The Comprehensive Housing Renovation Approach

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ABSTRACT: Over the last five years in the Netherlands only an average of 67,000 houses a year have been built, representing only 1% of the total building stock. In new housing modern standards of comfort and a limited energy consumption can be realized. The majority of the existing housing stock however consists of outdated dwellings with a unacceptable high energy consumption.

In this research a renovation method is described enabling an improvement of comfort and a reduction of energy use for outdated housing, stretching the service life with an extra 30 years.

Keywords: renovation, energy consumption, occupant comfort

1. INTRODUCTION

In the Netherlands some 6,800,000 houses exist. In recent years the production of new houses consists of some 67,000 units per year representing only 1% of the total stock. Thus the renewal of the total housing stock would take more than a century.

The majority of the existing houses have been built in the post World War II period. This period can be characterized by a high need for housing and a lack of material, skilled labour and money. As a consequence houses built in the 1945-1965 period are today regarded to be small offering limited quality and comfort and at the end of service life. An extra complication is the fact that directly after World War II energy was cheap. As a consequence in housing from the 1945-1965 period almost no thermal insulation is applied, resulting in high energy consumption.

Today these outdated houses are facing demolition, representing a serious problem regarding the destruction of capital, the destruction of social and physical infrastructures, the creation of debris, the need for massive flows of transportation of debris, new material and people and the cost for new houses.

In this research a model is developed for renovation of outdated 1945-1965 housing resulting in more comfort for the occupant and a serious reduction of the use of fossil fuel.

2. HOUSING IN THE NETHERLANDS

2.1. General

In the Netherlands the construction of housing is extremely dependent on government policy. The housing market and especially the social housing renting sector can be characterized by high demand and limited offer and completely controlled by government regulations regarding amounts, place and code requirements. The cost of housing is high, in the year 2000 an average of 27% of the gross income is spent on housing cost. (table 1)

Countries	1996	1997	1998	1999	2000
Austria	**18**	**17**	**17**	**16**	**16**
Belgium	**21**	**21**	**20**	**20**	**22**
Denmark	**25**	**24**	**25**	**26**	**26**
Finland	**29**	**30**	**29**	**28**	**26**
France	**25**	**24**	**24**	**25**	**24**
Germany	**26**	**27**	**26**	**26**	**25**
Greece	**20**	**20**	**19**	**20**	**17**
Ireland	**15**	**15**	**14**	**13**	**13**
Italy	**21**	**21**	**21**	**21**	**21**
Luxembourg	**18**	**18**	**17**	**18**	**17**
Netherlands	**23**	**24**	**24**	**23**	**27**
Portugal	**14**	**14**	**14**	**14**	**13**
Spain	**19**	**20**	**19**	**19**	**20**
UK	**21**	**21**	**23**	**25**	**22**

Table 1 Average housing cost as percentage of household income over the 1996-2000 period. [1, ECHP]

At the moment (2006) there is even a public discussion about possibilities for government financial support for young people entering the market, the so called “starters”.

2.2. History

Directly after World War II there was an enormous shortage of housing due to destruction during the war and the growth of the population. An intensive building programme was developed and within a period of only 20 years over 1.3 million houses have been built. Roughly 40% or some 550,000 units are row houses, or terraced single family homes (figure 1, Amsterdam 1953)

Figure 1. Post World War II housing. Amsterdam, Geuzenveld, 1953.

The picture clearly shows the limited economical situation in that period, only one car to be seen, very small identical houses, no TV antennas on the roofs.

2.3. Technical

The technical condition of the house also shows the limited possibilities of that period, single pane windows, no thermal insulation in the brick cavity walls, thermal bridges and a non insulated tiled roof.

These characteristics are illustrated in figure 2.

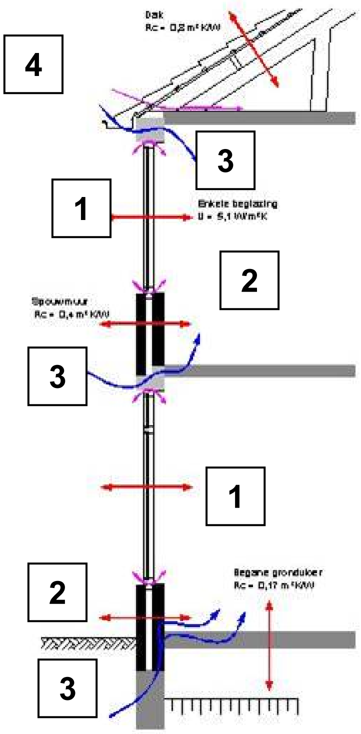

Figure 2. Section of a single family row house showing thermal deficiencies:
Single pane windows [1], Cavity wall without thermal insulation [2], Thermal bridges [3] and Thermal leaks [4] .

The technical condition as shown in figure 2 is considered outdated. According to today's building code at least thermal insulation with a thickness of some 100 mm or an R value of minimum 2.5 m²K/W would be mandatory. The situation as described leads to an average yearly energy consumption of some 3000 m³ of natural gas for heating only. As 1 m³ of natural gas represents an emission of 1.78 kg CO_2 the contribution of housing to the national CO_2 emissions is significant.

2.4. Layout

Not only the technical condition of this type of houses needs upgrading, also the layout of ground floor plan and first floor plan does not meet current standards. Living room, kitchen and bedrooms are too small (figure 3 ground floor plan)

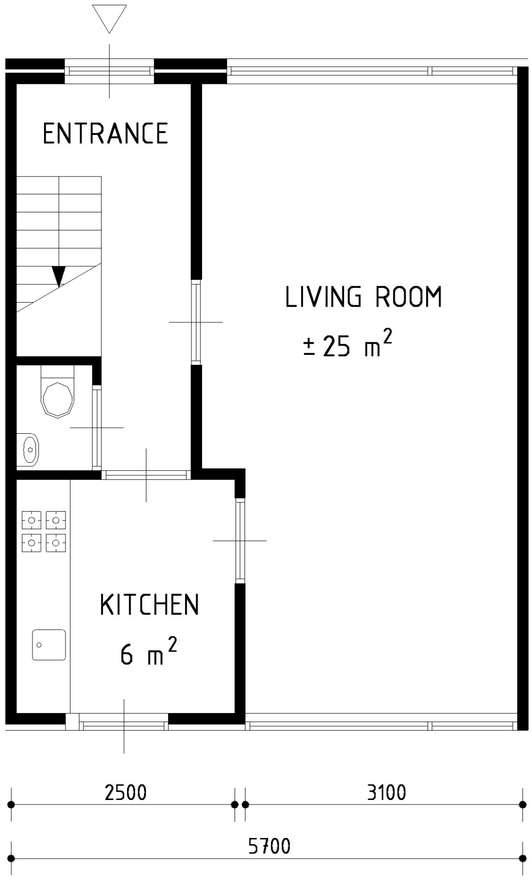

Figure 3. Ground floor plan single family row housing built in the 1945 -1965 period.

Footprint	6.0 x 7.5 meters	(20 x 25 feet)
Kitchen	2.6 x 2.5 meters	(8 x 8 feet)
Living room	7.0 x 3.6 meters	(23 x 12 feet)

The first floor shows a similar situation, a small bath room and small bedrooms in combination with a limited storage capacity.
Also an extra room for a home office is not provided.

2.5. Conclusion

The condition of more than 500,000 post Wold War II houses in the Netherlands is outdated in many aspects. Already the process of demolition has started, resulting in a giant amount of debris and the destruction of physical and social infrastructures. The cost for new housing is high and the housing shortage in the social sector will increase.

Extensive renovation focussed on both the technical condition and the space and comfort for the occupant is needed in order to avoid demolition. A strategy for enlargement and technical upgrading is needed.

3. APPROACH

In this research the main focus is on the increase of occupant comfort and the reduction of the use of fossil energy. Occupant comfort consists of various aspects like physical, social and psychological well being. In this research the aim is to demonstrate the possibilities of outdated dwellings regarding fossil energy consumption and occupant comfort in general. The comfort for the occupant therefore is limited to the building related space required by the occupant.

It is obvious that more space is needed, hence an extension are to be realized. As the existing house represents a relative high amount of material, both in volume and in weight, and foundation cost generally are high, regarding the addition there is a need for light weight construction. The recent development and publication of the slimbouwen® strategy perfectly fits in this approach. [2, Lichtenberg 2005]

In Dutch, Slimbouwen® means “smart” building and consists of a structure offering possibilities to the user with the use of limited material. Thus slimbouwen® also means building with the smallest possible effort performing only for specific purposes and hence reducing cost, labour, the amount of material, transportation, the creation of debris and so on.

In the case of the combination of upgrading the thermal performance and space enlargement offers the possibility of a comprehensive approach.

Demonstration projects on “zero energy” houses show that the combination of a thick layer of thermal insulation **and** high performance windows **and** an airtight structure **and** heat recovery ventilation **and** the use of active and passive solar energy can bring a serious reduction of the use of fossil energy.

The consequence is that comprehensive housing renovation consists of at least a ground floor extension containing an up to date kitchen and living room enlargement. This enlargement can be produced industrial and transported to the existing house. The advantage of prefabrication is obvious, the advantage for the occupant is that no need exists to move to another place and the permanent availability of the kitchen, when the addition with the new kitchen is installed and operative the old kitchen can be removed.

4. DESIGN CONCEPT

The principle of the design concept is to place extra space where needed. This can be limited to the ground floor only containing extra space for the living room or an entire new and large kitchen. The enlargement at the first floor can accommodate a bath room enlargement and or bedroom enlargement.

The extra equipment containing the heat recovery system and additional piping and wiring also needs space. In order to realize this space without disturbing the physical interior structure of the house and the life of the occupants, an external services shaft is introduced. This services shaft also offers the possibility to add extra comfort for the occupant when realizing a central vacuum cleaning system, a very easy method for cleaning the interior and making it a healthy place.

5. CASE STUDY.

5.1. General

A design concept is of no use without application and checking. A case has been found with easy data access. With this actual data, a calculation has been made for the meteorological years 1993-1999. As the energy bills for that period were available the accuracy of the computer modeling according to the Matlab Hambase program could be established. The results are given in figure 4.

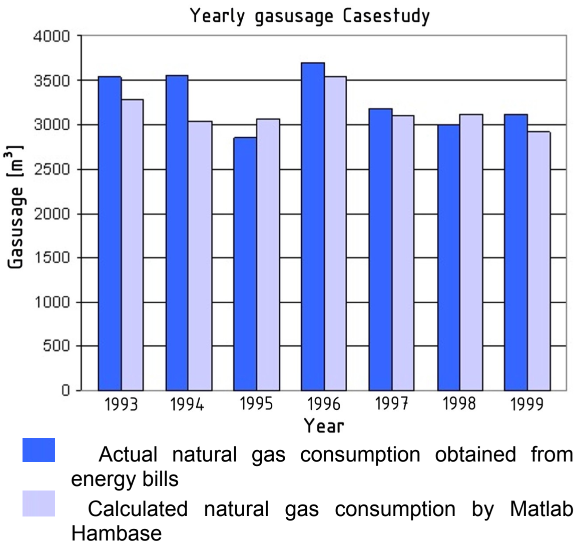

Figure 4. Actual and calculated yearly natural gas consumption of the case study.

The calculated and actual amounts of natural gas needed for heating show an acceptable accuracy with an average difference of 4.0%.

5.2. Spatial analysis

The spatial functionality of the dwelling is analyzed, according to the design guideline and the occupant’s desires [3, Hilhorst 1997]. On the ground floor, the entrance, living room and kitchen do not meet the required standards. On the first floor, two out of three bedrooms and the bathroom are too small, so is the bedroom on the second floor. In order to meet the standards, the expansions needed are shown in figure 5.

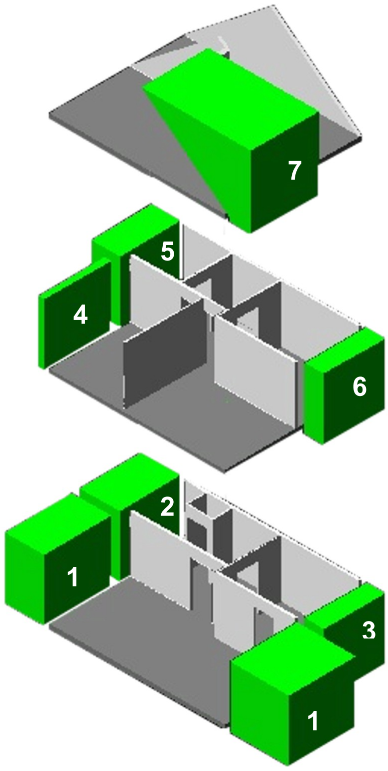

Figure 5. Required spatial expansions: living room 14.5 m² [1], entrance 4.0 m² [2], kitchen 2.5 m² [3], bedroom II 1.0 m² [4], bathroom 3.5 m² [5], bedroom III 2.5 m² [6], bedroom IV 3.1 m² [7]

5.3. Energy concept

To achieve the most sustainable energetic concept, a three-step-strategy is introduced, the so called 'Trias Energetica', which serves as a guide-line to achieve the most energy-efficient design. As many measures possible are taken to reduce the energy demand (step 1). Sustainable energy is used for the remaining demand (step 2). For an eventual rest, fossil fuels are used, but only as efficient and clean as possible (step 3).

5.4. Calculating the natural gas usage

Looking at the available meteorological data for calculation (1970-2000), the meteorological year 1978 has the lowest average year temperature of 8,5 °C and therefore is used for each simulation.

As a start, the case study's energy usage is calculated (basemodel). Furthermore, five other models are simulated, each representing another fossil energy demand decreasing measure.

Model 1: applying external thermal insulation on ground floor, façades and roof, with an R value of 5.0 m²K/W.

Model 2: Replacing the single pane windows with energy-efficient windows, with a U value of 1.0 W/m²K.

Model 3: zoned model, in which the rooms that require a higher room temperature a situated on the south façade, and the other rooms are situated on the north façade.

Model 4: a two-storey high sun-room with single pane windows is added on the south orientated façade.

Model 5: the glass surface on the south orientated façade is increased to 200% in contrary to the glass surface on the north orientated façade, which is decreased with 50%. The calculated results of the models are given in figure 7.

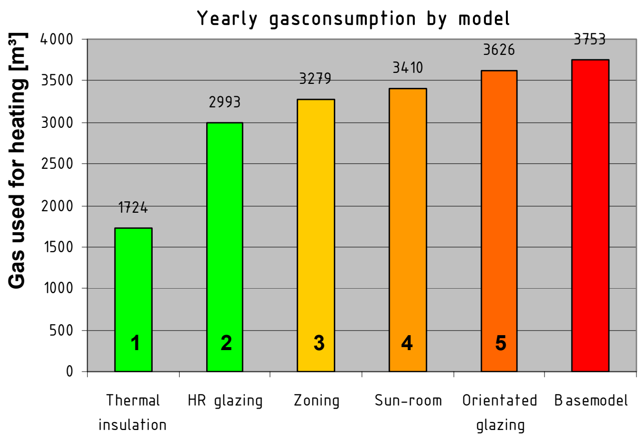

Figure 6. Calculated yearly natural gas consumption for heating per model.

As the bar chart shows, thermal insulation [1] and high-efficiency pane windows [2] prove most effective and respectively result in a decrease in gas consumption by 54% and 20%, followed by the zoned model [3] with a 13% decrease.

Less effective are, the model with sun-room [4] with a 9,1% decrease, and the model with orientated glazing [5] which leads to a 3,4% decrease. This can be explained. The sun-room indeed decreases the transmission loss trough the façade, but also prevents solar radiation from heating the active building mass, so less solar energy is gained inside the dwelling. Orientated glazing increases the solar gained energy in the dwelling, but also causes enormous transmission losses trough the large single pane window surface.

Yet, a more effective model can be made, where thermal insulation and energy-efficient windows are combined. For each individual thermal insulation measure, the effect is calculated and presented in the bar-chart in figure 7.

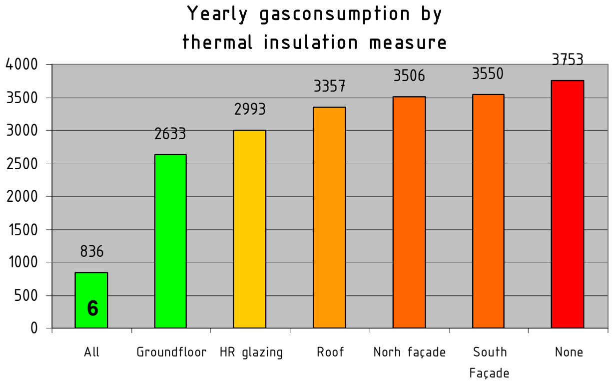

Figure 7. Calculated yearly gas consumption (in [m^3]) for heating by thermal insulation measure

Calculations have been made with the actual heating behavior of the occupants of the case study, who mainly heat the ground floor, with less heating hours for the first and second floor. This explains why applying external thermal insulation on the ground floor is more effective in comparison with, for example, the appliance of external thermal roof insulation.

Of course, the best result is achieved by combining all thermal insulation measures [6], which leads to a 78% decrease in gas consumption.

5.5. The “zero-energy” heating balance

The amount of energy required for heating, can be calculated by adding all energy losses minus all energy gains. As mentioned above, external thermal insulation combined with energy-efficient windows leads to a 78% decrease in gas consumption. The specific energy gains and losses are visualized in the bar-chart in figure 8.

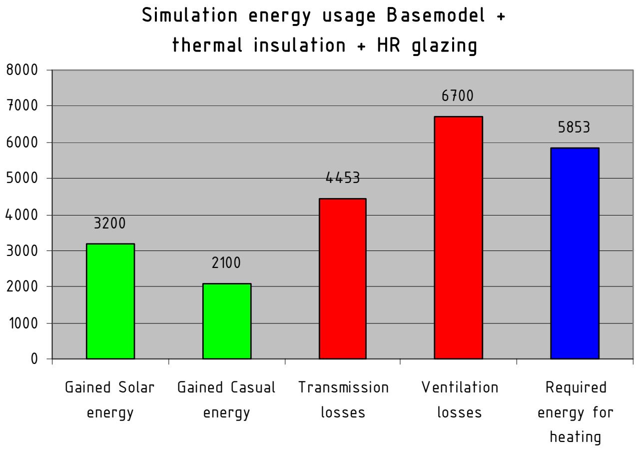

Figure 8. Calculated yearly energy gains and losses by Matlab Hambase (in [kWh]).

Thus the transmission losses + ventilation losses – gained solar energy – gained casual energy = the amount of energy, required for heating (4453 + 6700 – 3200 – 2100 = 5853 kWh). To achieve a “zero-energy” heating balance, the sum of the energy losses has to be equal to the sum of the energy gains.

According to the energy concept (5.3.), the second step of the “Trias Energetica” can be introduced.

Balancing the energy management, the 6700 kWh ventilation losses need a 5853 kWh reduction. This reduction is obtained by replacing the natural ventilation with a mechanical ventilation system with heat recovery. The efficiency of the heat-recovery-unit should at least be 87,4% (5853/67), this efficiency is considered reasonable in theory. In reality, the heat-recovery is less efficient because not all ventilation-rates pass the heat exchanger, for example ventilation trough opened windows. Therefore, the realistic efficiency of the heat exchanger will be approximately 60-65%.

5.6. Structural design

Realization of the expansion needs to meet the conditions, mentioned in the slimbouwen® strategy. The structural design is shown in figure 9.

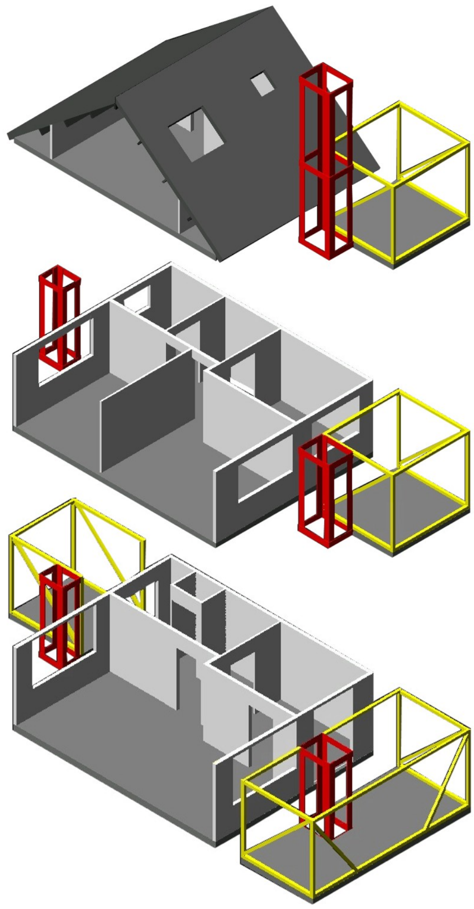

Figure 9. Structural design

Prefabricated elements are mounted on the existing load bearing structure of the case study. To add this extra weight without expanding the foundation, the outer leave of the cavity wall is removed.

Installations stay reachable and adjustable in the external shaft (figure 9. marked red). The maximum measurements of the element are approximately 6.0 x 2.7 x 2.8 meters (20 x 9 x 10 feet), so no exceptional transport is needed for transportation.

5.8. Architectural design

Only where needed, extra space is added to the dwelling. Rooms with a higher room temperature (living room and bedrooms) are placed on the south orientated façade. On both facades, the entrances function as air-locked thermal buffers. The architectural design is shown in figure 10.

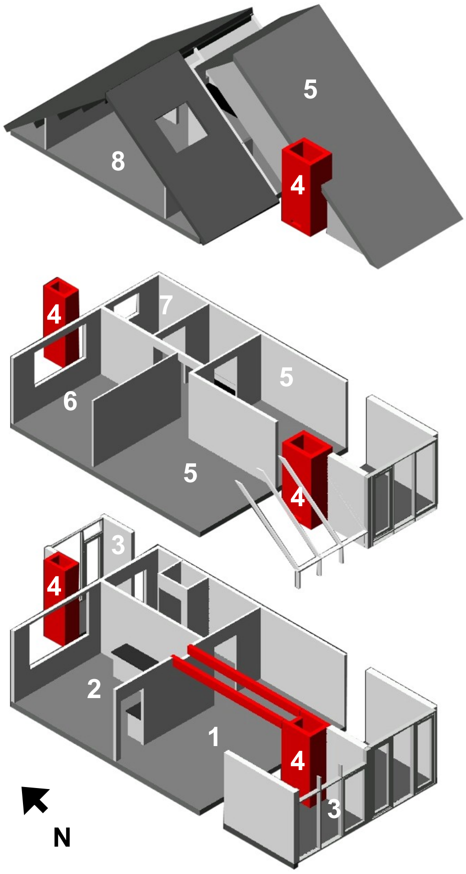

Figure 10. Architectural design
living room [1], kitchen [2], air-lock[3], services shaft [4], bedroom [5], bathroom [6], washing room [7], home office [8]

5.9 Conclusions

The spatial expansions are: living room 9.5 m², kitchen 4.7 m², front entrance 3.7 m², bedrooms 7.4 / 1.9 m², bathroom 6.0 m² and a 4.7 m² washing room is added.

The consumption of fossil fuel (natural gas) for heating can be reduced with 3540 m³/year, a reduction of 94%.

At the moment (2006), this represents a yearly reduction in heating cost of approximately 3500 x 0.60 = € 2100,00. It is remarkable that an investment of some € 30,000,= will be paid back in only 15 years.

In the case study, only the energy demand for heating is eliminated. Natural gas is consumed by the water heater as well, next to the (electrical) power consumption.

The 42 m² south-orientated roof surface offers opportunities for the addition of solar cells or a solar water heater.

REFERENCES

[1] European Community Household Panel 1994-2000, European Foundation for the improvement of living and working conditions, www.eurofond.eu.int/areas/qualityoflife/eurlife

[2] J.J.N Lichtenberg, SlimBouwen, WAeneas Boxtel, 2005

[3] H.L.C. Hilhorst, VAC-kwaliteitswijzer, Utrecht, 1997