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The Low-Energy House Project
The Danish Ministry of Energy

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127

Thermal Insulation Laboratory
Technical University of Denmark
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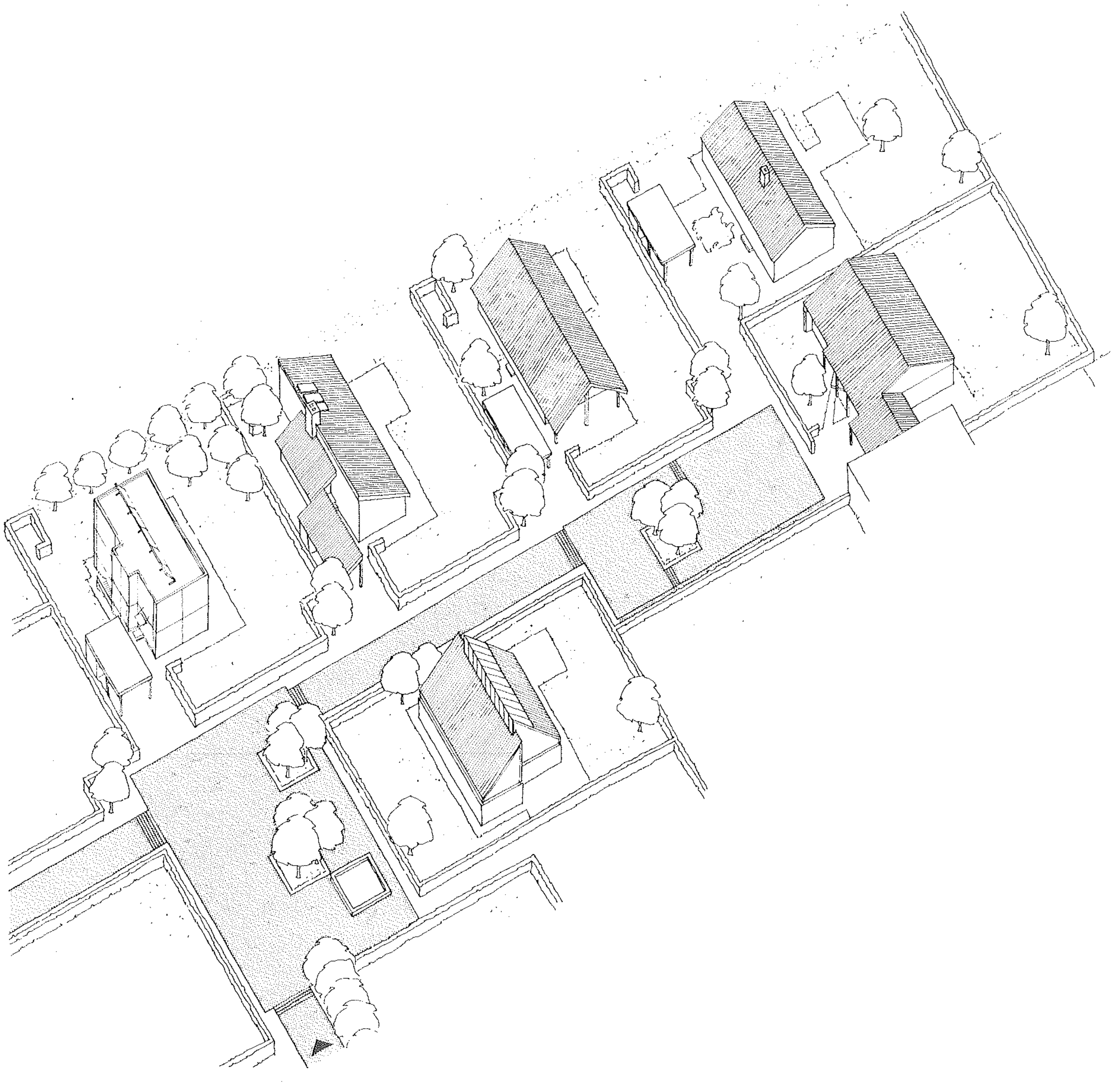

DO CONSERVATION HOUSES REQUIRE SOPHISTICATED TECHNICAL INSTALLATIONS ?

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ABSTRACT

Investigations on the performance of the technical installations in six different low-energy houses in Denmark have shown that traditional design technique is not sufficient to secure high energy conservation effect. For the maximum utilization of the free heat it is necessary that the heating system can be completely switched off. For heating systems including water for energy transportation the inevitable energy losses from the distribution lines and from boilers should be minimized. The operation time for pumps, magnetic valves and other energy consuming devices should be minimized too.

The paper shows measured values and energy balances for selected heating systems from six low-energy houses. Proposals for improvement of the installations are shown.

INTRODUCTION

Some investigations on the energy performance of the installations in six different conservation houses have shown that designers of heating systems for such houses have to realize, that heat losses from installations in some cases may spoil the efforts of conserving energy by using well insulated constructions.

At Hjortekær, north of Copenhagen, six different low-energy houses have been designed and built in 1978-79. The houses are detached, single family houses with a living area of 120 m^2. The constructions are heavily insulated (200 - 300 mm of insulation material in outer walls and 300 - 400 mm in roofs) they have very low infiltration rates (.03 - .09 a.c.h.) (1) and all of them are supplied with mechanical ventilation systems including energy recovering units.

A common feature for the six houses is that the design value of the amount af energy bought for heating, ventilation and domestic hot water should not exceed 5000 kWh/year (corresponding to 650 litres of oil). Denmark has 70,000 degree hours/year.

During the years 79 to 81 intensive and detailed energy measurements have been carried out in the houses by a team from the Technical University of Denmark. In shorter periods special investigations on the performance of the technical installations (boilers, heat pumps, hot water tanks, heating systems etc.) have taken place.

The heating systems included in the analysis range from electric ceiling heating, conventional radiator heating, warm air heating to floor heating with pipes in concrete slabs (2).

The main results of the investigations are:

1. The thermal insulation of the houses has fulfilled the aim of the project, so that the calculated and the measured transmission losses correspond quite well.

2. The air tightness of the houses being remarkably high is obtained by consequent utilization of well-known and simple technology.

3. In some of the houses the energy consumption has been much higher than predicted - due to the performance of the heating systems.

This paper deals with the installations, some of the systems are analysed, consumption figures are shown and it is pointed out how important it is to take care of every small amount of energy in conservation houses.

ENERGY BALANCE, HOUSES

For a typical low-energy house of 120 m^2 with a window area of 21 m^2 (11 m^2 facing south, 5 m^2 facing west) the calculated energy balance is shown in table 1. The calculations are based on the programme BA-4 (3) and the Danish reference year (4). The transmission and ventilation losses are covered by the utilized amount af free heat, by the heat recovery from the exhaust air and by supply from the heating system. Especially in the summer months the amount of available free heat cannot be completely utilized. The free heat consists of solar gain through the windows, emission from persons and emission from electrical lighting and house keeping. Hourly values of the emission from persons and lighting has been fixed according to a standard pattern of living for a Danish family of four persons (5). The same pattern has been used during the simulated habitation of the houses Oct. 78 to Apr. 80. The normal room temperature is 21 C. If the room temperature due to solar gain etc. exceeds 25 C the remaining free heat is marked unusable.

Figure 1

HEATING REQUIREMENTS ON FEB. 19.

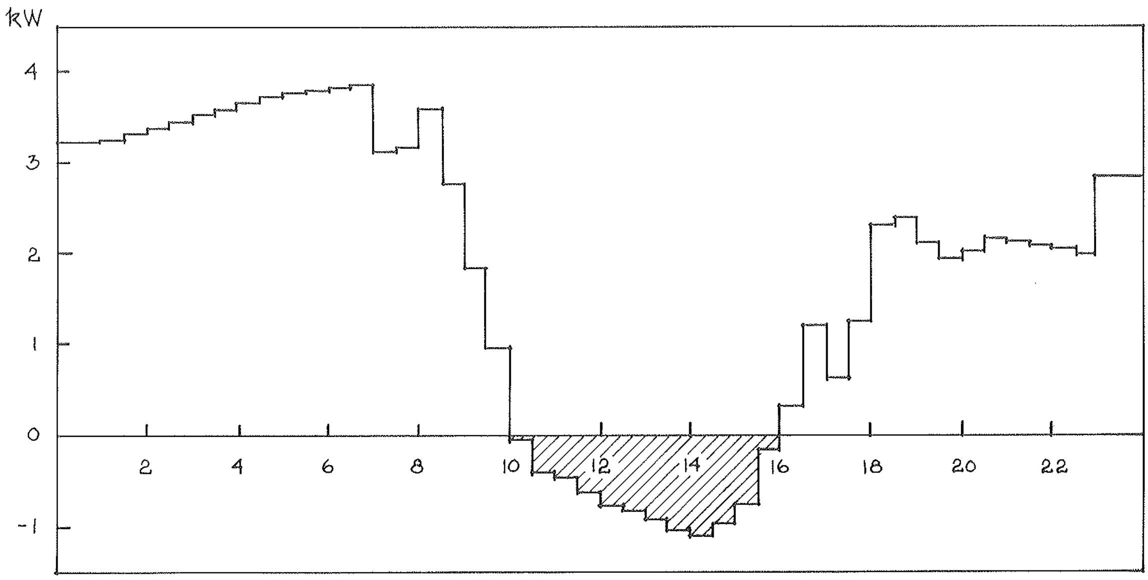


Table 1 CALCULATED ENERGY BALANCE FOR LOW-ENERGY HOUSE

kWh per	year	month Feb.	day Feb.19.
transmission	11,100	1,280	68
ventilation excl.recov.	8,200	1,100	20
	19,300	2,380	88
utilized free heat	8,700	860	40
recovered f.exhaust	4,900	660	12
heating system	5,700	860	36
	19,300	2,380	88
available free heat			
solar gain	6,100	440	27
persons	2,500	195	7
lighting	4,100	315	11
	12,700	950	45
unusable free heat	4,000	90	5

Figure 1 shows the variation of the heating requirement on Feb. 19. Although the outdoor temperature is not above -5.3 C the free heat per hour in the middle of the day is greater than the transmission plus ventilation loss per hour resulting in room temperatures exceeding 25 C.

Note. Feb. 19. in the reference year is a day with low outdoor temperature in the morning (min -13.5 C9 and bright sunshine in the middle of the day.

For the heating system this means: 1) within 1 or 2 hours the output should be controlled from maximum to minimum and 2) the minimum output should equal zero to obtain the max. utilization of the free heat. In the summer time this is even more important.

TRANSMISSION LOSSES UNDER IDLE RUNNING

An electrical resistance heater will often be controlled by a thermostat. When the thermostat has switched off the heater, the output is zero and there will be no idle running loss. This is an ideal situation from a conservation point of view.

Contrary to this, heating systems including liquid (water) for energy transportation will inevitably have transmission losses from boilers and in most cases from distribution lines too. Normally these energy losses are only a small percentage of the total energy balance, but in conservation houses where no heating is needed for long periods these losses might show a high percentage of the energy balance.

The transmission losses from boilers under idle running have been measured as the gross consumption of energy for maintaining 50 C in the boiler tank at 20 C room temperature. All circulation pumps were stopped and the outlet valves closed. Three types of boilers were investigated:

1. Electrically heated boiler (hot water tank).

2. Boiler unit including hot water tank with oil burner of the pressure atomizing type.

3. Boiler with gas burner of the open air-type.

The results of the investigation are shown in table 2.

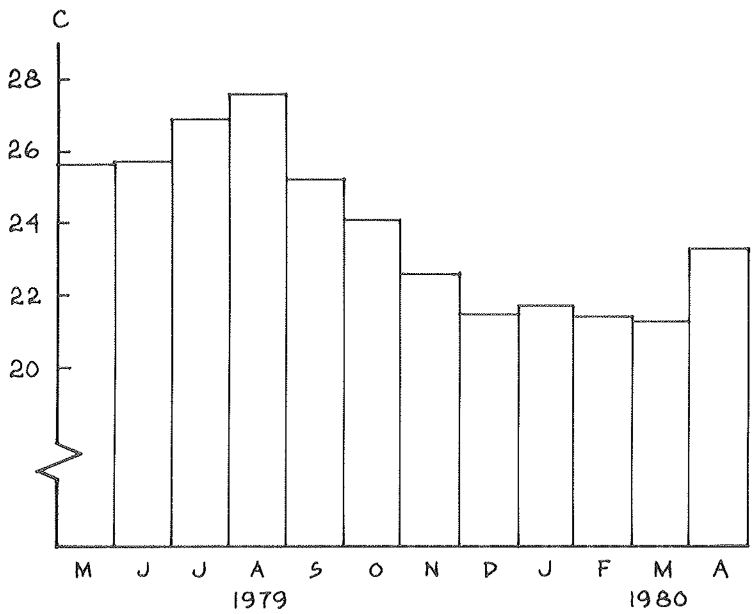
Table 2 MEASURED IDLE RUNNING LOSSES FROM BOILERS

electrically heated boiler	1.7 kWh/day
boiler with oil burner	3.0 kWh/day
boiler with gas burner, summer	7.3 kWh/day
boiler with gas burner, winter	13.3 kWh/day

For the electrically heated boiler the energy is transmitted to the boiler room, for the two other boiler types the main portion of the losses is due to chimney losses, particularly as the efficiency of the burners is low under these conditions.

Figure 2

MEASURED BOILER ROOM TEMPERATURES



Normally the transmission losses from boilers, distribution lines, valves etc. are used for the heating of the boiler room. In conservation houses the constructions of this room should be heavily insulated like the rest of the house. This means that even during the winter time unacceptably high boiler room temperatures will be obtained and it is still worse in the summer time. Figure 2 shows an example of measured boiler room temperatures.

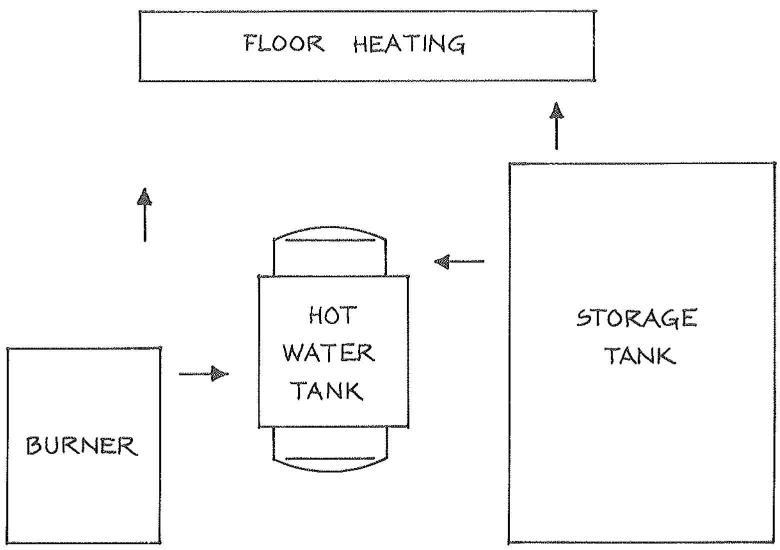
It is obvious that the boiler room is overheated. This increases the transmission loss from the house approximately 150 kWh/year. What is more important is the discomfort you feel during the summer time. As conservation houses are more compact than traditional houses there is a tendency to use even secondary rooms as an active part of the house. To solve this problem you will have to increase the lagging of the boilers, tanks and pipes including valves.

ANALYSIS OF BOILER ROOM INSTALLATIONS

The heating and hot water system of one of the low-energy houses will be analysed in details. Figure 3 shows the main components situated in the boiler room. The gas burner supplies both the floor heating system and the hot water tank in winter time. The solar absorbers on the roof likewise supply the heating system and the water tank in the summer time. The arrows of figure 3 show the heat flows.

Figure 3

MAIN COMPONENTS OF BOILER ROOM, EXAMPLE



Sufficient heat flow meters have been installed to set up energy balances for the hot water tank and the storage tank. In addition to this the transmission losses from the two tanks have been measured by letting the tanks cool down over several days, all valves being closed. The transmission figures (W/deg) have been used to verify the energy balances.

In the balance for the hot water tank e.g. the loss is defined as the difference between energy supplied from the burner and the storage and energy used for heating of hot water. Table 3 shows the measured values over one year.

Table 3 ENERGY BALANCE FOR HOT WATER TANK (kWh)

Month	Hot water	f.Boiler	f.Storage	Loss
May 79	100	133	45	78
June 79	132	54	144	66
July 79	342	106	309	73
Aug 79	329	86	311	68
Sep 79	244	66	242	64
Oct 79	298	131	252	85
Nov 79	295	306	77	88
Dec 79	328	362	57	91
Jan 80	254	268	81	95
Feb 80	199	245	29	75
Mar 80	182	233	0	51
Apr 80	261	123	197	59
	2964	2113	1744	893

The loss is 30% of the energy for heating of the hot water and what is more important it is nearly 18% of the original estimate for the amount of bought energy. For the storage tank the corresponding figures read:

Table 4 ENERGY BALANCE FOR STORAGE TANK (kWh)

Period	From solar Absorbers	To hot water tank	To floor heating	Loss
May 79-	3383	1744	551	1088
Apr 80	100%	52%	16%	32%

It is remarkable that 1) the loss is 32% and 2) only 16% of the absorbed energy is used for space heating of the house. Once more it is demonstrated that - at least in Denmark - it is not advisable to design complicated solar systems for space heating, especially as the delivered 550 kWh is less than 10% of the output of the floor heating system.

Further the sum of the losses from the water tank and the storage tank is nearly 2000 kWh, including a small heat flow from the boiler room to the storage tank in the months Dec., Jan. and Feb. In these months the temperature of the storage tank is very low as the hot water is preheated by a heat exchanger in the storage tank. Of the mentioned 2000 kWh at least 500 kWh is supplied from the burner and the rest from the solar absorber.

ELECTRICITY FOR CIRCULATION PUMPS

The boiler room installation of figure 3 includes three circulation pumps: one for the solar system (125 W), one for the floor heating system (140 W), and a smaller one (65 W) for energy supply from burner to hot water tank. Unfortunately we do not know the exact operation hours of these pumps but our estimate is:

1. Solar pump:	1/8 of the year	140 kWh
2. Heating pump:	3/4 of the year	920 kWh
3. Hot water pump:	1/5 of the year	135 kWh
		1195 kWh

On the other hand the measured energy consumption for the pumps plus the controlling system is 1530 kWh. The controlling system includes 12 continuously operated magnetic valves, one for each of the heated rooms in the house. So 335 kWh for the controlling system makes reason, but you must remember that the figures only give magnitudes.

From a conservation point of view the question is: Is it necessary to use electricity for these purposes?

1. For the solar system: Yes.

2. For the heating system: Yes, but the consumption could be decreased considerably if the heating system was switched off during the night and in the middle of the day. It is our experience that the room temperature decreases very slowly in conservation houses so you may not feel any discomfort by the suggested discontinued heating.

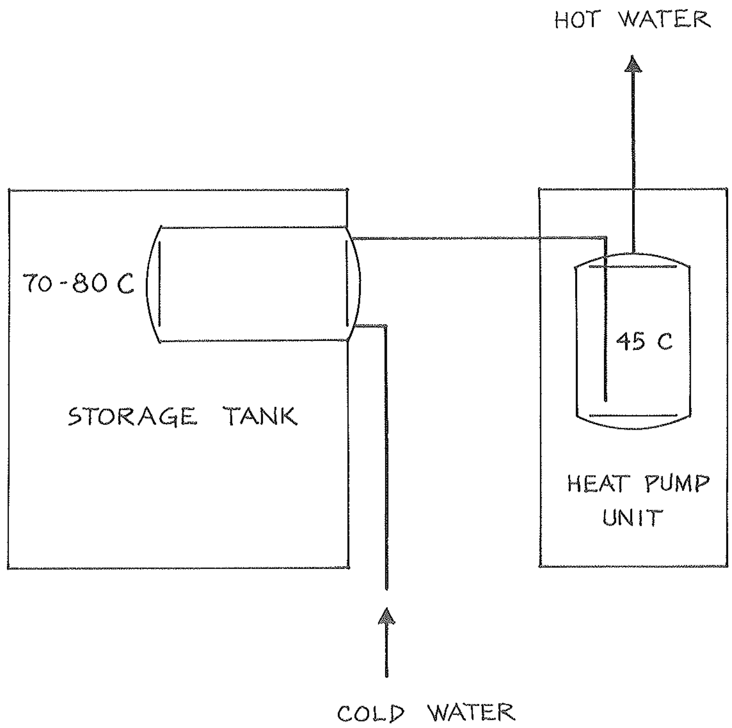
3. For the hot water system: No, natural circulation due to gravitation will do if the hot water tank is situated at the top of the room.

4. For the controlling system: Partially. For controlling of the supply temperature of the heating system it is convenient particularly if the control is correlated to the outdoor temperature, but for control of the room temperature it should not be necessary.

IMPROVEMENT OF SYSTEM EFFICIENCY

If you look at hot water units whether it is in combination with an oil burner or a heat pump you will often find that both the cold and the hot water line should be connected to the top of the tank. Normally this design will give you no trouble. If you combine the hot water unit with a storage tank as indicated in figure 4 we have had the experience that only storage temperatures higher than 70 - 80 C will secure sufficient hot water temperatures without running of the heat pump (oil burner). The storage tank is intended to be connected to a solar absorber. Under Danish climatic conditions you will find, that the storage tank will mostly function as preheater of the hot water supply, and only in the late summer the solar system can supply the hot water directly.

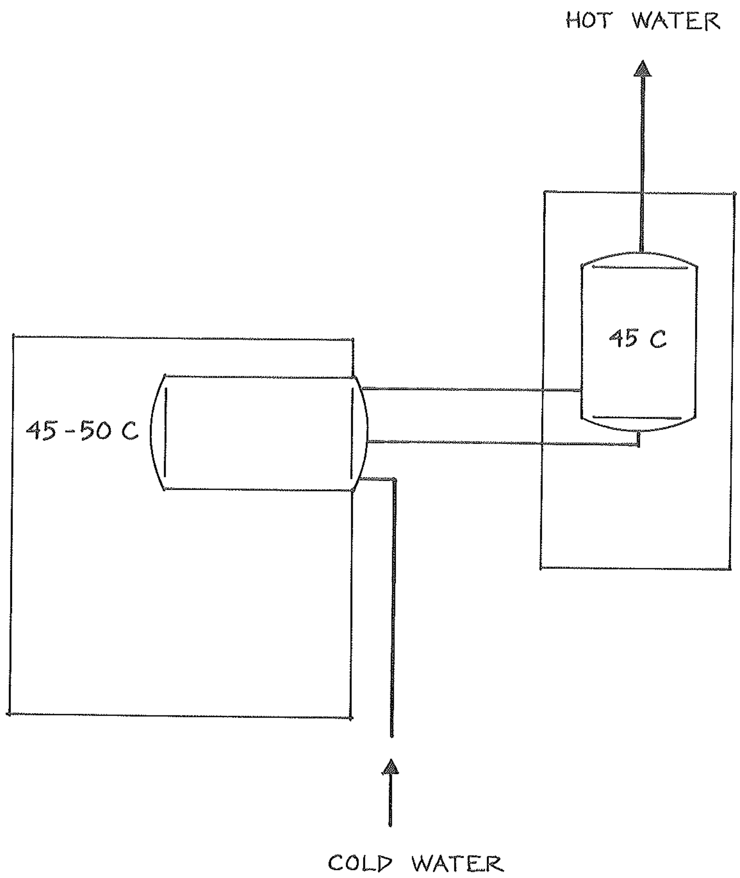
Figure 4
SOLAR SYSTEM STORAGE TANK
USED FOR PREHEATING OF HOT WATER SUPPLY



The efficiency of the solar system could be improved in many ways e.g. by installing a circulation pump, thermostatically controlled shunt lines etc. A non-sophisticated improved version is shown in figure 5. The system is based on natural circulation on condition of extra connections suited for the indicated circulation lines. Under these conditions the operating time of the heat pump will be much shorter and you will save electricity.

Figure 5

IMPROVED VERSION OF FIGURE 4



CONCLUSION

Illustrated by examples the paper shows the importance of careful design of the technical installations in conservation houses. Particularly the heat losses from the installations have to be studied for two reasons: 1) The heat losses can directly cause increased energy consumption as the room temperatures will be too high, and 2) the heat losses can indirectly cause increased energy consumption as the free heat may not be utilized as well as possible.

The examples are taken from detailed investigations on the performance of the installations in six low-energy houses, north of Copenhagen, built in 1978-79 and monitored under simulated habitation Oct. 78 to Apr. 80 and under real habitation Mar. 81 to May 82.

Measured energy balances for a hot water tank and a storage tank for a solar system are shown and it is pointed out that under Danish conditions the portion of the gained solar energy which can be used for space heating is to small to justify a complicated combined solar and burner supplied heating system.

Further it is discussed whether it is necessary to install energy consuming devices as pumps, control systems etc. It is pointed out, that the operation time of pumps for heating systems may be decreased.

An example of how natural circulation can improve the efficiency of a hot water solar system is shown.

The conclusion of the investigations is that simple compact technical installations are preferable to sophisticated complex systems.

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