Renovation of apartments adding portal structures and façade-elements for extra space and high energy performance

Michiel Ham and Arend Schamhart

Faculty of Architecture, Building and Planning
University of Technology, Eindhoven, The Netherlands

ABSTRACT: In almost every European country the majority of post war multi-storey dwellings is outdated regarding space offered, level of comfort and especially energy performance. In the Netherlands approximately 900,000 multi-storey dwellings, built during the 1955-1975 period and representing about 13% of the total housing stock, are now facing either renovation or demolition. This study focuses on a method of replacing the existing façades with outside portal structures and multifunctional façade-elements. The newly developed façade is placed directly in front of the existing (access) balconies, gaining additional living space. The portal structure supports the new balconies, and prevents thermal bridges. The multifunctional façade-elements combine super-insulation, HVAC-installations and the use of passive solar energy. Furthermore the apartment blocks can be rearranged and equipped with solar collectors on the roof.
In combination with the SlimBouwen® building strategy, the result of this approach is prevention of demolition of outdated apartments. The occupants will enjoy more space, increasing from an average of approximately 68 to 84 m^2, and a well-adjustable indoor-climate at a low energy consumption of approximately 46 kWh/m^2a.

Keywords: housing, durable renovation, energy, SlimBouwen®

1. INTRODUCTION

During the 60's and 70's a considerable stock of multi-storey dwellings or apartment blocks were build in The Netherlands, intending to provide a comfortable living for the rapidly increasing number of families after World War II. In those days the idea was cherished that high-rise residential buildings were the best solution for housing the urban working class [1]. Nowadays, these apartment blocks are considered to be outdated. Judged by present standards, these dwellings, either hallway-access- or gallery-apartments, appear to be too small, while the building physics are insufficient and, the energy consumption of generally 220 kWh/m^2a for heating is at least 2-times higher compared to current standard apartment building [2]. A rapid, efficient and cost-effective solution is of utmost importance. Recently, within the International Energy Agency's (IEA) Solar Heating and Cooling Programme's Task 13: Advanced Solar Low Energy Buildings, a large, new apartment building was realized in The Netherlands with ≈ 40 kWh/m^2a [3].

Although demolition of 60's and 70's apartment blocks is practised, various arguments can be raised to consider renovation, under certain well-defined conditions, as an alternative, possibly viable approach. The large number of apartments itself can be of advantage since any universally applicable renovation strategy can be applied on a large-scale basis. Moreover, within a renovation concept the existing structure and infrastructure remain valuable objects with less waste and less required process energy.

This study attempts to develop a novel renovation design focusing on removal of the façades, addition of portal structures and multifunctional façade-elements, and reduction of energy consumption per apartment.

2. APPROACH

Recognizing various structural criteria, such as size, flexibility and homogeneity, renovation of gallery-apartments, contrary to hallway-access-apart-

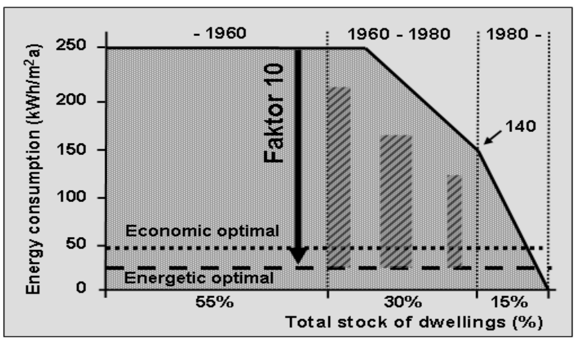

Figure 1: Possible energy (heating) reduction of dwellings by the Faktor-10 vision. Shown are the economic and energetic optima's and the required

reduction of energy (simplified after Schulze-Darup [9]). The striped bars indicate the possible total energy reduction of the 60's-70's apartment stock.

ments were considered to offer the most promising opportunity to arrive at a universally applicable renovation strategy. Accepting preservation of the existing core structure of gallery-apartments as valuable, a renovation concept characterized by adding portal structures and façade-elements was explored. After analysis of current needs and expectations of the consumers and the energy consumption of the existing dwellings, several comfort and energy criteria were defined [4, 5]. The SlimBouwen® vision, and Passiv-Haus or the similar Dutch PZE-woning concept were incorporated [6, 7, 8]. The aspect of energy reduction was judged according to the Faktor-10 vision (Fig. 1) [9, 10]. Furthermore, the regulations as appointed in the Dutch Building Decree (2003) were considered as an important point of reference [11].

Total heat flow calculations were evaluated with EPCheck (version 2.01).

3. RESULTS

3.1 Analysis of 60's and 70's apartment blocks

Of a total 900,000 dwellings associated with 60's-70's apartment blocks 405,000 (45%) and 495,000 (55%) are gallery- and hallway-access-apartments, respectively [1]. Due to their relatively high structural quality, homogenous structure and an equal structural distance of 4.0 m, a well-defined selection of gallery-apartments (29% or 120,000 dwellings) was considered to be of interest for a universally applicable renovation approach. The average size of these gallery-apartments is 75 m^2. Interestingly and contrary to the general belief, a recent survey indicated that the absolute square meters are not always experienced as the major source of discomfort. The lack of interior flexibility, outdated heating and ventilation, and the general size or absence of "special" rooms for storage, laundry and hobby-like activities appears to be of greater importance [5, 12]. Especially the "utility rooms" are considered to be too small (Table 1). Also, the dimensions of the balcony (with little privacy) are generally experienced as impractical.

Table 1: Comparison of average room size of a 60's-70's gallery-apartment and the currently preferred size.

Average room size (m^2)		
	60's & 70's	Current preference
Kitchen	6.7	9.0 (134%)
Bathroom (laundry)	5.7	7.5 (131%)
Inside storage	3.0	4.5 (150%)
Other rooms	57.9	68.2 (117%)
Total	73.3	89.2 (122%)
		+ 15.9

A series of technically outdated constructions, comprehending opaque (R_c = 1.3 m^2K/W) and transparent (U = 5.8 W/m^2K) insulation, thermal bridges (7% of total heat loss), air tightness, ventilation and heating installation, causes a undesirable large heat flow (Fig. 2). The energy consumption for heating is generally 2-times higher compared to the nowadays accepted standard (Table 2).

As shown in Table 3, the inferior air sound and impact sound insulation, especially of the floors, requires close attention within any renovation design [13]. Compared to the accepted feeling of comfort the required noise reduction is $\Delta I_{lu:k} \approx +9$ dB and $\Delta I_{co} \approx$ +7 dB, and $\Delta I_{lu:k} \approx +16$ dB and $\Delta I_{co} \approx +21$ dB for the walls and floors, respectively. Consequently, solutions like soundproofing floating floors and acoustic insulation panels should be applied.

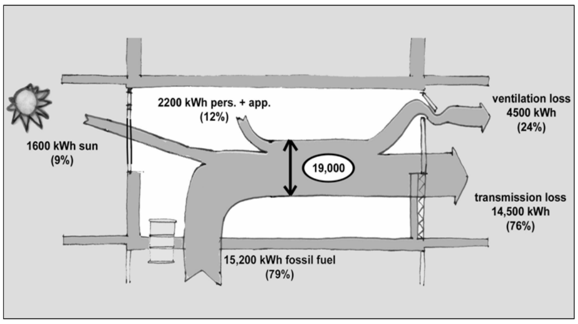

Figure 2: Heat flow from an apartment, build during the 60's and 70's.

Table 2: Total energy and natural gas consumption and R_c value of 60's-70's apartments compared to the current standard (Dutch Building Decree) and the Passiv-Haus concept.

	60's & 70's	Dutch National Building Decree	Passive Solar House / Passiv-Haus
Energy consumption (kWh/m^2a)	220	110	25
Natural gas (m^3/a)	1400	700	200
R_c-value	1.3	2.5	7.0

Table 3: Sound insulation of 60's-70's apartments compared to the Dutch Building Decree (DBD) and experience of comfort.

Sound insulation between dwellings (dB)						
	60's & 70's apartments		DBD		Comfort target	
	$I_{lu:k}$	I_{co}	$I_{lu:k}$	I_{co}	$I_{lu:k}$	I_{co}
Wall	-5 to -3	+2 to +4	0	+5	+5	+10
Floor	-14 to -4	-13 to -10	0	+5	+5	+10

3.2 Basics of the design

The principal of the renovation design encompasses removal of existing façades leaving the major structure (≈75% of the weight) intact and limiting the debris of the light-weighted façade to manageable proportions. Subsequently, a portal structure and prefabricated, multifunctional façade elements are placed directly in front of the existing (access) balconies, enclosing additional living space derived from the former balconies and galleries.

The portal structure is constructed by 3D-colums with supporting cantilever beams (Fig. 3). The horizontal as well as the vertical load is absorbed by an *independent* element, resulting in space for a duct shaft, a column-free gallery and an arbitrarily positioning of other elements. According to the SlimBouwen® vision this allows for separation of the duct work from the structural design for the benefit of flexibility and dismountability. In the present concept gas, electricity, (warm) water and ventilation exhaust air ducts are situated in the external shafts of the access, north façade.

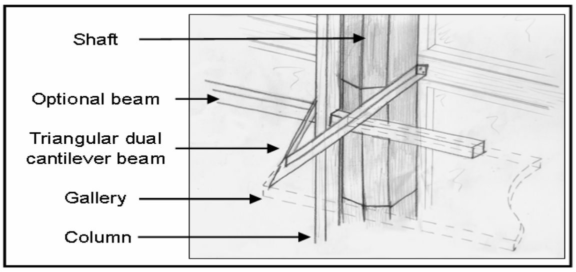

Figure 3: 3D-columns with triangular beams with space for a duct shaft, a column-free gallery and arbitrarily positioning of all sorts of elements.

3.3 A detailed design

A detailed design of an apartment is outlined in Fig. 4. The addition of the façade and converting the existing, access galleries and balconies in living space increases the latter from an average of approximately 73 to 93 m^2. Moreover, situating the shafts externally permits to create normal, single as well as duplex apartments within a *single* apartment block.

The external shafts, located at the north façade, contain ducts for gas, electricity, (warm/domestic) water and most importantly the new outlet ventilation ducts. In the presented concept the sewerage shaft remains necessarily internal, because the horizontal distance of a sewerage pipe is limited. A large, new internal shaft for all ductwork can not be realized due to structural and spatial reasons. So, shaft separation is required. The small internal shaft, that solely contains a single drainpipe (Ø = 120 mm), is centralized between the structural walls, allowing floor-plan-mirroring. Placement of a raised floor in the "machinery"-room in order to connect the bathroom drainage with the internal shaft is inevitable.

Some drawbacks of external shafts are however the necessary insulation of the shafts and that these shafts take width and depth of the façade. Furthermore, a horizontal air duct that connects the central exhaust outlet in the machinery-room with the external shaft should be realized. This small horizontal duct can be easily hided between the ceiling and kitchen cupboards. However, the technical features of an external shaft, such as flexibility, and their architectural appearance within the access façade are considered to be major quality features.

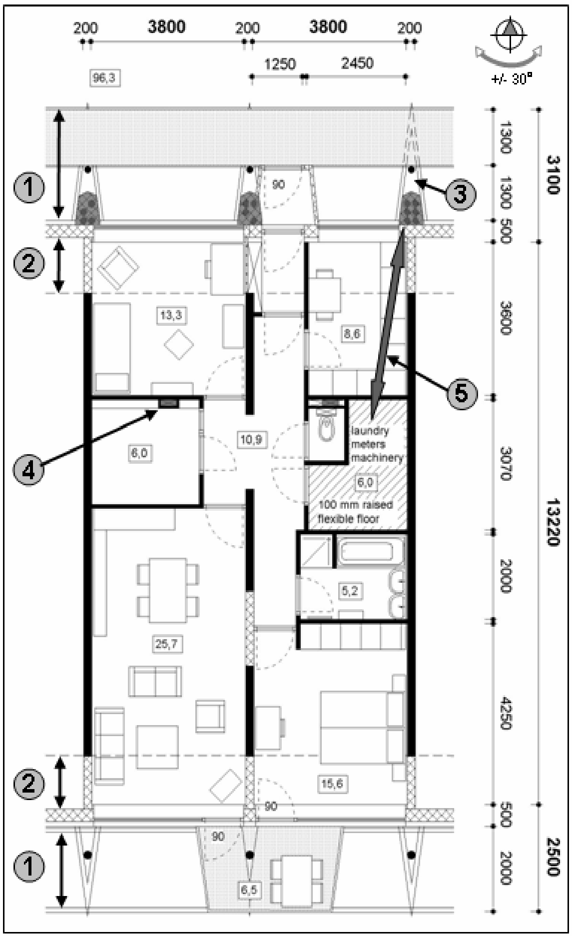

Figure 4: Detailed floor plan of dwelling in renovated apartment block. **(1)** Portal structure with façade elements; **(2)** Former gallery/balcony; **(3)** 3D-colum with supporting cantilever beams and external shaft; **(4)** Centralized, internal sewerage shaft; **(5)** Raised floor in the "machinery-room, and cased air duct from centre to the external shaft.

3.4 Energy consumption

Reduction of energy consumption was a major prerequisite for the feasibility of the renovation of the existing apartment blocks [14]. As summarized in Fig. 5, a series of measures needs to be taken to reach the targets of the Faktor-10 vision. For example, extensive prevention of thermal bridges may provide a 40% saving of the total transmission loss (R_c = 7,0 en U = 1,0 W/m^{2}K) [15]. In this respect the portal structure may prevent among others thermal bridges applying a draught gate and sun lounge. Moreover, the multifunctional façade-element allows for a combination of super-insulation, HVAC-installations and the use of passive solar energy.

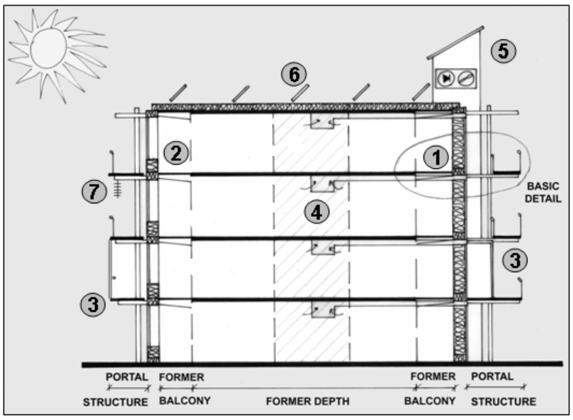

Figure 5: Cross-section of renovated apartment block. **(1)** Thermal insulation of structure; **(2)** Passive solar energy with an optimal glazing system; **(3)** “Slim” portal frame to prevent thermal bridges with a draught gate and sun lounge; **(4)** “Dark” zone for utility rooms; **(5)** Heat recovery from outlet-ventilation with a heat-pump; **(6)** Solar collectors for domestic hot-water; **(7)** Sun protection. Note the former balconies and new portal structures.

3.5 Hybrid ventilation

The 60’s-70’s apartments suffer from outdated ventilation technology. Additional to the significant loss of energy (4500 kWh/a, 24 %), the adjustability of temperature and amount of fresh air is poor. In accord with contemporary practice, application of a balanced ventilation system with an air-to-air heat recovery, characterized by its high (85%) efficiency, seems to be a worthwhile improvement. Recently, however, several disadvantages of this system have been recognized, ranging from health problems (noise, insufficient fresh air, contaminated filters) to adjustability [16].

A novel system, known as the hybrid system, combines controlled natural inlet ventilation with a central-placed (wind-powered) exhaust fan [17]. The structural consequences of a hybrid system are minor. It consists of controlled (for example CO_2 sensors) inlet grids in the façade with or without pre-heating by an adjusted radiator, offering the occupant the opportunity to affect the ventilation rate in a proper manner. The supply ducts of a hybrid system are relative easy to install, while opening the windows does not affect the functioning of the system. Depending on the future price movement of especially the CO_2 sensors the additionally gained comfort associated with this system is considered to be a worthwhile, cost-effective investment. A disadvantage is the absence of air-to-air heat recovery, although an air-to-water exchanger with a heat pump enables heat recovery of exhaust air for preheating domestic water (42% efficiency).

3.6 SlimFac10 façade element

The designed multifunctional façade-element, to be named SlimFac10, provides an efficient separation between the in- and outdoor climate. The prefabricated element with a total thickness of 450 mm unites super insulation (R_c = 7.0 m^2K/W, 300 mm), triple glazing (U = 0.8 W/m^2K), hybrid ventilation, (pre-) heating and necessary sun protection (Fig. 6). The latter, complemented with the possibility of summer night ventilation, is essential for a highly insulated dwelling [8]. The sun protection encompasses an internal straightforward roller blind with a dark outside for preheating, operated manually. The horizontal blinds on the outside are self-activated by a control-unit that also responds to the inside temperature.

Some durable features of the façade element are worthwhile noting. It consists of a timber frame construction with reduced I-posts, build up by two small slats of timber and a plywood plate, filled with mineral wool [7]. At the inside, there is a plywood panel with a installation envelope of 70 mm, finished off with plasterboard at the building site. So, the small ductwork does not penetrate the vapour barrier. The outside exists of a waterproof and fire resisting slab with in front of that framing and a slender façade panel. The façade element is strengthened with two steel L-beams on the top and the bottom to provide sufficient overall stiffness for easy fixing.

The inevitable heat transmission due to the connection between the outside portal structure and the main inside construction will be limited by a mini-framework of stainless steel.

If preferred, the former balcony floor slab can be replaced without major effort by a flatter and lighter floor element resulting in a smooth ceiling finish (Fig. 6).

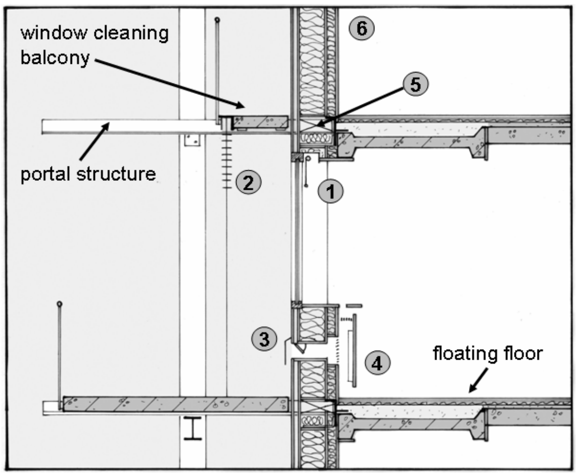

Figure 6: SlimFac10 multifunctional façade element. **(1)** Roller blind; **(2)** Horizontal blinds; **(3)** Hybrid air inlet; **(4)** Pre-heating/radiator; **(5)** Thermal break; **(6)** Installation envelope.

4. TESTING THE CONCEPT

As an initial approach, the assumed reduction of energy consumption was tested using the EPCheck model. It provides a reasonable indication about the energy consumption of the dwellings. Taking into account the major demands of comfort of living, a

Table 4: Input parameters for the EPCheck model and comfort targets.

Faktor-10: input	
Insulation ≥ 300 mm (R_c = m²K/W)	> 7.0
Glass HR++ / triple (U = W/m²K)	< 0.8
Air tightness (qv_{10} = dm³/s.m²)	< 0.15
Ventilation rate (h^{-1})	0.8
Solar collector / dwelling (m²)	6
Comfort targets	
Exceeding hours > 25 ^{0}C (h)	150
Sound insulation between dwellings ($I_{lu;k}$ / I_{co} = dB)	+5 / +10
"Quiet" room ($I_{lu;k}$ / I_{co} = dB)	0 / -10
Minimal dimension of an occupied room (m)	2.4 x 2.4

series of design-included Faktor-10 criteria (220 to ≈25 kWh/m2a) served as input for the model (Table 4). Related to the integrated sun protection system, it seems appropriate to decrease the exceeding hours of > 25 °C to 150 hours compared to the more regularly applied Dutch guideline of 300 hours [19, 20]. Several other items, such as a heat-pump boiler with solar collectors, that covers the total need for domestic hot water, were also included.

The results of this preliminary modelling indicate that renovation of 60's-70's apartment dwellings can be accomplished with a considerable reduction of energy consumption (Fig. 7). A calculated total heat flow of 46 kWh/m^{2}a was obtained. This summarizes as a reduction of energy consumption by approximately a factor of 5 compared to the current situation. The new design performs far better than the current standard defined by the Dutch Building Decree (110 kWh/m^{2}a) [11], but the Faktor-10 target (25 kWh/m^{2}a) has not been completely fulfilled. At present, the exact effect of inclusion of hybrid ventilation is far from clear, but for the time being a further reduction to a total heat flow of 35 kWh/m^{2}a seems to be reasonable [18].

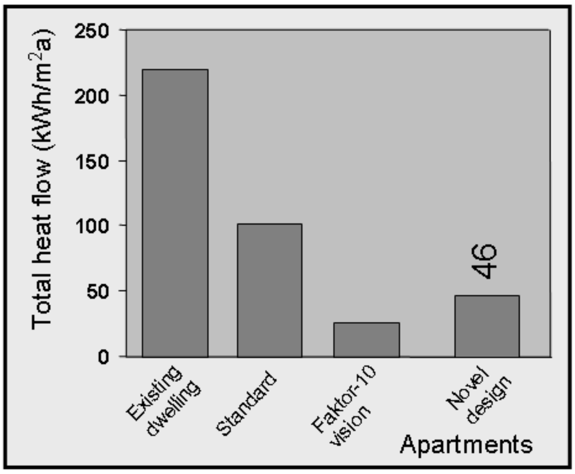

Figure 7: Total heat flow of renovated 60-70's apartment dwelling (novel design) compared to that of an existing apartment, the current Dutch standard and the Faktor-10 vision.

5. CONCLUSION

"*Space and light and order. Those are things that men need. Just as much as they need bread or a place to sleep*" - Le Corbusier. Based on this design philosophy a novel approach for renovation of outdated apartment blocks, build during the 60's and 70's, is suggested. Although demolition of these apartments has been frequently put forward, it is argued that the outlined renovation, according to the contemporary building standards, pays off with respect to limited debris, building materials, transport, comfort and finally the low energy consumption during a renewed life period (at least 40 years) of the building [6, 11].

Stripping of the existing façades, adding portal structures and multifunctional façade-elements (SlimFac10 element) provide an opportunity to rearrange an apartment block with various types of enlarged dwellings. Even without inclusion of hybrid ventilation a significant reduction of the heat flow, reaching a total of ≈ 46 kWh/m^{2}a, appears to be a feasible goal. Although an extensive dynamic simulation is required to predict the precise heat flow, the amount of temperature exceeding hours and cost-effectiveness, it is tempting to speculate that renovation, contrary to demolition, of Dutch 60's-70's apartments is possible. Moreover, several aspects of the presented approach may be of value for other types of apartments, both within renovation and new development concepts.

REFERENCES

[1] J.F.T. Roeloffzen, R. Lanting, N.P.M. Scholten *et al.*, Ministry of Housing, Spatial Planning and The Environment, Den Haag - The Netherlands (2004).
[2] F. Stofberg *et al.*, Vademecum, Novem, Sittard - The Netherlands (1999), 110.
[3] A.G. Hestnes (Ed.), Solar Energy Houses IEA, James & James Ltd., London - England (1997), 133.
[4] H.L.C. Hilhorst and K.O. van der Linden (Eds.), VAC-Kwaliteitswijzer: integrale visie op de gebruiks-kwaliteit van woning en woonomgeving, Landelijk Contact VAC's, Utrecht - The Netherlands (1997).
[5] S. Silvester and G. de Vries (Eds.), Woonsatisfactie, bewonersgedrag en bij Voorbeeld-projecten Duurzaam Bouwen, SEV, Rotterdam - The Netherlands (1999).
[6] J. Lichtenberg, Slimbouwen®. Aeneas, Boxtel - The Netherlands (2005).
[7] W. Feist, Das Passivhaus, C.F. Müller - Verlagsgruppe Hüthig, Heidelberg - Germany (1999)
[8] B.J. de Boer et al., De Optimale PZE-Woning. ECN projectnumber 7.4861 (2003).
[9] B. Schulze Darup, Dissertation Universität Hannover / Fachbereich Architektur (2003).
[10] F. Lichtblau, Herausforderung Gebäudebestand: Gesamtwirtschaftlichkeit erneuern für Generationen - mit Beispiel. lichtblau-fw@t-online.de.
[11] Regeling Bouwbesluit 2003 (Dutch Building Decree) (2006). www.vrom.nl/pagina.html?id=18335.

[12] P.Dogge *et al.*, Eindhoven doorgelicht. Deel1: Dynamiek, waardering en woonvoorkeur (1996).
[13] L.C.J. Luxemburg and T.M.J. Raijmakers, SMD Educatieve Uitgevers, Leiden - The Netherlands (1997), 79.
[14] J. Hoogers (Ed.), Bouwen met Tijd, SEV, Rotterdam - The Netherlands (2004).
[15] A. Poel, BouwWereld 24 (1995), 20.
[16] F. Duijm, CoBouw, feb (2006).
[17] P. Heiselberg (Ed.), Principles of Hybrid Ventilation. Aalborg University, Aalborg - Denmark (2002).
[18] E.M.M. Willems and Y.K. Wertwijn, Ventilatie & Verwarming, mrt (2003), 153.
[19] Energy performance of residential functions and residential buildings, NPR 5129, NEN (2005).
[20] Toolkit Duurzame Woningbouw, SenterNovem, Sittard - The Netherlands (2004).