DUTCH SOLAR VS CONSERVATION: AN UNBALANCED MATCH?

J.L.M. Hensen* and P.J.J. Hoen**

* Eindhoven University of Technology
P.O. Box 513, 5600 MB Eindhoven
** NV Bouwfonds Nederlandse Gemeenten
P.O. Box 15, 3870 DA HOEVELAEREN
The Netherlands

ABSTRACT

A real scale experiment with energy efficient single-family housing has been carried out. This paper outlines the experiment and the main results. It concentrates on the results related to the balance of conservation vs solar measures and the factors which influence this balance. Under current Dutch circumstances and for newly built houses conservation measures put more weight on the solar conservation balance than solar systems. Of course this does not apply to solar measures which cost nothing. In our view solar systems will only become more economically attractive when the costs decrease or when the energy prices increase.

KEYWORDS

energy conservation; solar energy; housing; experiment.

INTRODUCTION

The Energieproeftuin (energy test park) is a real scale experiment with 56 low-energy single-family houses. It is a part of the Dutch national research programme on rational use of energy in the built environment. The houses are located in Hoofddorp (near Amsterdam). The research programme connected to this project (government subsidized) is coordinated and managed by the Energy Research Project Office. The NV Bouwfonds Nederlandse Gemeenten - also the principal - investigated the financial and realization aspects. The computations and measurements regarding the use of energy etc. were carried out by the TNO Institute of Applied Physics and the Eindhoven University of Technology.

The purpose of this experiment was to investigate the interaction between different kinds of energy saving measures. A very important restriction was that the measures and provisions had to comply with the financial restrictions of state-subsidized housing.

The aim was that the Energieproeftuin will be an example of the possibilities by the end of the 1980's in the field of energy efficient housing.

THE HOUSES

The project includes 7 different types of single-family houses. Of each
type 8 houses were built in a row (in the course of 1984). They have been owner-occupied since then.

Because this project is intended to serve as an example, almost all current construction techniques — in The Netherlands — are represented: traditional brickwork, prefabricated elements, cast and lightweight concrete and wood-frame.

TABLE 1 Energy Saving Measures for the Different House Types

<table>
<thead>
<tr>
<th>House type</th>
<th>measure:</th>
<th>conservation</th>
<th>solar extra costs</th>
<th>passive hybrid</th>
<th>ECU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakker &amp; Boots</td>
<td>a,c,d,e</td>
<td>g,i</td>
<td></td>
<td></td>
<td>8,300.-</td>
</tr>
<tr>
<td>Hopman</td>
<td>a,c,e</td>
<td>f,g</td>
<td></td>
<td></td>
<td>4,900.-</td>
</tr>
<tr>
<td>Kol &amp; Lindeman</td>
<td>a,c,e</td>
<td>f,g,k</td>
<td></td>
<td></td>
<td>5,100.-</td>
</tr>
<tr>
<td>Kristinsson</td>
<td>d,e</td>
<td>g,i</td>
<td></td>
<td></td>
<td>10,250.-</td>
</tr>
<tr>
<td>Van Ringen</td>
<td>a,c,e</td>
<td>g,i,j,k</td>
<td></td>
<td></td>
<td>10,750.-</td>
</tr>
<tr>
<td>Tauber</td>
<td>a</td>
<td>g,j</td>
<td></td>
<td></td>
<td>6,000.0</td>
</tr>
<tr>
<td>WEB</td>
<td>a,b</td>
<td>g,h</td>
<td></td>
<td></td>
<td>2,600.-</td>
</tr>
</tbody>
</table>

a thermal partitioning  g thermal zoning
b narrow floor plan     h enlarged 'south' windows
c small 'north' windows i sunspace
d shutters              j air collector
e heat recovery         k solar cavity
f broad floor plan      l heat storage

The expected low heating demand (approx 75% reduction compared to normal Dutch practice) is achieved by both conservation and solar measures. The number and kind of measures which were taken are different for each house type as can be seen in Table 1. All types have high insulation levels (2.5...4 times thicker than usual), favourable orientation, draught lobby on north side, improved draughtproofing and auxiliary heating systems with improved efficiency. The extra costs (for the measures exceeding the Dutch regulations) are only indicative, because they are partly the result of both the small number of houses and the experimental nature of the project.

A more extensive description of the different house types (named after their designer(s)) can be found elsewhere (Hensen, 1985).

RESEARCH PROGRAMME AND MAIN RESULTS

An extensive government sponsored research programme is connected to this project. The research started in 1983 and will end in 1987 and consisted of several parts: computations in all design stages, extensive short-term measurements prior to habitation, long-term measurements after completion (mainly concerning energy consumption) and inquiries (about occupants' behaviour and appreciation). The results are extensively reported elsewhere (Hensen, 1987). The results for the fuel consumption for spaceheating only can be seen in Fig.1.

From the results of the measurements we conclude that the predicted reduction of the energy consumption by conservation measures is achieved in practice. The overall efficiency of the heating and ventilation systems turned out to be less than expected. The predicted — relatively small — contribution from the solar systems agreed well with the measurements. It appeared again that comparatively small differences in occupants' behaviour
lead to comparatively large differences in fuel consumption. The occupants' appreciation for the different house types is rather divergent. Some types are almost unanimously regarded as good, whilst in other types the opinions differ.

**SOLAR CONSERVATION BALANCE**

To be able to indicate the energy saving from the different kinds of measures a number of calculations were carried out for each house type. The results are summarized in Table 2.

Based on a fuel consumption for space heating of 62 GJ/a in a normal Dutch house, the predicted saving due to a different lay-out, different window arrangement, favourable orientation etc. is on average 10 GJ/a. The average extra saving due to improved draughtproofing is about 15 GJ/a (A-B). The average extra saving due to improved insulation is about 16 GJ/a (A-C) and the average extra saving due to heat recovery, improved auxiliary heating system, sunspace, shutters etc. is about 9 GJ/a (C-D). The average extra saving due to the solar energy systems is only about 3 GJ/a (D-E).

The costs for version A were on average 4,800,- ECU above those of a standard house (partly resulting from the small number of houses, the experimental nature and the different construction types). The extra costs for the draughtproofing improvement were on average 200,- ECU. The extra costs for the improved insulation were on average 3,100,- ECU. When we leave out the sunspaces the extra costs for the realized version compared with the former were 1,800,- ECU and including the sunspaces 2,900,- ECU. Finally the extra costs for the solar systems were on average 1,800,- ECU (in 3 types only).
TABLE 2 Predicted Fuel Consumption for Spaceheating (GJ/a)

<table>
<thead>
<tr>
<th>House type</th>
<th>version</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakker &amp; Boots</td>
<td></td>
<td>53</td>
<td>36</td>
<td>20</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Hopman</td>
<td></td>
<td>61</td>
<td>43</td>
<td>25</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Kol &amp; Lindeman, upper</td>
<td></td>
<td>42</td>
<td>31</td>
<td>15</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Kol &amp; Lindeman, lower</td>
<td></td>
<td>40</td>
<td>34</td>
<td>20</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Kristinsson</td>
<td></td>
<td>51</td>
<td>34</td>
<td>17</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Van Ringen</td>
<td></td>
<td>54</td>
<td>36</td>
<td>16</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Tauber</td>
<td></td>
<td>58</td>
<td>43</td>
<td>28</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>WEB</td>
<td></td>
<td>53</td>
<td>36</td>
<td>21</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

A architecturally identical to realized version, however without measures like heat recovery, improved draughtproofing, solar systems etc.; insulated according to current standards and with a conventional heating system
B like A, but with improved draughtproofing
C like B, but with improved insulation
D realized version, however without solar energy system
E as realized

When we compare the costs with the savings it is clear that improving the airtightness has the best cost-benefit ratio. Second best are adding insulation and measures like improved auxiliary heating system, heat recovery, shutters etc. The cost-benefit ratio increases when we include the sunspaces. The solar systems give the worst cost-benefit ratio. Of course this does not apply to solar measures which cost "nothing" like favourable orientation, different window arrangement etc.

Of course we have to bear in mind that these figures apply to this project. In retrofitting projects for example the cost-benefit ratios could easily be different. Furthermore it has to be recognized that the "measure packages" were chosen more or less arbitrary. Optimization studies could easily lead to better balanced packages.

Nevertheless it is clear that from an economical point of view the solar systems are not in favour when deciding on which measures should be taken to reduce the energy consumption for spaceheating. One of the main reasons for this is the low solar radiation availability in The Netherlands. This is illustrated in Table 3, in which for a number of European countries values are given for factors which influence the solar conservation balance.

It is evident that the ratio between solar radiation availability and degree days is one of those factors. Another important factor is the useful energy price because this strongly determines the total available budget for energy reduction measures. As the cost-benefit ratio for solar systems is in general higher than for conservation measures, solar systems will be lower in the economical feasibility hierarchy of energy reduction measures. Thus with a larger budget the economical attractiveness of solar systems increases. As can be seen in Table 3 the ratio between solar availability and degree days is lower for Denmark than for The Netherlands. For France and Italy this ratio is higher. The Dutch useful energy prices are however markedly lower than in the other countries. From this we conclude that in The Netherlands conservation puts more weight on the solar conservation balance in comparison with other countries.
TABLE 3 Factors which Influence the Solar Conservation Balance

<table>
<thead>
<tr>
<th>Country</th>
<th>NL</th>
<th>DK</th>
<th>F(Paris)</th>
<th>I(Rome)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree days Radiation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- global</td>
<td>3145</td>
<td>3558(113%)</td>
<td>2996( 95%)</td>
<td>1401( 45%)</td>
</tr>
<tr>
<td>- south 45</td>
<td>1.18</td>
<td>1.10( 94%)</td>
<td>1.42(121%)</td>
<td>2.16(184%)</td>
</tr>
<tr>
<td>Useful energy price:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- natural gas</td>
<td>1.56</td>
<td>1.54( 99%)</td>
<td>1.85(119%)</td>
<td>2.92(187%)</td>
</tr>
<tr>
<td>- heating gasoil</td>
<td>12.4</td>
<td>22.7(183%)</td>
<td>15.5(125%)</td>
<td>15.8(127%)</td>
</tr>
<tr>
<td></td>
<td>13.5</td>
<td>17.3(128%)</td>
<td>15.4(114%)</td>
<td>16.7(124%)</td>
</tr>
</tbody>
</table>

Degree days (all year; base 10.3°C) and radiation (in GJ/m²; for October - April) from (Archard, 1986)
Energy prices (in ECU/GJ) from (Bulletin, 1986)

CONCLUSIONS

The houses in the Energieproeftuin have an average energy consumption for spaceheating of approx. 20 GJ/a. It is shown that such a low heating demand can be achieved with a variety of construction techniques, heating systems, energy conservation and solar measures. However under Dutch circumstances and for newly built houses conservation measures put more weight on the solar conservation balance than solar systems. Of course this does not apply to solar measures which cost nothing (favourable orientation, different window arrangement, etc.). In our view solar systems will only become more economically attractive when the costs decrease or when the energy prices increase.

REFERENCES

Bulletin of Energy Prices (1986). No.2, Commission of the European Communities DB XII, Brussels
DUTCH SOLAR VS. CONSERVATION: AN UNBALANCED MATCH?

J.L.M. Hensen
Eindhoven University of Technology
P.O. Box 513, 5600 MB EINDHOVEN
The Netherlands

P.J.J. Hoen
NV Bouwfonds Nederlandse Gemeenten
P.O. Box 15, 3870 DA HOEVELAKEN
The Netherlands

Within the Dutch national research program on rational energy use in the built environment (REGO) a practical experiment with energy efficient single-family housing - called Energieproeftuin (experimental energy park) - has been carried out. The purpose of this project was to show what can be achieved in this field by the end of the eighties and to investigate in practice the relation and interaction of different kinds of measures and provisions to decrease the energy consumption for spaceheating.

The project resulted in 56 single-family houses which were built in the course of 1984 and have been owner-occupied since then. There are 7 different house types. The expected mean annual fuel consumption for spaceheating is about 500 m³ natural gas which is approx. 25% of the energy consumption for spaceheating in a comparable house built according to current Dutch regulations.

This low heating demand is achieved both by conservation measures (high insulation levels, ventilation heat recovery, infiltration reducing measures, thermal partitioning, etc.) as well as by solar measures (passive or hybride solar energy systems, thermal zoning, favourable orientation, etc.). The number and kind of measures which were taken are different for each house type.

An extensive government sponsored research program is connected to this project. The research started in 1983 and will end in 1987 and consists of several parts: computations since the early design stages, extensive short-term measurements prior to habitation, long-term measurements after completion (mainly concerning energy consumption) and inquiries (about occupants' behaviour and appreciation). The two latter parts were carried out during two heating seasons and the summer in between.

From the results of the measurements we may conclude that the predicted energy consumption reduction by conservation measures will be achieved in practice. The overall efficiency of the heating and ventilation systems turned out to be less than expected. The predicted - relatively small - contribution from the solar systems appeared to agree well with the measurements. It appeared again that comparatively small differences in occupants' behaviour can lead to comparatively large differences in fuel consumption. The occupants' appreciation for the different house types is rather divergent. Some types are almost unanimously regarded as good, whilst in other types the opinions differ.

The proposed paper will give an overview of the research and the results obtained thus far. It will more extensively describe the results related to the balance of conservation vs. solar measures under Dutch circumstances and the factors which influence this balance.