ːion programs SUNCODE and
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Vh/a are due to the ventilated
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# HOW FEASIBLE ARE ZERO ENERGY BUILDINGS?

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In the discussion on practice-oriented measures to reduce the $CO_2$-emission, one measure most demanded is the development of zero heating energy houses. The technology applied and investigated in the first pilot projects seems to indicate a possible future without any $CO_2$-emission with respect to residential building. What is really hidden behind this technology and whether it is feasible to introduce it into construction practice, is to be discussed in this contribution with regard to practical experiences.

## 1. DEVELOPMENTS TOWARDS THE ZERO HEATING ENERGY HOUSE

The first buildings in Germany that consumed significantly less heating energy than normal new buildings were constructed during the oil crises in the seventies. At that time, the changes were instigated by high oil prices whereas today, the main driving force is the threatening climatic changes. The first generation of low-energy buildings which still have an experimental nature was analysed within the demonstration project "Landstuhl" from 1984 through 1988. As a reference for the solar houses, an average single-family house was built. Several of the examined houses reached the low-energy house standard.

The results of the investigation were used as a basis for the conception of the 2nd generation of low-energy buildings which were realized in the demonstration project "Low-Energy Houses Heidenheim". Here, six different semi-detached houses with different building and plant constructions were built. Their heating energy demand was 60 kWh/m² per year. The average heating energy gains due to the new conceptions were around 60-80 per cent. The low-energy house settlement turned the town Heidenheim situated on the Suabian Highlands into a place of pilgrimage for many architects, public and private building owners as it was there for the first time demonstrated that low-energy buildings can be built with building components available on the market. These components are neither restricting the functionality nor the appearance of the houses and were not significantly more expensive to build than usual semi-detached houses. Monitoring results showed that all the experimental houses achieved the standard of low-energy buildings. Built with conventional construction practices and heating technology they require a net heating energy between 36-54 kWh/m²a. The industrial partners involved in this project meanwhile are offering variations of these low-energy houses as a standard. In 1990, one of the participating prefabricators made the committment as the first project partner to build his houses henceforth exclusively to the low-energy standard.

An even more drastic reduction of the energy consumption was realized by the building owner "Siedlungswerk Stuttgart". In Rottweil, eight energy-efficient houses and one semi-detached house were built. One half of the semi-detached house is constructed as low-energy building (50 kWh/m² per year), the other half is an Ultra house consuming only 20 kWh/m² per year. This trend-setting energy-efficient duplex house was constructed under the auspices of the International Energy Agency and was funded by the Federal Ministry of Research. Measurements showed that, in practice, the heating energy consumption was approximately 18 kWh/m²a. Since 1993, the IBP in Stuttgart has been dealing with the development of practicable concepts for zero heating energy houses. The basis for such concepts are solar systems that do not only passively collect solar energy but are capable of storing it and releasing it to the interior when required. During cold winter days, even the best insulation, high-quality windows and the most intensive use of solar gains are no longer sufficient to keep the house warm. This being the case, heat has to be supplied and if this is to be done without burning fossil fuels, the only way is to store the heat gained in summer for the wintertime. Another German contribution within the framework of the International Energy Agency is a zero heating energy house erected in Berlin. In the center of this house is placed a large water tank to store the solar gains in summer for the wintertime. Thus the house can be heated without boiler while still having it comfortably warm on cold winter days.

All the experiences gained from the research projects of the International Energy Agency are now used in the construction of prefabricated houses for the general public in collaboration with one of Germany's leading prefabricators. Besides the standard low-energy houses, it is planned to offer in future Ultra and zero heating energy houses.

## 2. COSTS AND ADVANTAGES OF ZERO HEATING ENERGY HOUSES

The way to zero heating energy houses can only be achieved by using all available resources. Prerequisite are a solar-oriented design to collect the required solar energy and extremely low heat losses of the building. Table 1 shows the development of the thermal insulation of the heat exchanging building components which has been achieved by the improvement of the products during the last few years. The new building components show only about 10% of the losses of existing buildings. Apart from the improved features of opaque components regarding insulation, the transparent envelope

surfaces render possible
to low heating energy de

Table 1. Developmen
env

| Comparison | |
|---|---|
| building component | existi buildi before |
| wall | 1.40 |
| window | 5.20 |
| glazing | 5.70 |
| roof | 1.00 |
| basement ceiling | 0.80 |

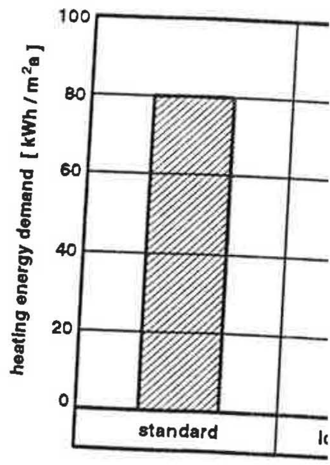


Figure 1. Development of

surfaces render possible an extremely high reduction of heat losses which lead to low heating energy demand values in new buildings shown in Figure 1.

Table 1. Development of the thermal insulation of the heat exchanging envelope during the last few years.

| Comparison of thermal insulation [U-values W/m²K] | | | | | | |
|---|---|---|---|---|---|---|
| building component | existing buildings before 1970 | standard 1984 | standard 1995 | low-energy building | Ultra | zero-heating energy building |
| wall | 1.40 | 0.60 | 0.50 | 0.30 | 0.15 | 0.08 |
| window | 5.20 | 2.60 | 1.80 | 1.40 | 0.75 | 0.60 |
| glazing | 5.70 | 3.10 | 2.00 | 1.30 | 0.50 | 0.40 |
| roof | 1.00 | 0.30 | 0.22 | 0.18 | 0.12 | 0.08 |
| basement ceiling | 0.80 | 0.55 | 0.35 | 0.24 | 0.18 | 0.10 |

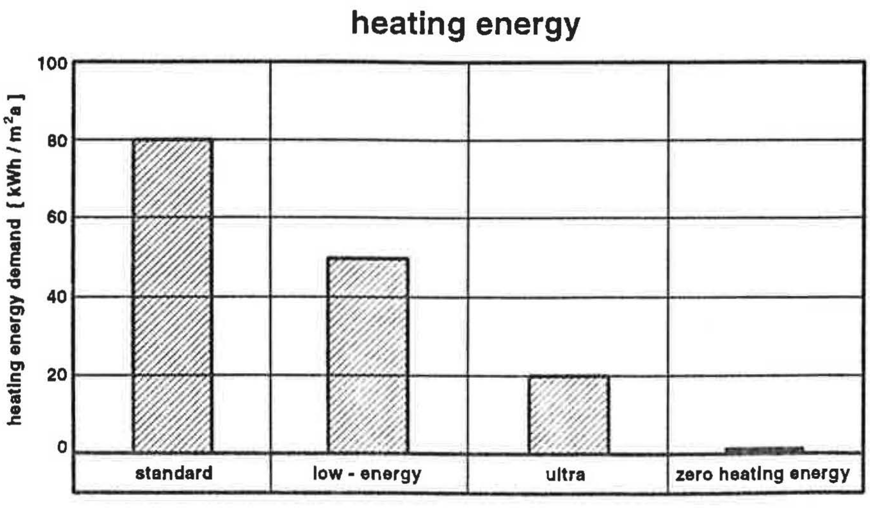


Figure 1. Development of the heating energy demand of new buildings.

Parallel to the decreasing heating energy demands though, the electrical demand for mechanical and control systems in the buildings increased because in buildings with lower energy demand, more complex mechanical systems are necessary to manage the residual energy. In Table 2 are shown the energy consumptions of the heating system and the power required to drive the mechanical systems of an average single-family house with a living space of 150 m².

Table 2. Energy consumption of average single-family house (150 m²) built in different variations.

| energy consumer | energy consumption [kWh/a] | | | |
|---|---|---|---|---|
| | standard | low-energy building | ultra | zero-heating energy |
| heating (gas) | 12,000 | 7,500 | 3,000 | 0 |
| mechanical systems | 500 | 500 | 1,000 | 1,500 |
| total | 12,500 | 8,000 | 4,000 | 1,500 |

It demonstrates that the total energy consumption has been decreasing continuously. However, there is a shift from the energy source gas to electric power which also affects the energy costs. In Table 3 are shown the energy costs for different construction types. While the German standard requires heating costs of about 730 US$/a, the total costs for the zero heating energy house are about half of the standard house costs. The higher constructional standard of the Ultra house means in reality only a reduction of 25% of the heating costs. This is caused by high fixed costs of the energy supply and very low consumption-linked costs as well as by the increasing consumption of "very expensive" electric power. In Table 4 are shown the necessary extra investments for the different building standards to be achieved. The low-energy house standard can be achieved by extra costs of less than 7,000 US$, whereas the additional expenses for the Ultra house amount to 27,000 US$ and more. The zero heating energy house requires an extra investment of 110,000 - 133,000 US$.



Table 3. En

| costs |
|---|
| gas heating | consumpti (0.03 US$/ |
| | fixed costs chimney-sw |
| electric power | mechanical (0.18 US$/ |
| total costs | absol |
| | per m [US$ |

Table 4. Required addi (150 m

| costs |
|---|
| thermal insulation |
| heating plant |
| ventilation plant |
| solar plant |
| total |

Here, most of the cost Figure 2 shows the redu extra investments. It in achieve the zero heat

hough, the electrical
ngs increased because
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ouse (150 m²) built in

| kWh/a] | |
|---|---|
| | zero-heating energy |
| 0 | 0 |
| 0 | 1,500 |
| 0 | 1,500 |

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source gas to electric
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Table 3. Energy costs for different types of construction.

| costs | | operating costs [US$/a] | | | |
|---|---|---|---|---|---|
| | | standard | low-energy | ultra | zero heating energy |
| gas heating | consumption-related (0.03 US$//kWh) | 360 | 230 | 90 | - |
| gas heating | fixed costs (meter; chimney-sweeper; etc.) | 270 | 270 | 270 | 70 |
| electric power | mechanical systems (0.18 US$/kWh) | 90 | 90 | 190 | 270 |
| total costs | absolute | 720 | 590 | 550 | 340 |
| total costs | per m² living area [US$/m²a] | 4.80 | 3.90 | 3.70 | 2.30 |

Table 4. Required additional investments for an average single-family house (150 m²) with different construction features.

| costs | required additional investments [10³ US$] | | | |
|---|---|---|---|---|
| | standard | low-energy | ultra | zero heating energy |
| thermal insulation | 0 | 4 - 7 | 17 - 27 | 27 - 33 |
| heating plant | 0 | 1 | 3 | 13 - 20 |
| ventilation plant | 0 | 0 | 7 - 10 | 10 - 13 |
| solar plant | 0 | (7) | (7) | 60 - 67 |
| total | 0 | 5 - 15 | 27 - 47 | 110-133 |

Here, most of the costs are due to the more complex mechanical systems. Figure 2 shows the reduction of the heating energy demand dependent on the extra investments. It indicates the significant increase of costs required to achieve the zero heating energy value. While extra expenses of up to

133 US$/m² allow for a significant reduction of the heating energy demand, covering the residual 20 kWh/m²a causes a considerable rise in price of the building construction by up to 670 US$/m².

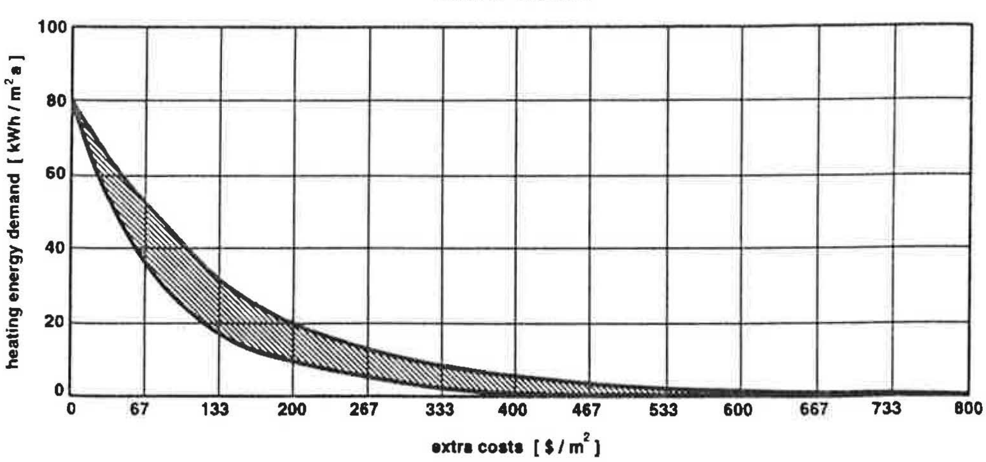


Figure 2. Reduction of heating energy demand dependent on the required extra cost.

## 3. SUMMARY AND EVALUATION

The preceding discussion shows that zero heating energy houses do not lead to "zero" heating costs. The development of the zero heating energy house has enabled a significant energy saving potential. However, this causes considerable additional costs. Due to the tariff policy of the energy suppliers (low and consumption-bound costs and high fixed costs), even the low-energy house cannot be considered profitable. 300 years are required for the savings in energy to pay for the extra costs in construction of a low-energy house, which is 10 times higher than the operating life of the technical equipment. The decisions for erecting a zero heating energy house therefore should not be based on economic considerations. As a significant decrease in price is not expected after the introduction of this building type on the market as a series production, the significance of a low-energy building lies in the important part of the low-energy building owner's contribution to the protection of the environment, even if this is quite expensive. Apart from that, such a building certainly has become as much a status symbol as for example a luxury car. Due to the unfavourable characteristic parameters though, it is not expected to achieve a large share of the market with this type of building concept in the near future.

ENERGY DEVEL
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**ABSTRACT** In this pa
process of $FeSi_2$ element
85mV, when temperature
a better element was pro
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element, electric power
35K (using four modules

## 1. INTRODUCTION

Energy development th
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press pressure, heat sinter
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Thermoelectric gener
kind to environments and
efficiency, and it is used
thermoelectric generation
element.[4],[5]

## 2. EXPERIMENTAL PR

**2.1 Preparation of thermo**
Figure 1 shows the manufac
of $FeSi_2$ with Mn-doping (P
mixing, fusing, powderi
subsequently sintering and