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HJORTEKAER - A CENTRAL SOLAR HEATING PLANT WITH SEASONAL STORAGE

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ABSTRACT

Calculations and system design of the central solar heating plant with seasonal storage has been carried through.

The solar energy system and the houses are considered to be situated nearby the Technical University of Denmark and next to a small residential quarter named Hjortekaer.

The heat requirement is covered by heat from a solar energy system with a heat pump. It has been provided that at least 80% of the energy demand for DHW and space heating is covered by solar energy, and the remainder by electricity for the heat pump. An oil fired hot water boiler is connected as a reserve and peak load heat facility.

The solar energy system consists of 6.600 m^2 high efficient flat plate solar collectors mounted on the roofs of 200 terrace houses. Each terrace house has a space heating load of 10.000 kWh/yr and a DHW of 3.500 kWh/yr. The heat storage is a 49.400 m^3 excavated pyramidical pit, uninsulated at the store/soil interface. The temperature in the storage has a maximum temperature of about 40°C and a minimum temperature of about 10°C.

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DESCRIPTION OF THE SURROUNDING ENVIRONMENT

Location and site

The solar heating plant and the houses are considered to be situated on an area of 500.000 m^2 open, flat land nearby the Technical University of Denmark and next to a small residential quarter named Hjortekaer. Hjortekaer is situated about 10 kilometers NNW of Copenhagen in the latitude of 55° N 45', the longitude of 12° E 30', and located at an altitude of 40 m above sea level. The ground water is located 40 m below the ground, and the area presents no geotechnical problems in order to excavate a pyramidical water pit for the heat storage.

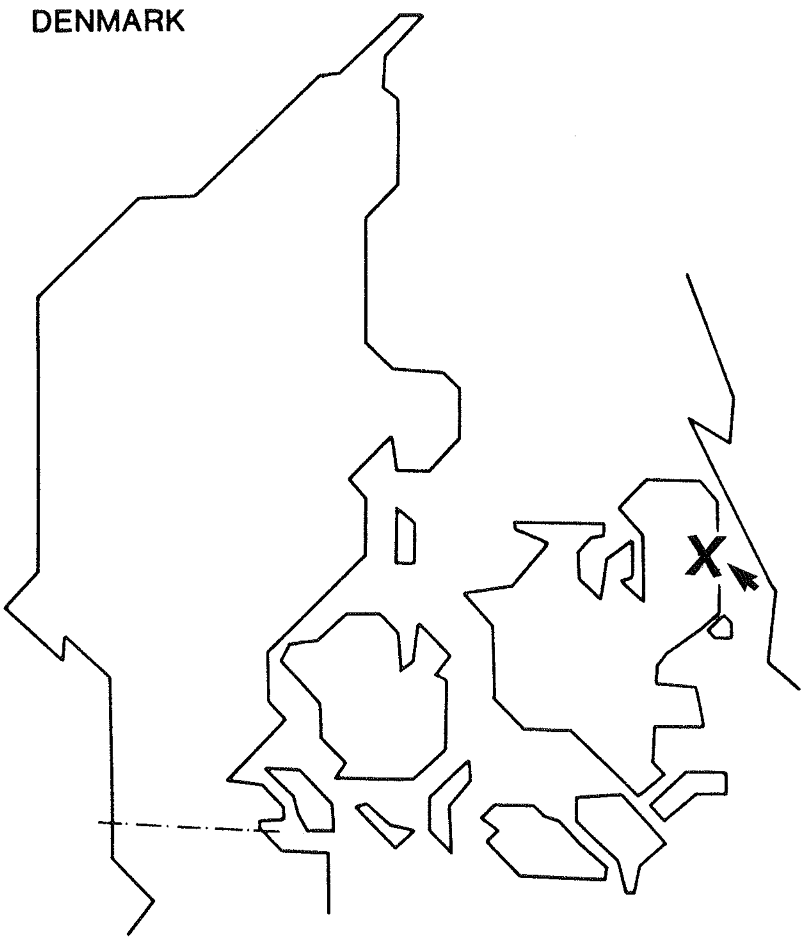

Figure 1. The location of the solar seasonal storage system

Climate

The climate data are based on data from the Danish Test Reference Year. Figure 2 shows the monthly average outdoor temperature and the monthly solar radiation.

The number of degree days are 2850. The degree days are calculated from a theoretical room temperature of 17°C.

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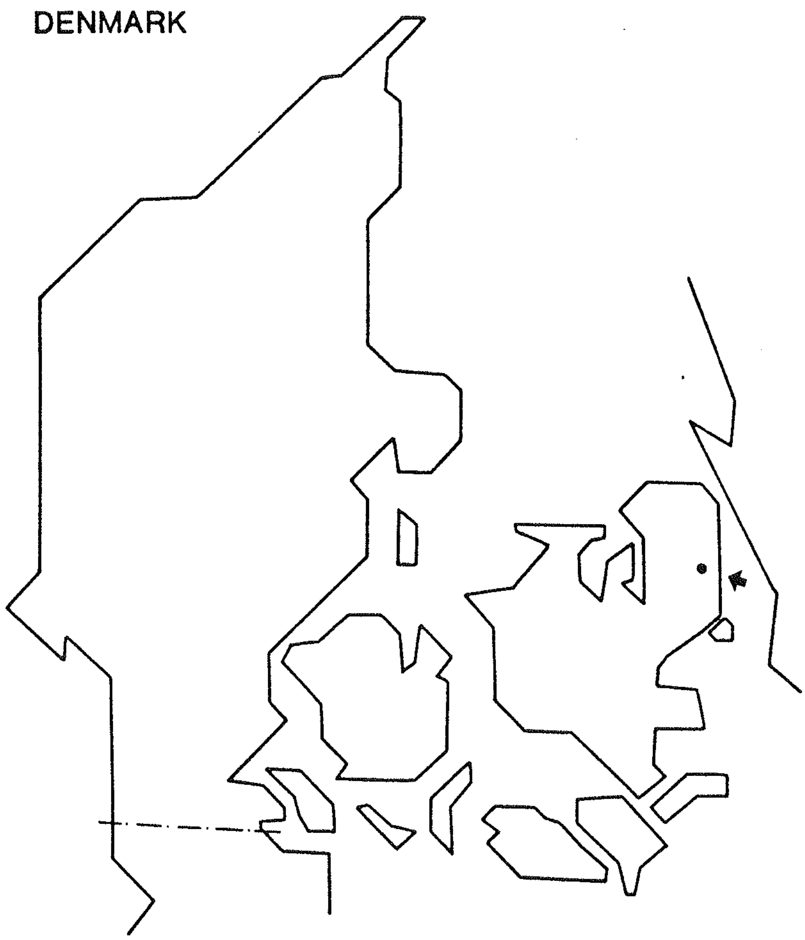

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Month	Average Temp. [°C]	Solar Radiation [MJ/m^2]
1	-1	96
2	-1	207
3	3	270
4	7	485
5	11	568
6	16	646
7	16	570
8	17	543
9	14	387
10	9	246
11	5	139
12	2	123
Year	mean: 8	total: 4280 (1190 kWh/m^2)

Figure 2. The monthly average outdoor temperature and the monthly solar radiation

ARCHITECTURAL INFORMATION

Site plan

The selected site plan of the entire project is shown in figure 3. The number of single family houses is 200 and most of the houses are terrace houses with one common wall. Each house has a residential floor area of 150 m^2 and the area of a single building parcel is approx. 800 m^2.

In the solar heating plant the storage system is a 49.400 m^3 pyramidical water pit, uninsulated at the store/ground interface. The area occupied by the storage itself is about 10.000 m^2 which is about 8% of the total area. The location of the small secondary storage and the subsidiary buildings is just beside the primary storage.

The collector array consists of high efficient flat plate collectors mounted on the roofs, as shown in figure 4 (33 m^2/house). The collectors have a selective absorption surface and the energy supply to the storage is about 450 kWh/m^2 at the temperatures 56°C/30°C. The collectors are in operation only for half a year.

The load

The dimensioning heat loss for a terrace house is 4240 W based on an outdoor temperature of -12°C and a theoretical indoor temperature of 17°C. This heat loss gives a load for space heating of 10.000 kWh/yr.

A simple model for domestic hot water consumption has been established. The total consumption per house is 3.500 kWh/yr.

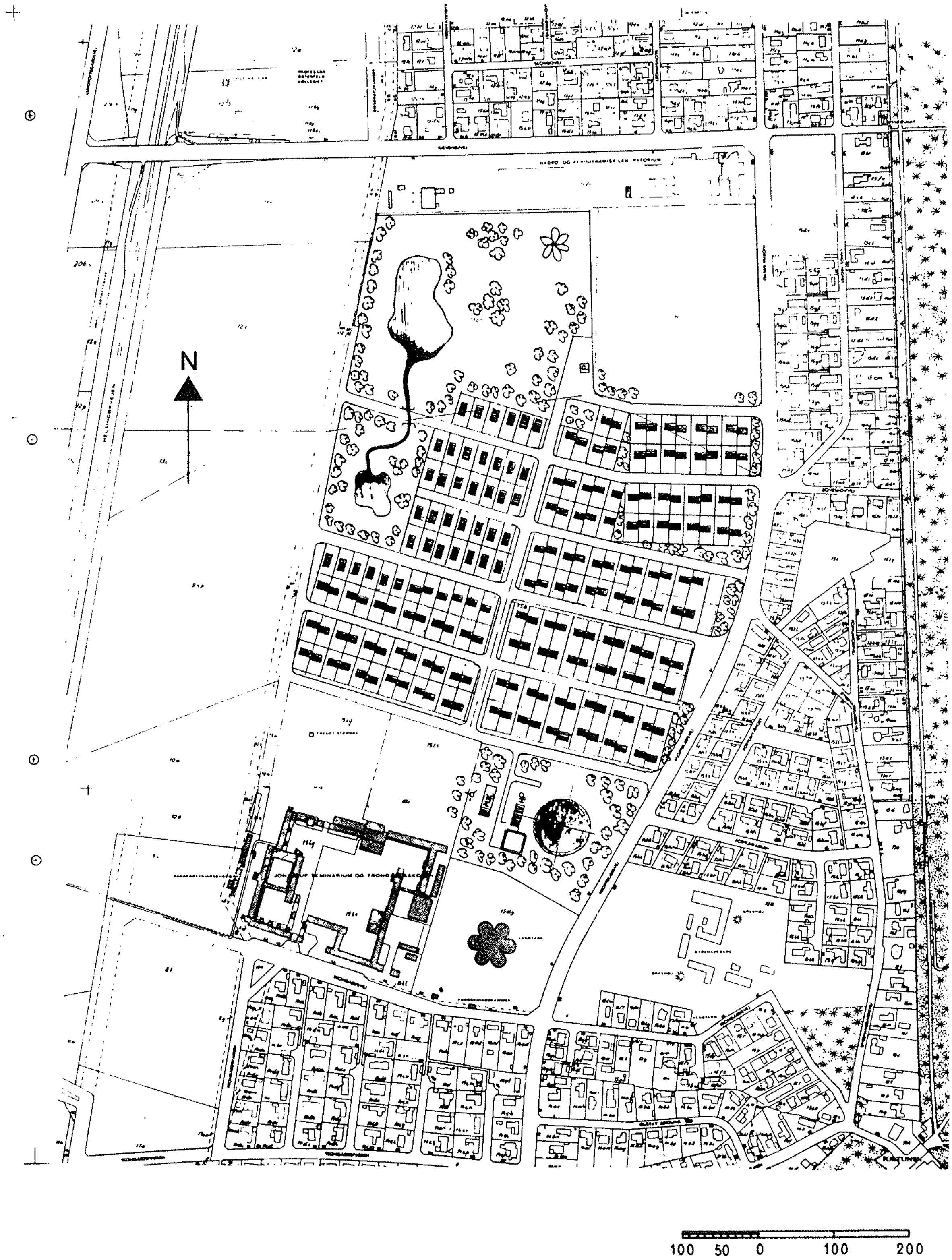

Figure 3. The site plan of the entire project.

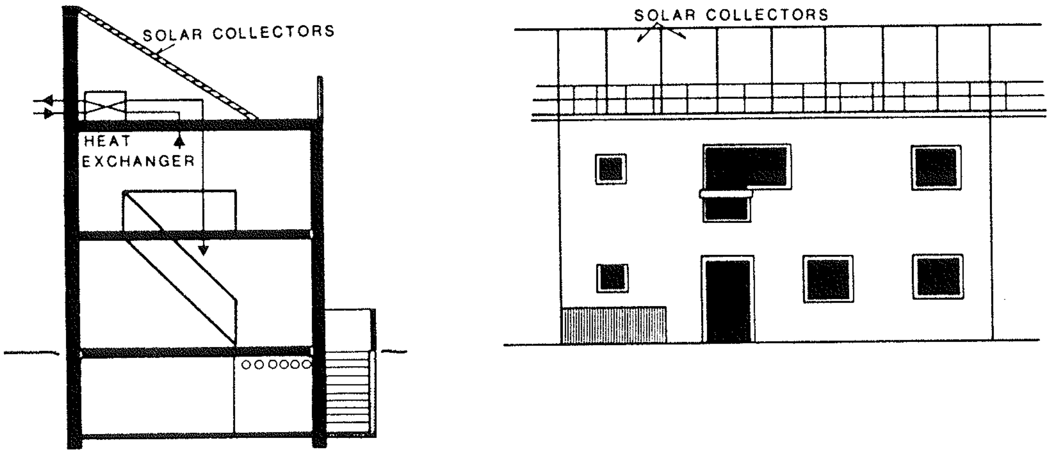

Figure 4. Cross section and south front of a terrace house

SYSTEM DESIGN

The basic design of the system is shown in figure 5. A heat pump is located between the pit and the daily buffer storage (the secondary storage), and the heat pump is working when the temperature in the pit is below 50°C.

The water for the houses is supplied by a two-pipe district heating system with a palm tree structure. The forward temperature is always 40°C and the return temperature varies between 25°C in winter and 36°C in summer. The mass flow rate is constant during the year.

In the houses the water is circulated partly directly through the radiators and partly through a heat exchanger in the DHW store. The DHW heated in this way is not warm enough for dishwashing, so the few liters of water for this purpose must be reheated in an electric heater.

SYSTEM PERFORMANCE

The performance is theoretically determined with a Danish computer program, Dytczak et al. (1983), and in figure 6 the results are indicated by curves for the whole year with a timestep equal to one day. Especially it can be seen that the average temperature in the store varies between 40.5°C and 10.0°C, and that the heat pump is working the whole year.

The annual energy supplied by the solar plant on a monthly basis is shown in figure 7. The montly load is divided into the portion supplied by solar energy and the portion supplied by electrical energy. On an annual basis the solar utilization is 83% and the amount of electricity 17% of the total energy delivered by the system.

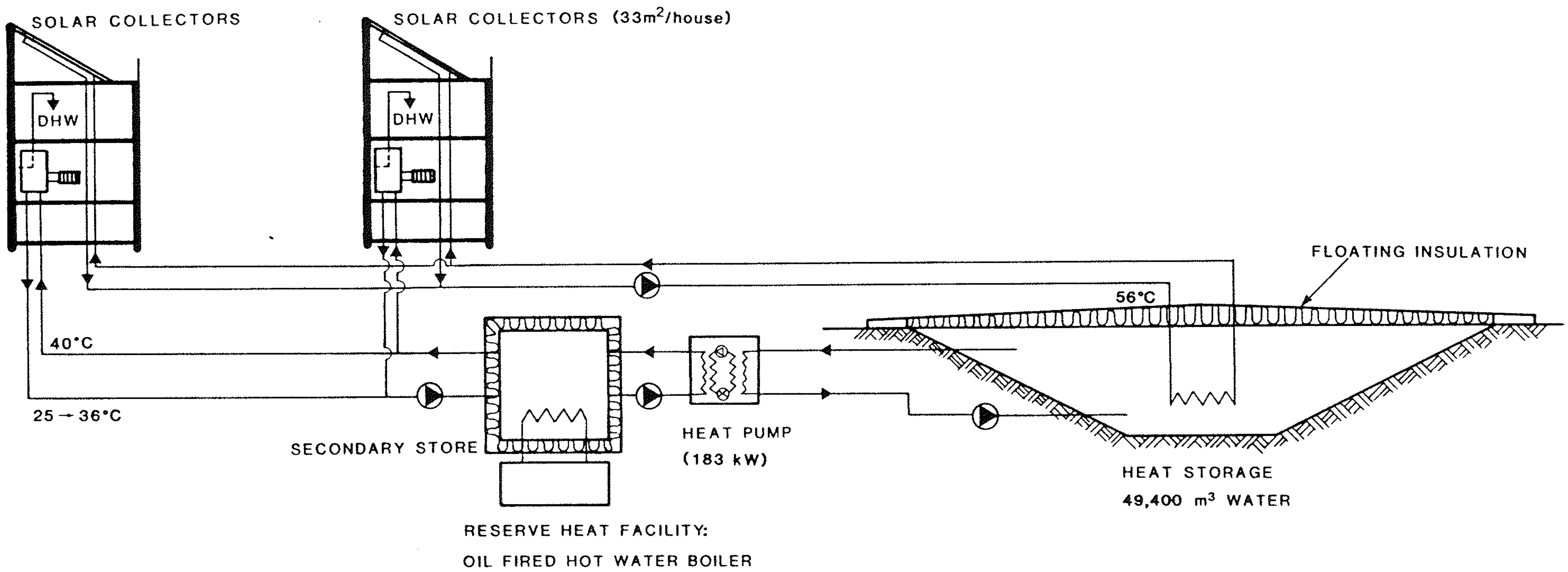

Figure 5. System designed for 200 single family houses. The heat storage is an escavated pyramidical pit uninsulated at the store/ground interface.

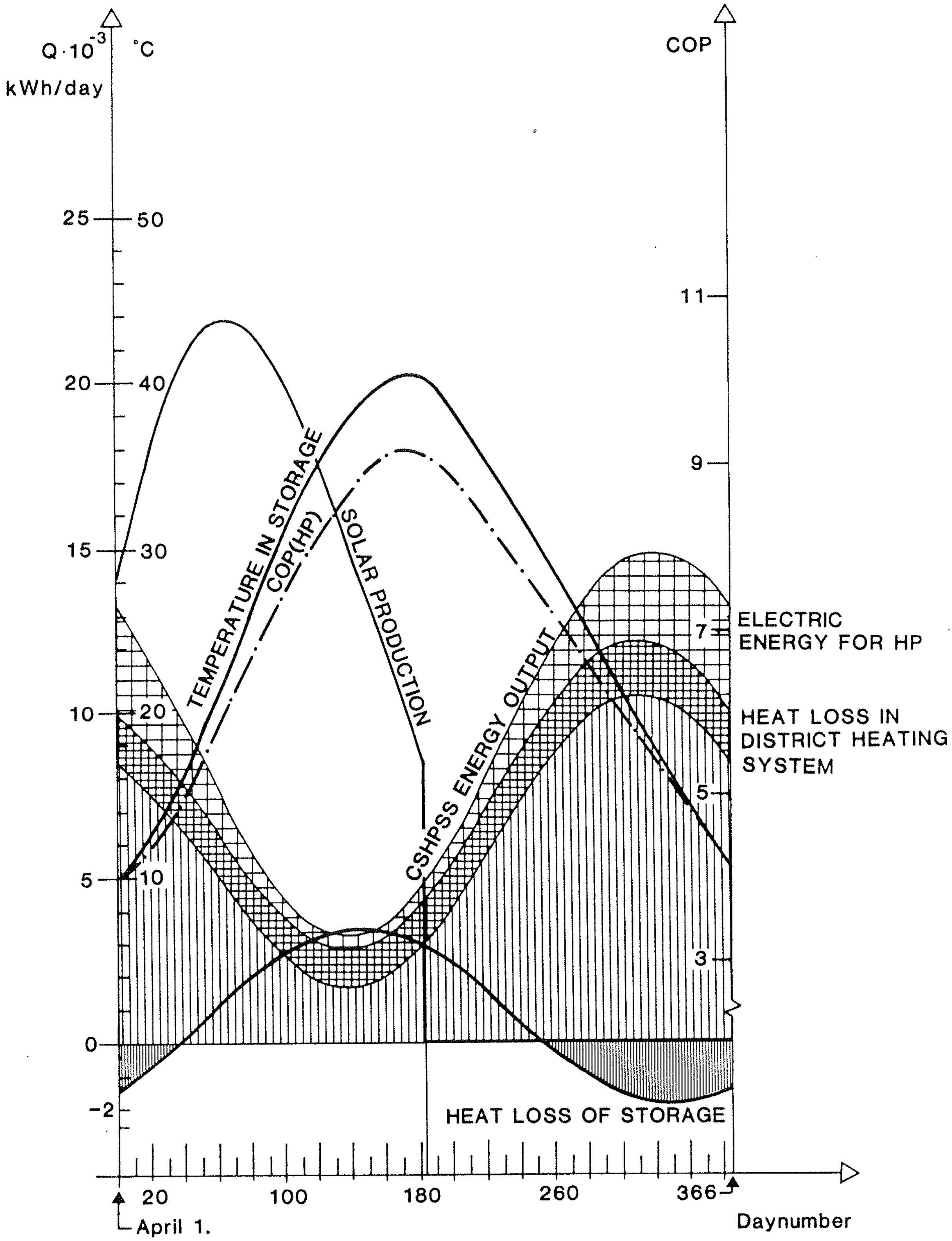

Figure 6. Energy performance of solar system with seasonal storage for 200 single family houses. The total area of solar collectors is 6.600 m^2, and the storage is 49.400 m^3.

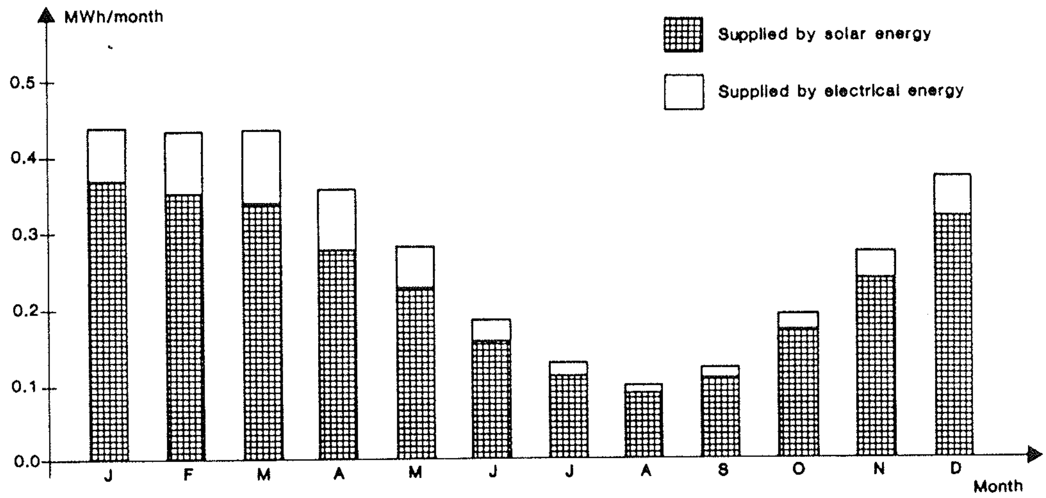

Figure 7. Energy supplied by the system on a monthly basis

ECONOMICS

The total life-cycle costs for the system are calculated with the present value method. In the calculations the initial investment as well as future replacements and operating costs are taken into account (prices July 1980 "constant dollars"). With a collector price of 150 US$/$m^2$, a store price of 20 US$/m^3, an electricity price of 0.17 US$/kWh and a life-cycle of 30 years, the price for the energy from the solar plant is 0.11 US$/kWh.

This energy price is almost identical with the price of electricity. This shows that the CSHPSS seems to be economically attractive.

ACKNOWLEDGEMENT

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