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CALCULATIONS OF THE HEAT BALANCES OF AN APARTMENT HOUSE

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In a paper (1) about the Philips experimental house in Aachen there is a paragraph that reads about as follows:
Measures for the efficient use of energy can have their most succesful effect in the following areas:

1. Reduction of heat losses in buildings.
2. Heat recovery from waste water and air.
3. The use of alternative forms of energy which are not harmful to the environment, c.q. solar radiation and solar energy stored in the earth.
4. Development of integrated energy systems for buildings.

Here alternative energy sources and heat recovery could be used to optimum effect, along with conventional sources of energy.
The research program of the Philips Research Laboratory in Aachen is directed towards the objectives mentioned in these four points.

The section for fysical-control of the indoor-environment of the above mentioned department was working jointly with the Philips Research Laboratory Aachen. The research group used it's own mathematical model of the dynamic thermal behaviour of a building (2).
The case of the Philips house, well equipped with instruments, was one of the occasions where the group had the opportunity to test the validity of the mathematical model. It proved to be accurate for the indoor temperature within several tenth of a degree centigrade in cases where the ventilation rate was relatively constant. In these cases one could make an estimate of the ventilation rate on the basis of a few measurements well apart from each other (2).
The model was used for extensive calculations of the energy demand over a heating season for a floor area with rooms as in the experimental house. The floor plan used is shown in figure 1. The experimental house area was regarded as one apartment building with the same plan and the same indoor temperatures. So there was no heatflow through ceiling and floor except for some heat storage in and some heat release from ceiling and floor.
The quality of the outer-walls has been varied as follows:

	u-value wall in $W/m^2\ {}^oC$	u-value windows in $W/m^2\ {}^oC$
Case I	1,5	6,0
II	1,5	3,25
III	1,0	6,0
IV	1,0	3,25
V	0,5	3,25
VI	0,15	3,25
VII	0,15	1,9

Case I represents a normal dutch dwelling as built up to about 1975, a cavity-wall with two 10 cm bricklayers and single-pane windows.
Case V represents what is within easy reach of the dutch designers and builders. A cavity of 6 cm width in case I is filled with mineral wool, the windows are of the normal double-pane type. The dutch building codes do not yet request this quality however, people who's concern is energy saving, promote quality V.
As soon as building practices move to case VI one will have to introduce a new type of wall construction in the Netherlands with all the difficulties that go along with such an introduction. Case VII is the case of the Philips experimental house. (In other papers one can find a u-value of 0.17). The double pane windows are coated in order to restrict the infrared radiation loss from the inside to outdoors.

Calculations were made with a ventilation rate of one air volume change per hour and a heat recovery from the waste air ranging from zero to a 100%; or, what results in the same heat losses, the ventilation rate was changed from 1 to zero.
A ventilation rate of one is regarded sufficient in the Netherlands. One could probably do with less. There are however no reliable ventilation rate figures available. Therefore it is difficult to give a sound judgment on this point.
There is a feeling that the ventilation rate sometimes is much higher than 1, especially on windy days.
One can get near to a heat recovery of 100% in the case of the Philips house, because the house is not only fitted with a thermal wheel heat exchanger (Econovent) but the fresh air also passes a system of ducts alongside the cellar walls (a hollow cinder brickwall called "Porwand").
These ducts are often used in Germany to direct a groundwater flow beyond the house after heavy rainfall. In taking the air from these ducts one has the advantage of cool ventilation air in summer (18°C)

and relatively warm ventilation air in winter (always above $0^{o}C$).
Calculations were made for the so called reference year (2).

The internal load, that was taken into account, varied over the day according to the number of persons present and their activities. The average load was 0,6 kW.

During day-time the indoor temperatures are kept at the temperatures shown in figure 1. This is done by supplying heat as long as the internal heat load and the insolation do not raise the temperatures above the given limits. From midnight to 7 o'clock the indoor temperature was floating.

The results of the computations are shown in figure 2. Very low energy demands or even demands that are negative indicate that the greater part or even the whole heat demand can be met by internal load and insolation, and in case of recovery by heat recovery.

The interpretation of figure 2 for the climate of the Netherlands and an apartment as shown in figure 1, is, that coming from the Dutch building practice of before 1975, i.e. case I, and a ventilation rate of 1 one could halve the energy demand by filling a cavity of 6 cm width with mineral wool and changing the single-pane windows for double-pane one's. Further saving by improving the u-value not seems justified.
One could however halve the energy demand another time by 50% heat recovery from the waste air.
In this situation one has fulfilled measures 1 and 2 quoted above in that one has reduced the heat losses and introduced the heat recovery.

What are the circumstances for the introduction of solar energy as an alternative form of energy, measure 3?
In this respect it is important to look at the length of the heating season. In case I, with a ventilation rate of 1 it will last from the 1st of October to the 22nd of May, in case V with a waste heat recovery of 50% the season has been shortened. It starts the 1st of November and ends the 7th of April, so it is shortened from 233 days to 158 days or by 1/3. The heating season is limited to that period in which the monthly availability of sloar energy is going through its minimum, figure 3.
In a well-insulated house, with an internal heat load, recovery of heat from the waste air will be a competitor for the application of solar energy. It could well be that the constant availability of waste heat and the cost of the installations will result in recovery as the best solution. This certenly is the case in the month November through February when the ambient temperature is lowest, figure 4. From an energy conservation point of view heat recovery and solar energy together are best. Solar for September, October, March, April and May. However for the time being the cost effectiness of solar energy is too low. On the other hand heat recovery tends towards closed windows. This causes in turn a so called psycho-sociologycal feeling of helplessness. Therefore solar energy that allows open windows in fall and spring may be favoured.

The sequence given in the introduction: i.e. reductions of losses, recovery, alternative sources ends with "integrated energy systems for buildings".

In starting this sequence with "the reduction of heat losses" the authors of reference 1 show already that the building is part of the system. In the above analyses we hope to have demonstrated that the building should indeed be regarded as such.

The apartment used as an example is not a normal building for the Netherlands. On the one hand an apartment building consists for the greater part of apartments with two and not with four outer walls. On the other hand a percentage of glas in the walls of 10% is low.
Furthermore about 80% of the houses are of the detached, or semi-detached type or are row houses. In these cases there is extra heat loss through a ground floor and a roof. In the many cases of houses in a row or in the case of apartment houses there is a variaty of houses that could have lower energy demands than the example used in the paper.
However higher energy demands will be more frequent. For a variaty of types systems analysis of the house and its heat supply system and/or heat recovery system will have to be made to come to a conclusion about the application of solar energy in the Dutch climate.

1. Bruno, R; Hermann, W; Hörster, H; Kersten, R; Klinkenberg, K; The Philips experimental house; Proceedings of the U.K. section of the Solar Energy Society 1976, Conference, London. Page 1.

2. A computing method to calculate both the maximum heating and cooling load under extreme conditions and the total energy demand by heating and cooling during a reference year in buildings.
Ir. R.J.A. v.d. Bruggen and Ir. J.T.H. Lammers. Contribution to the 1977 International Seminar on Heat Transfer in buildings, 29th August - 2nd September 1977, Dubrovnik.

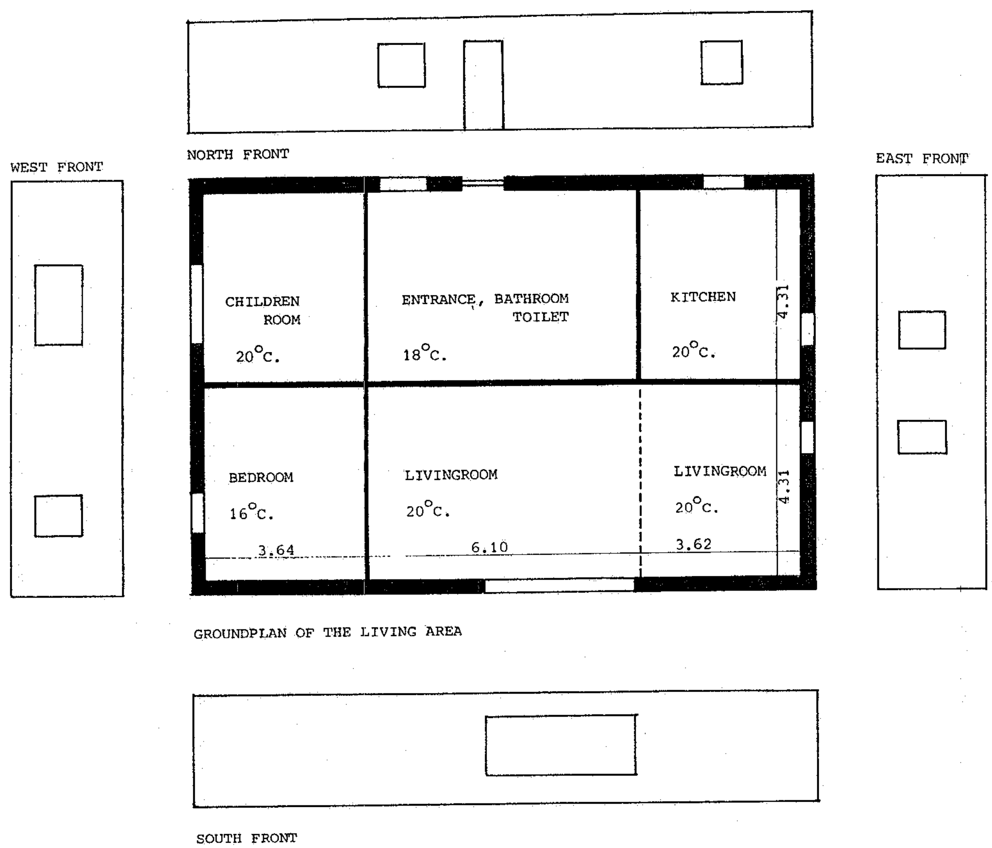


FIGURE 1

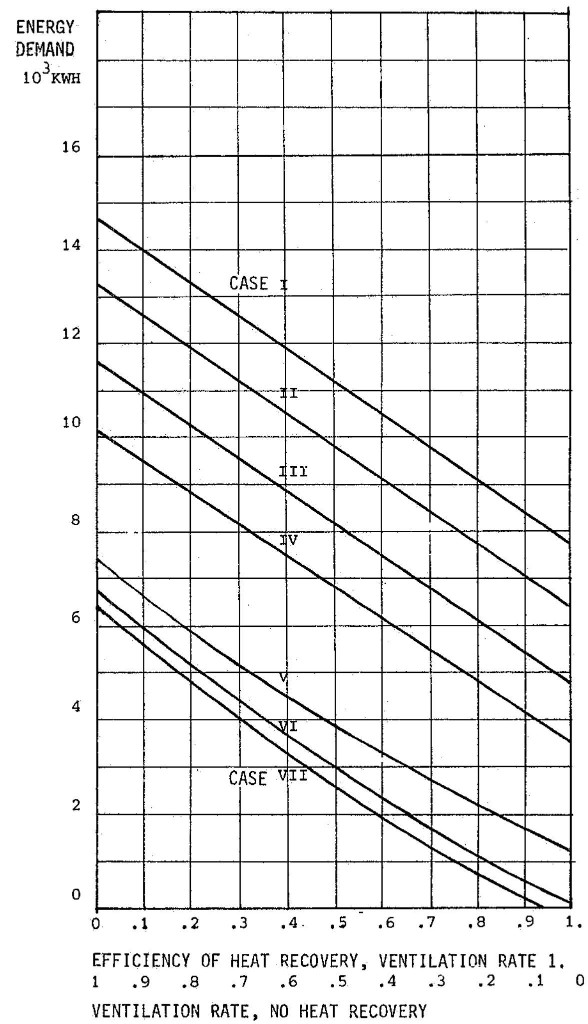
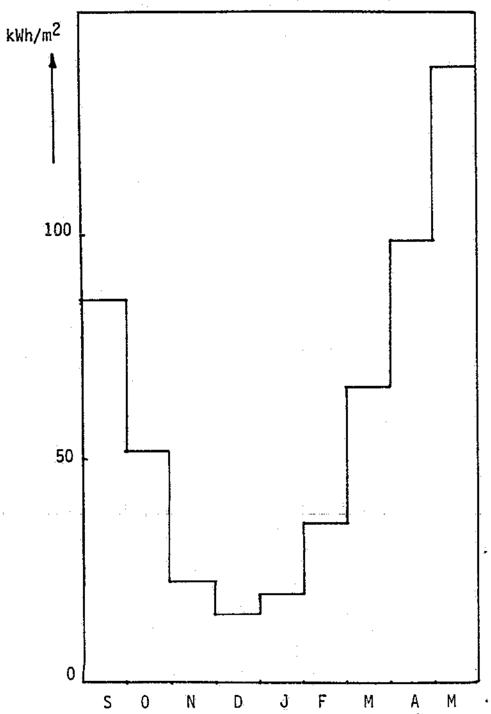
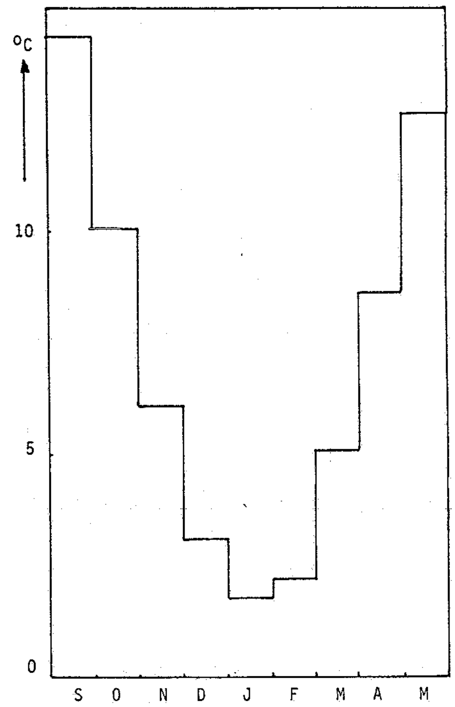


FIGURE 2



Mean monthly radiant energy in kWh/m^2
1961 - 1970 De Bilt.

FIGURE 3



Mean monthly temperature in °C 1931 - 1960
De Bilt.

FIGURE 4