the spring, so much water is available that hydropower may be used for base load as well as peak load production. Conversely in the autumn the hydropower production is used almost exclusively for peak load production.

In a period with relative low water availability hydropower is used only for peak load. In this situation the hydro power plants are run generation only a few hours every day. During the rest of the day the reservoirs may be used as pumped storage using cheap baseload production. Conversely in periods with relative high water availability hydropower plants are used both as base load plants and as peak load plants.

As a consequence of these different management problems for hydropower and thermal power production the Italian DESS simulation is done in three steps. First the hydro power production is simulated. Secondly the import and hydro power production are subtracted from the total production. Finally the thermal power production, split into different types of plants is simulated.

4.4. Load duration curves

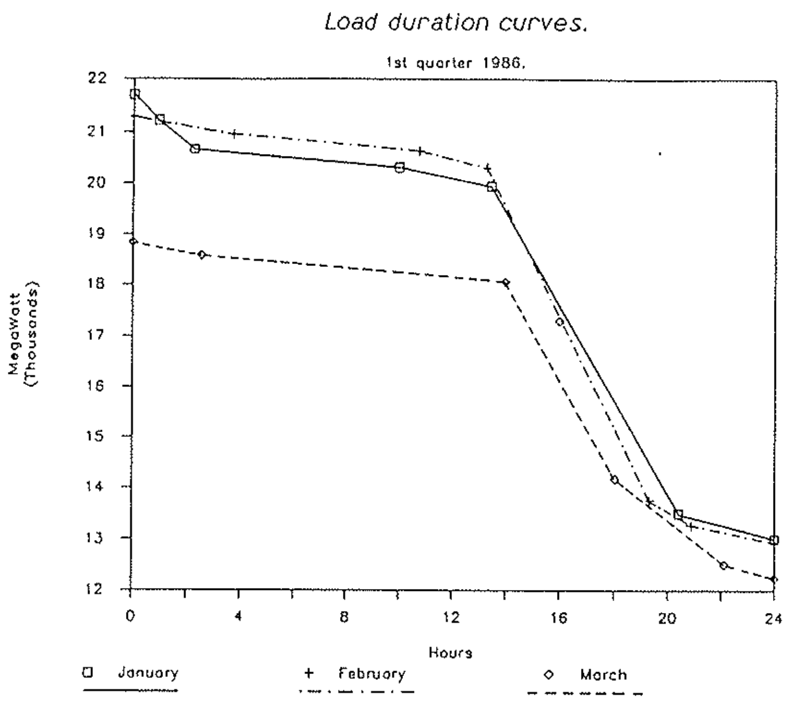
In the DESS-model the power demand as a function of time is represented by load duration curves calculated on basis of time series. Unfortunately only poor data about the Italian power system has been available for these calculations. Therefore the actual simulation are based on 12 24-hour time series for the 3rd Wednesday of each month for only one year, namely 1986 (ENEL 1986). A statistical analysis of the variation of the powerproduction structure (ENEL, 1987 and ENEL 1980) suggests that a reasonable basis model from a statistical point of view would have been load duration curves for about 10 years. As mentioned already this has unfortunately not been available.

The load duration curves for each month of the year which are used in the simulation are calculated on basis of the abovementioned time series for electricity demand for the third Wednesday in each month. These are used as representative average demand data in the simulation.

The load duration curves for the thermal power production are shown for each month of the year in the following figures 4.1a to 4.1d. These illustrate the very different optimization problems which occur in the different periods, depending on water availability.

In the above figures 4.1a to 4.1d the thermal load duration curves are grouped in quarters of the year to show the great deviations within the quarters. If 4 average load duration curves were used in the simulation each representing an average of the quarter, valuable information about the load management problem of the thermal power plants would be lost. A simple mean value load duration curve for each quarter would properly give the right energy production as totals for each year, but forecasts about the amount of electricity produced by peak-load units will be very uncertain and knowledge of the peak load is essential for dimensioning the capacity of the power plants.

Due to these variations we have chosen to use 12 load duration curves in the actual simulation.



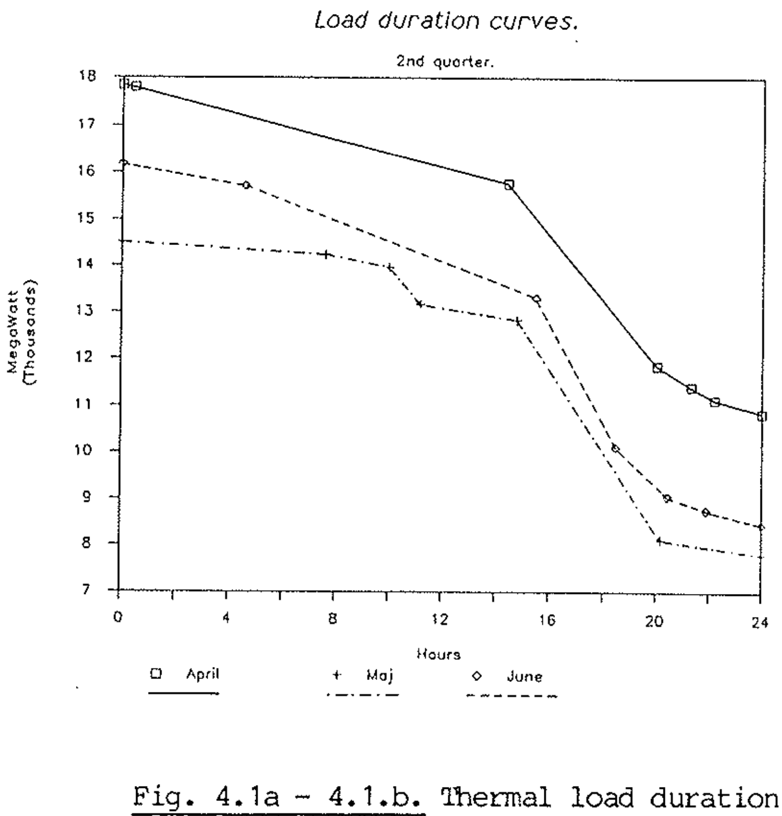
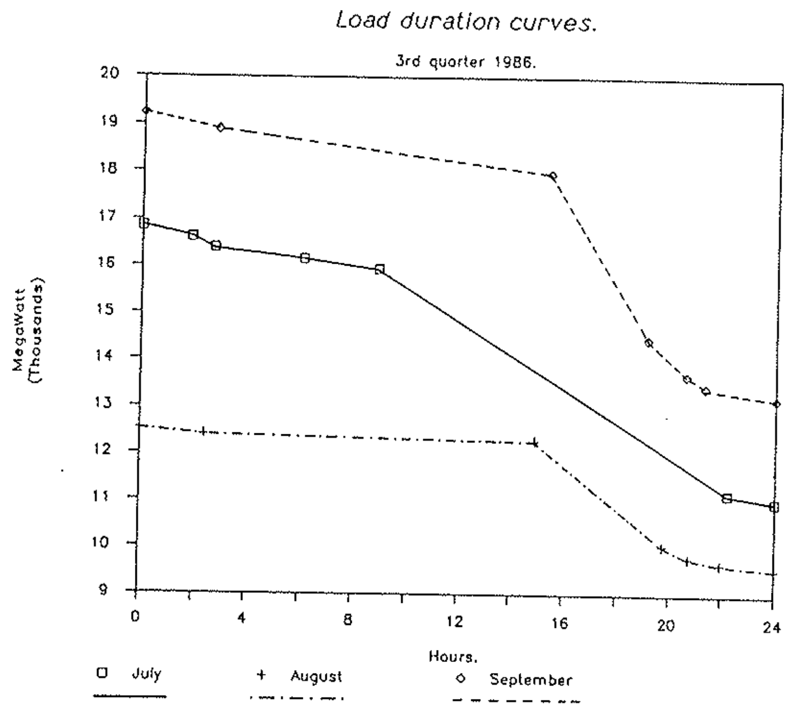


Fig. 4.1a - 4.1.b. Thermal load duration curves for Italy. (For 24 hours x 30 days).



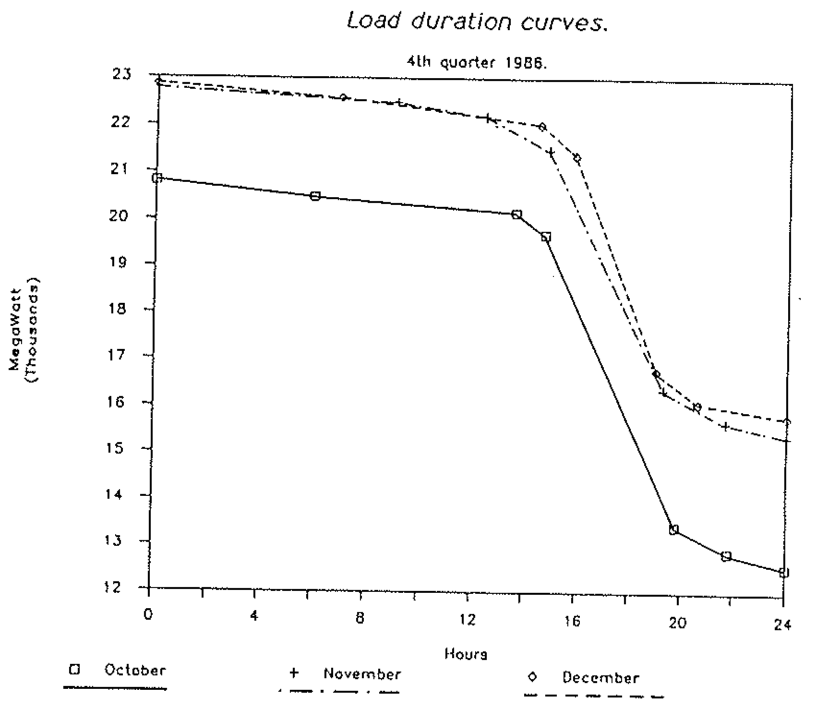


Fig. 4.1.c - 4.1.d. Thermal duration curves for Italy. (For 24 hours x 30 days).

Fig. 4.2 shows the difference in hydropower production between May, the month with largest amount of water available and November where most peak load is covered by thermal power production because of a low water availability.

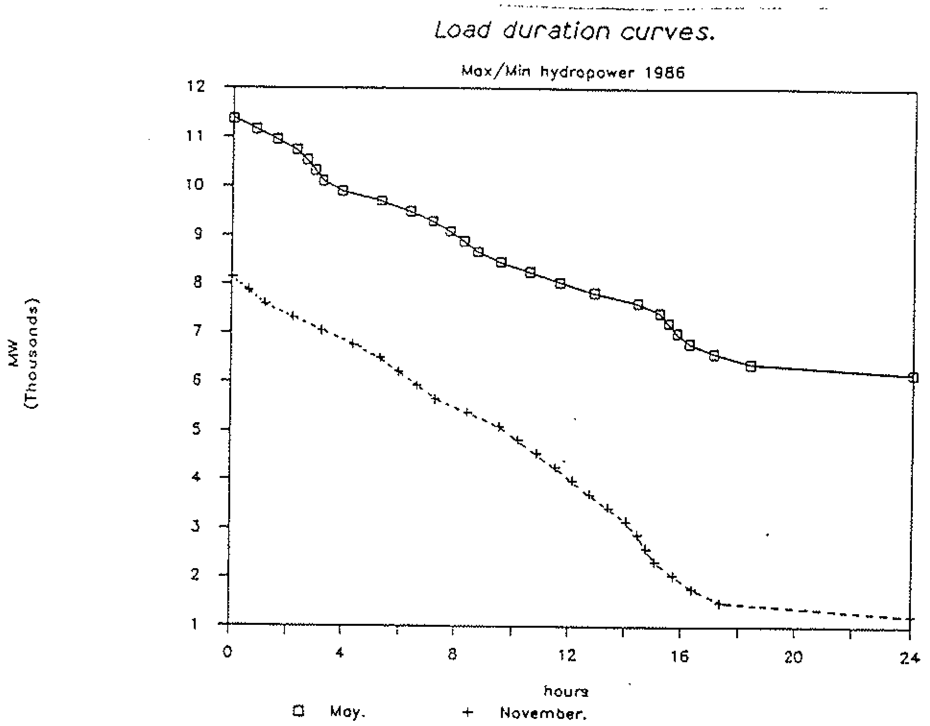


Fig. 4.2. Load duration curves for hydropower production in May and November.

When a great deal of water is available, the hydropower plants are capable of producing electricity both in the peak-load and the base-load hours. The two load duration curves in fig. 4.2 show this effect. The slope of the curve for May is less than the slope of that for November. This means that the hydropower plants produce electricity in shorter time intervals in November than in May.

4.5. Technical database and simulation parameters

The technical database of the DESS-model contains the following data about a unit or groups of identical units in nuclear and thermal power plants. Both existing and planned units are included.

- number of units
- installed capacity
- fuel type
- specific fuel consumption
- fuel consumption for start up and stand by
- investment costs
- costs of operation and maintenance
- minimal power
- reliability factor
- availability factor

For CHP-plants the following additional data are necessary:

- max. electricity production when unit operates in back-pressure mode and relation between power production and heat production.

All data in the database are based on (ENEL 1986) and typical German data about fuel consumption, availability and reliability.

Simulation parameters

The following list contains the main simulation parameters:

- Maximum load: Forecasts for the highest peak load each year.

- Worker's wage: Forecast, used for the costs of operation and maintenance.

- Reserve demand: Forecast for the reserve power which the system must provide during the simulation. This is used for calculating the possibilities for service on - and the availability of the power generating units.

- Fuel prices: Forecast about the development in fuel prices in the simulation period. This is used for calculating the fuels costs of each unit.

- New units: Insertion time of planned power plants. Refers to the technical database.

- Heat demand: Forecasts for the heat demand in each region each month.

Typical values of these parameters are shown in Table 4.6.

Tabel 4.5 Technical database for the Italian power system.

Plant type	No.	Max. Power (MW)	Fueltype	Fuel cons. (kJ/kWh)	Stand by (TJ/year)	Invest. (kLi/kW)	Op.&Maint. (kLi/MWh)	Relia.	Avail.
Comb. eng.	2	5.4	nat. gas	7934	10.8	58	6	0.90	0.85
"	3	540.0	fuel oil	10204	108.0	58	6	0.90	0.85
Gasturbines	3	247.2	nat. gas	12000	494.0	58	6	0.90	0.85
"	3	247.2	fuel oil	11782	494.0	58	6	0.90	0.85
"	10	24.7	gas deriv.	5581	49.4	58	6	0.90	0.85
Condensing	5	1453.0	coal	9136	2910.0	46	5	0.90	0.85
"	2	145.3	lignite	10819	291.0	65	6	0.90	0.85
"	4	1453.0	nat. gas	8939	2910.0	44	2	0.90	0.85
"	13	1453.0	fuel oil	9086	2910.0	38	3	0.90	0.85
"	4	145.3	gas deriv.	10899	291.0	44	2	0.90	0.85
Nuclear	7	253.7	uranium	10200	507.0	55	1	0.90	0.85

Plant type	No.	Max. Power (MW)	Fueltype	Fuel cons. (kJ/kWh)	Stand by (TJ/year)	Invest. (kLi/kW)	Op.&Maint. (kLi/MWh)	C_m	Relia.	Avail.
Back press.	10	43.4	coal	4488	87.0	55	5	.430	0.90	0.85
"	4	4.3	lignite	4459	8.7	70	8	.430	0.90	0.85
"	8	43.4	nat. gas	4794	87.0	58	6	.430	0.90	0.85
"	10	4.3	nat. gas	4794	8.7	58	6	.430	0.90	0.85
"	26	43.4	fuel oil	4836	87.0	42	2	.430	0.90	0.85
"	3	43.4	fuel oil	4836	87.0	42	2	.430	0.90	0.85
"	10	4.3	gas deriv.	4271	8.7	58	6	.430	0.90	0.85
"	1	4.3	other	4748	8.7	80	6	.430	0.90	0.85
Extract.	3	198.1	nat. gas	8667	396.0	39	6	.430	0.90	0.85
"	6	198.1	fuel oil	8495	396.0	34	5	.430	0.90	0.85
"	1	198.1	gas deriv.	13105	396.0	39	6	.430	0.90	0.85
"	4	19.8	other	8730	39.6	45	6	.430	0.90	0.85

Table 4.6. Simulation parameters.

Maximum load	22867 MW		
Worker's wage	12670 Lire/hour		
Reserve demand	20 %		
Fuel prices	Coal	3894	Lire/GJ
	Lignite	2921	"
	Natural gas	6490	"
	Fuel oil	8437	"
	Gas derivate	6490	"
	Other	2921	"
	Uranium	1558	"

Heat demand (GWh)		Northern region	Central region
	January	69.58	0.394
	February	75.42	0.427
	March	64.94	0.368
	April	53.87	0.305
	Maj	41.75	0.237
	June	26.94	0.153
	July	13.92	0.079
	August	13.92	0.079
	September	22.45	0.127
	October	32.47	0.184
	November	49.38	0.280
	December	64.94	0.368
	Total	529.58	3.001

New units — No new plants are brought into service in the simulation period due to lack of data.

Source: AIRU 1986, ELSAM 1978 and ENEL 1986

4.6. Simulation results

In the following Table 4.7 a comparison is made between the actual production structure for thermal power plants in Italy in 1986 and the DESS simulation.

Table 4.7. Simulated relative distribution of the power production in 1986 compared with statistical data (ENEL 1986).

Electricity production	Simulated %	Statistic %
Internal combustion engines	0.50	0.30
Gas turbines	1.90	0.70
Condensating plants	79.70	85.00
Backpressure -	0.10	3.40
Extraction -	8.70	4.60
Nuclear -	9.10	6.00
Total	100.0	100.00

Statistical source: ENEL, 1986

The differences between the simulated electricity generation and the statistical data is probably due to the following uncertainties in the model and data.

The availability of the Italian nuclear power plants is based on German data. If the correct availability for the Italian plants is lower than the data used in the simulation the nuclear production will decrease correspondingly. Furthermore the heat demand in the CHP districts is based on data on heat consumption and its geographical distribution. In the model Italy is split in 2 heat regions covering Northern and Central Italy and a similar distribution is made for the backpressure and extraction power plants. If the heat demand for these regions is overestimated then the corresponding electricity generation from these units will also be overestimated.

A correction towards a lower heat demand will increase the amount of electricity produced by condensing power plants.

The model assumes that all electricity produced in Italy can be distributed all over Italy without any restriction due to e.g. limited transmission capacities. This assumption may certainly influence the production by the various plants and result in a distribution different from the actual.

The load duration curves used in the simulation are based on load time series in which the 3rd Wednesday is assumed to be a typical day in each month. Comparisons between 1985 and 1986 statistics show only small differences in the load time series. This data may, however, introduce some uncertainties.

The numerical methods used for the calculation of load duration curves on the basis of time series as described above, including the conversion to the 6-straight line approximation, add an uncertainty of at most 3% to the total energy production. This uncertainty is calculated as the difference between the power production integrated from the time series and the power production integrated from the load duration curves.

4.7. Trends and possible scenarios for the Italian energy system

The model has been used for a simulation of the power generation structure for the period 1985 to 2000 under the constraint that the fuels used for thermal power generation are used according to a cost minimization principle. This simulation is based on a test development plan for the Italian power system (shown in Table 4.8), where all new plants constructed between 1990 and 1999 are coal fired thermal plants.

The simulation results are shown in Table 4.9. Compared with the actual fuel consumption in Italian thermal power plants the simulation gets out with a relative high share of natural gas and coal while fuel oil becomes a less important fuel than it actually is. This result depends on the fuel prices referred in Table 4.6 where coal and natural gas as a relatively cheap fuels displace fuel oil.

Tabel 4.8. Development plans for the Italian power system (Test data).

Construction year	Plant type	No.	Max. Power (MW)	Fueltype	Fuel cons. (kJ/kWh)	Stand by (TJ/year)	Invest. (kLi/kW)	Op.&Maint. (kLi/MWh)	C_V
1990	Condensing	1	700	coal	9400	1400	30	6.3	–
1991	"	1	700	coal	9400	1400	30	6.3	–
1992	"	1	700	coal	9400	1400	30	6.3	–
1993	"	1	700	coal	9400	1400	30	6.3	–
1994	"	1	700	coal	9400	1400	30	6.3	–
1995	"	2	700	coal	9400	1400	30	6.3	–
1996	"	2	700	coal	9400	1400	30	6.3	–
1997	"	2	700	coal	9400	1400	30	6.3	–
1998	"	2	700	coal	9400	1400	30	6.3	–
1999	"	2	700	coal	9400	1400	30	6.3	–
1999	Extract.	1	350	coal	9700	700	57	9	.579
1999	"	1	350	coal	9700	700	57	9	.579

Table 4.9. Simulated primary energy requirements for thermal power production in Italy.

Electricity simulation			1985	1986	1987	1988	1989	1990	1995	2000
Elsimul.·	fuel demand	TJ	1186680	1259420	1301799	1346999	1392709	1440766	1678812	2032521
Fuel	Coal	TJ	443848	444535	444739	444753	444902	488864	752164	1141183
Fuel	Lignite	TJ	21567	21567	21586	21567	21608	21567	21575	22801
Fuel	Natural gas	TJ	323345	337486	345910	350736	357048	354232	338382	315827
Fuel	Fuel oil	TJ	229447	285799	318461	318461	396230	403410	396559	385194
Fuel	Gas derivate	TJ	42957	44518	45589	45589	47405	47178	44616	41980
Fuel	Other combustible	TJ	4080	4080	4080	4080	4080	4080	4080	4101
Fuel	Uranium	TJ	121434	121434	121434	121434	121434	121434	121434	121434

5. THE PROCESS MODULE

In the process module the total fuel requirement for process energy purposes is simulated. The process energy requirements are split into the three sectors: industry, agriculture and the service sector. For this three sectors the fuel consumption for the period 1980-2000 is calculated for the following five energy forms:

1. Solid fuels
2. Oil products
3. Gas
4. Electricity
5. Other fuels

The energy demand forecasting model MEDEE 3 is used as a source for the sector specific fuel requirements. (Bingen, 1985).

The simulation results are shown in the following table 5.1.

Table 5.1. Simulation of fuel requirements for process purposes in Italy 1980-2000 (PJ).

FUEL CONSUMPTION BY SECTOR

FUELS PJ			1980	1981	1984	1985	1986	1987	1990	1995	2000
PR21:	1;SOLID FUELS INDUSTRY	PJ	206.00	204.75	201.00	199.75	198.50	197.25	193.50	187.25	181.00
PR21:	2;OIL PRODUCTS INDUSTRY	PJ	889.00	881.37	858.48	850.85	843.22	835.59	812.70	774.55	736.40
PR21:	3;GAS INDUSTRY	PJ	520.00	534.95	579.80	594.75	609.70	624.65	669.50	744.25	819.00
PR21:	4;ELECTRICITY INDUSTRY	PJ	337.70	342.79	358.06	363.15	368.24	373.33	383.60	414.05	439.50
PR21:	5;OTHER FUELS INDUSTRY	PJ	4.90	4.93	5.02	5.05	5.08	5.11	5.20	5.35	5.50
PR22:	1;SOLID FUELS AGRICULTURE	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR22:	2;OIL PRODUCTS AGRICULT.	PJ	92.40	93.23	95.72	96.55	97.38	98.21	100.70	104.85	109.00
PR22:	3;GAS AGRICULTURE	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR22:	4;ELECTRICITY AGRICULTURE	PJ	8.80	9.14	10.16	10.50	10.84	11.18	12.20	13.90	15.60
PR22:	5;OTHER FUELS AGRICULTURE	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR23:	1;SOLID FUELS SERVICESEC.	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR23:	2;OIL PRODUCTS SERVICESEC.	PJ	158.50	156.54	150.66	148.70	146.74	144.78	138.90	129.10	119.30
PR23:	3;GAS SERVICE SECTOR	PJ	61.70	62.50	64.90	65.70	66.50	67.30	69.70	73.70	77.70
PR23:	4;ELECTRICITY SERVICESEC.	PJ	79.00	82.50	93.00	96.50	100.00	103.50	114.00	131.50	149.00
PR23:	5;OTHER FUELS SERVICESEC.	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR31	;INDUSTRI FUEL TOTAL	PJ	1957.60	1968.79	2002.36	2013.55	2024.74	2035.93	2069.50	2125.45	2181.40
PR32	;AGRICULT. FUEL TOTAL	PJ	101.20	102.37	105.88	107.05	108.22	109.39	112.90	118.75	124.60
PR33	;SERVICESEC. FUEL TOTAL	PJ	299.20	301.54	308.56	310.90	313.24	315.58	322.60	334.30	346.00

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FUELS TJ			1980	1981	1984	1985	1986	1987	1990	1995	2000
PR11	;SOLID FUEL TOTAL	PJ	206.00	204.75	201.00	199.75	198.50	197.25	193.50	187.25	181.00
PR12	;OIL PRODUCTS TOTAL	PJ	1139.90	1131.14	1104.86	1096.10	1087.34	1078.58	1052.30	1008.50	964.70
PR13	;GAS TOTAL	PJ	581.70	597.45	644.70	660.45	676.20	691.95	739.20	817.95	896.70
PR14	;ELECTRICITY TOTAL	PJ	425.50	434.43	461.22	470.15	479.08	488.01	514.80	559.45	604.10
PR15	;OTHER FUELS TOTAL	PJ	4.90	4.93	5.02	5.05	5.08	5.11	5.20	5.35	5.50

As shown in table 5.1, the total fuel requirement for process energy is the main part of the process energy consumption with a share of more than 80 per cent of the total fuel consumption. The industrial fuel consumption grows by about 11 per cent from 1957,6 PJ in 1980 to 2181,4 PJ in 2000. In this period the industrial consumption of solid fuels and oil products decreases while the gas and electricity consumption increases. Also fuel consumption in the service sector and the agricultural sector is expected to increase from 1980-2000 and the same tendencies is expected in the development of the different types of fuels as for the industrial sector.

6. THE TRANSPORT MODULE

The transport module simulates the total fuel requirements in the period 1980-2000 for the following different forms of transport: Railway transport, road transport, air transport and sea transport. For these four transport forms the fuel consumption split in the following five fuels is calculated:

1. Petrol
2. Gasoil
3. LPG
4. Aviation fuel
5. Electricity

The energy demand forecasting model MEDEE 3 is used as a source for the fuel requirements for the different forms of transport (Bingen, 1985).

The simulation results are shown in the following Table 6.1.

Table 6.1. Simulation of fuel requirements for transport purposes in Italy 1980-2000 (PJ).

FUEL CONSUMPTION BY SECTOR			1980	1981	1984	1985	1986	1987	1990	1995	2000
FUELS PJ											
TR21:	1;PETROL RAILWAY	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR21:	2;GASOIL RTAILWAY	PJ	7.15	7.39	8.11	8.35	8.59	8.83	9.55	10.75	11.95
TR21:	3;LPG RAILWAY	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR21:	4;AIR FUEL RAILWAY	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR21:	5;ELECTRICITY RAILWAY	PJ	16.96	17.32	18.40	18.76	19.12	19.48	20.56	22.36	24.16
TR22:	1;PETROL ROAD TRANSPORT	PJ	513.64	509.02	495.16	490.54	485.92	481.30	467.44	444.34	421.24
TR22:	2;GASOIL ROAD TRANSPORT	PJ	367.57	380.07	417.57	430.07	442.57	455.07	492.57	555.07	617.57
TR22:	3;LPG ROAD TRANSPORT	PJ	33.31	34.51	38.11	39.31	40.51	41.71	45.31	51.31	57.31
TR22:	4;AIR FUEL ROAD TRANSPORT	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR22:	5;ELECTRICITY ROAD TRANSP.	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR23:	1;PETROL AIR TRANSPORT	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR23:	2;GASOIL AIR TRANSPORT	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR23:	3;LPG AIR TRANSPORT	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR23:	4;AIR FUEL AIR TRANSPORT	PJ	59.04	59.25	59.88	60.09	60.30	60.51	61.14	62.19	63.24
TR23:	5;ELECTRICITY AIR TRANSP.	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR24:	1;PETROL SEA TRANSPORT	PJ	7.49	7.42	7.21	7.14	7.07	7.00	6.79	6.44	6.09
TR24:	2;GASOIL SEA TRANSPORT	PJ	7.70	7.96	8.74	9.00	9.26	9.52	10.30	11.60	12.90
TR24:	3;LPG SEA TRANSPORT	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR24:	4;AIR FUEL SEA TRANSPORT	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR24:	5;ELECTRICITY SEA TRANSP.	PJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TR31	;RAILWAY FUEL TOTAL	PJ	24.12	24.72	26.52	27.12	27.72	28.32	30.12	33.12	36.12
TR32	;ROAD FUEL TOTAL	PJ	914.52	923.60	950.84	959.92	969.00	978.08	1005.32	1050.72	1096.12
TR33	;AIR FUEL TOTAL	PJ	59.04	59.25	59.88	60.09	60.30	60.51	61.14	62.19	63.24
TR34	;SEA FUEL TOTAL	PJ	15.19	15.38	15.95	16.14	16.33	16.52	17.09	18.04	18.99

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FUELS			1980	1981	1984	1985	1986	1987	1990	1995	2000
TJ											
TR11	;PETROL TOTAL	PJ	521.13	516.44	502.37	497.69	492.99	488.30	474.23	450.79	427.33
TR12	;GASOIL TOTAL	PJ	382.43	395.43	434.43	447.43	460.43	473.43	512.43	577.43	642.43
TR13	;LPG TOTAL	PJ	33.31	34.51	38.11	39.31	40.51	41.71	45.31	51.31	57.31
TR14	;AIR FUEL TOTAL	PJ	59.04	59.25	59.88	60.09	60.30	60.51	61.14	62.19	63.24
TR15	;ELECTRICITY TOTAL	PJ	16.96	17.32	18.40	18.76	19.12	19.48	20.56	22.36	24.16

The main consumer of the energy in the transport sector is as Table 6.1 shows road transport which amounts to about 90 per cent of the total fuel consumption. Petrol amount to about 56 per cent of the road transport fuel consumption and gasoil almost covers the rest of the requirements.

It is assumed in the simulation that the total consumption of the different transport fuels will develop in the following way from 1980 to 2000. The petrol consumption will fall with about 18 per cent, gasoil consumption will grow by 68 per cent, LPG consumption will grow by 72 per cent, aviation fuel will grow by 7 per cent and finally electricity consumption will grow by 43 per cent. As a result the total fuel consumption for transportation is expected to increase by 20 per cent from a level of 1012 PJ in 1980 to 1215 PJ in 2000.

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Title and author(s)	
Simulation of the Italian Energy System with the DESS-Model Kirsten Halsnæs Henrik Sørensen	**Date** June 1989 **Department or group** Systems Analysis **Groups own registration number(s)** 4426547-85-059 **Project/contract no.** EN3M-0022-DK

Pages 69 **Tables** 28 **Illustrations** 10 **References** 17 **ISBN** 87-550-1542-5

Abstract (Max. 2000 char.)

Abstract. This report describes a simulation of the Italian energy system for the period 1980 to 2000 with the energy simulation model DESS (Detailed Energy Simulation System). The Italian model comprises a detailed database for the most important part of the energy demand and conversion system. This database is split into the following five parts: the building stock, district heating, power system, the process sector, and the transport sector. As a result of the simulation a total gross energy balance for Italy is generated. The actual simulation referred to in this report is made according to some main assumptions in the National Italian Energy Plan where nuclear power production is kept constant and all new constructed power plants are coal fired.

Descriptors – EDB

COMPUTERIZED SIMULATION; D CODES; DISTRICT HEATING; ENERGY CONSUMPTION; ENERGY DEMAND; HYDROELECTRIC POWER PLANTS; ITALY; NUMERICAL DATA; SPACE HEATING; THERMAL POWER PLANTS

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