Upgrading post-war dwellings with solar energy

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Abstract: This paper presents a renovation design concept for upgrading postwar row houses in the Netherlands built during the period 1966-1976 (650,000 houses). Besides a low energy performance of these houses, its dimensions, equipment and flexibility are important issues, which do not match today's increased demands for living space and comfort.

By using active- and passive solar applications and thermal insulation; sun-orientated floor-plan divisions, glazed areas and cantilevers, as well as solar applications, the energy performance of these houses will be improved. These measurements result in a reduction of approximately 85% of the total energy consumption compared to the existing situation (domestic energy consumption included), in spite of an enlargement of 50% of the floor surface, which among other things will foresee in satisfying the need for living quality and convenience. By executing this concept over just 650,000 houses, the entire Dutch CO2-reduction objective as arranged in the Kyoto-agreement could be realized.

Conference Topic: Recycled Architecture, re-use, upgrading and rehabilitation of buildings.
Keywords: upgrading, energy saving, solar energy, living quality and convenience.

1. INTRODUCTION

In the Netherlands in the period 1966-1976 650,000 houses have been built [1]. The typical front view is given in Fig 1.

Figure 1: a typical front view of a post-war row house in the Netherlands.

The lay-out of the ground floor (Fig. 2) generally consist of 6 meter wide and 8.2 meters deep footprint.(20' x 27') offering a 6 meter front façade overlooking the street and a façade at the back overlooking the garden. Usually the living room and dining room consist of some 26 m² (260 sq.ft.), the kitchen usually measures 6 m² (65 sq.ft). Further there is an entrance, toilet and hall with stairs to the first floor.

The first floor (Fig. 3) usually contains two normal bedrooms and a smaller bedroom. The bathroom measures 3.5 m² (38 sq.ft.). The attic, which only can be used as a storage room, can only be reached by a folding stair.

Figure 2: Typical layout of a ground floor in terraced houses.

Figure 3: Typical layout of a first floor in terraced houses.
The outside walls generally consist of non-insulated cavity brick walls, with single glazed wooden frames. The pitched roof consists of ceramic tiles over a cavity and a wooden roof boarding, no thermal insulation installed. The concrete ground floor is also non-insulated.

The result of this type of construction is a poor energy performance. The house consumes over two times more primary energy (approximately 80,000 MJ [2]) than a house built according to today’s standards (approximately 40,000 MJ [3]), mainly due to a high consumption of natural gas for heating. This in combination with occupant’s dissatisfaction regarding space, number of rooms, possibility for flexibility and limited equipment of kitchen and bathroom represents a housing problem [4].

The described dwellings are outdated. The choice is demolition or renovation. Demolition and building new houses represents an enormous financial and ecological input. Current renovation methods offer only limited energy savings, with a maximum of 20%-35% of the total energy consumption. This is an outcome of insulating only some parts of the buildings instead of all. Also, application of sustainable energy sources isn’t common in current renovation of such low-rise buildings. Second, regarding space and comfort, only kitchen and sanitary furniture are now and then replaced, but surface expansion is rarely being used in practice [5].

2. APPROACH

2.1 General

The housing problem in the Netherlands is, based on a literature study, being divided into basically two items: high energy consumption and lack of space and comfort. The aim of this study was to create a design concept, which not only contributes to energy saving on a large scale, but which also provides in upgrading the living space and comfort of the houses, so that they can match again to current and future occupants demands. Based on further research specific space requirements (in m²) and the requested energy use (in MJ) can be determined. These will be the starting points for the design proposal. During the design process, with generated data of its energy performance, an optimal design proposal can be made. Finally the design proposal has to be analysed in relation to the starting points.

2.2 Design concept

Several spaces in the existing houses have to be enlarged. Beside this enlargement also extra spaces or functions have to be added. E.g. the attic has to be made useful, by creating a space which can easily be divided in more than one room by the occupant.

Therefore in this study prefabricated light-weight insulated units have been designed, which can easily be attached to the existing supporting dividing walls. These units can already be provided with kitchen, sanitary furniture and a front facade, in a way a short construction time can be realized. Therefore current occupants can return to their houses within a short period of time. For the expansion of the attic these units will also be used, after removing the total existing pitched roof construction. The units, one at both the ground floor and the first floor, will be applied regarding the possibilities of using passive solar energy (Fig. 4).

Building Technology aspects of the units are not discussed further in this paper.

Figure 4: the design concept in 4 steps from top to bottom (Orientation is valid for each picture).
1: the existing situation (for one house).
2: removing the existing facades and attaching the units, facade elements and conservatory (only south or west orientated). Facades are mainly untransparent at a north or east situation. Facades are mainly transparent at a south or west situation.
3: removing the existing pitched roof top and to place three units on top of the second floor.
4: applying the active solar applications on roofs (south or west orientated).
2.3 Energy saving

The energy problem is approached in different aspects: Thermal insulation is being applied in the walls, floors and roofs of the units, under the existing ground floor and also in prefabricated facade-elements, which will replace the existing non-insulated cavity brick walls, at places where no units are being applied.

Existing buildings have an existing orientation, often not suitable for an intensive use of passive and active solar energy. In this study the existing floor plans have been re-designed in a way that primary spaces (e.g. the living room) are sun-orientated and that their facades mainly consist of large insulated glazed surfaces (Fig. 5).

Figure 5: Floor plan new situation.

The units have been located in a way that a maximum use of passive energy is possible. The unit at the first floor creates a cantilever, which prevents the living room from overheating in summer situation. The living room can be heated by the sun in winter situation. Underneath the cantilever, a conservatory is applied to reduce energy losses due to transmission. Besides this energetic function, it is a welcome additional covered outdoor space of 13.5 m² (145 sq.ft.) (Fig. 6).

Active solar applications being used are thermal active solar applications (9-11 m²; 100-120 sq.ft. depending on orientation) and photo-voltaic solar applications (PV) (41-48 m²; 455-520 sq.ft. depending on orientation). Both are applied sun-orientated and on top of the flat roofs of the new units, with a sloping gradient of 25 degrees. Some of these applications also create cantilevers for facade windows lying below (Fig. 6).

Figure 6: Cross-section for the new situation. New units, façade elements and solar applications are hatched and the former contour is dashed.

3. RESULTS

3.1 Total energy savings

The total energy consumption, consisting of primary energy consumption and domestic energy consumption, in the new situation is reduced by more than 84% for west-orientated houses [6]. This stands for an energy reduction from approximately 100,000 MJ into a new energy consumption of approximately 16,500 MJ. South-orientated houses reach a 87.5% reduction which results in a new energy consumption of approximately 12,400 MJ (Fig. 7).

These reductions have to be seen regarding to the expansion in floor surface by 50 m² (540 sq.ft.) which results in a 35% larger volume. Also the surfaces of ground floor, facades and roof increase all together by 50%.

Figure 7: Comparison between energy consumption in existing and new situation; the energy consumption of newly build houses according to energy standards in 2002 is given as a reference.
3.2 Natural gas savings

By using passive solar energy, a significant amount of solar boiler surface and by applying insulation (minimum U=0.125 W/m²K) to all of the building parts, the consumption of natural gas is reduced by over 75% [6]. This includes domestic energy consumption. The amount of the new consumption of natural gas is 500 m³ (Fig. 8).

![Figure 8: Comparison between average natural gas consumption in existing and new situation (west-orientated houses). Domestic use contains energy consumption for cooking][7]

3.3 Electricity savings

In the existing situation almost no electricity was used due to natural ventilation. In the new situation, a mechanical ventilation system, using heat-recovery and new heating installations demand more electricity (1033 kWh of electricity a year [6]). Including the average domestic use of electricity [7], the total demand for electricity is 4162 kWh/year [6].

Therefore a mono-crystalline PV-system of 41 m² (455 sq.ft.) is being applied, which results in a rated power of 5425 Wp for each south-orientated house. This equals a supply of 4300 kWh of electricity a year [6]. West-orientated houses generate 6300 Wp each (48 m² PV-system, 522 sq.ft.), which equals 4400 kWh/year [6].

So, by using as much as the average domestic electricity use, it’s even possible to sell the self generated electricity to electricity companies, in a way occupants even can lower their total energy costs.

Generating electricity at power plants consumes 2.5 times more primary energy, because during transport to users a 60% of energy is lost. So by using self generated electricity, energy savings at power plants also appears as a positive side effect.

3.4 Solar applications

Integration of the several solar applications in this concept results in a saving amount of over 84% (67.200 MJ/year) on the total energy consumption (for west-orientated houses) [6]. Within this saving amount, PV-applications contribute for over 30% and active thermal applications contribute for over 10% [6].

3.5 CO₂-reduction

The domestic CO₂-reduction objective for the Dutch government amounts 2 Mton over the period 1990-2010. This stands for 10% of the level of emissions in 1990 (20 Mton) [8].

Actually, these emissions only depend on domestic consumption of natural gas. However, because of the addition of energy consumption by electricity, which normally is calculated to the energy industry, the CO₂-reduction objective in this study was increased to 2.8 Mton.

The CO₂-emissions caused by the existing situation approximately amounts 3.8 Mton over 650.000 houses. This is the result of an average emission of 6000 kg CO₂ for each house (1m³ of natural gas results in an emission of 1.78 kg CO₂ and 1 kWh of electricity generated results in an emission of 0.56 kg CO₂).

In the new situation the CO₂-emissions will be approximately 0.5 Mton over 650.000 houses. This is the result of a reduction by an average of 5275 kg of CO₂ for each house (depending on the orientation).

So, a reduction of over 3 Mton is being realized, equal to 12 % reduction on the total of domestic emissions (level 1990). This means that by applying this concept to only 650.000 houses can provide in the total domestic CO₂-reduction objective and even beyond.

4. CONCLUSIONS

Renovation is preferred to the combination of demolition and new development. An environmental aspect is the larger amount of rubble, not only during demolition but also during construction. Economical and social aspects are e.g. low production capacity needed, no negative effects to the tight housing market and the cultural value and infrastructure of existing neighbourhoods is preserved.

Using this concept, instead of traditional renovation methods, it’s possible to upgrade houses for another 40 years within a short period, to even beyond today’s standards of energy consumption and living quality and convenience.

The costs saved by using the existing structure, combined with the energy costs savings over 40 years, make this concept economic manageable.

Applying this concept to the total amount of terraced houses build in the period 1966-1976, the government goal of domestic CO₂-reduction (2.8 Mton for 2010) can be realized by only these 650.000 houses. Because of the short construction time, this is also practically possible, without using all the production capacity for new housing development.
REFERENCES