
# STATE-OF-THE-ART DEEP RENOVATION CONCEPT WITH MODULAR PREFABRICATED FAÇADE AND ROOF PANELS: *EXPERIENCES FROM THE NETHERLANDS*

### *D 3.3 PRODUCTION AND CONSTRUCTION SPECIFICATIONS: BUILDING BLOCKS OF DEEP RETROFITTING*

MORE-CONNECT, November 2017, J.A.W.H. van Oorschot, MSc., ed.

# STATE-OF-THE-ART DEEP RENOVATION CONCEPT WITH MODULAR PREFABRICATED FAÇADE AND ROOF PANELS: *EXPERIENCES FROM THE NETHERLANDS*

## *D 3.3 PRODUCTION AND CONSTRUCTION SPECIFICATIONS: BUILDING BLOCKS OF DEEP RETROFITTING*

**J.A.W.H. van Oorschot, MSc., ed.**
**May, 2017**

**List of Contributing Authors:**

| Author | Abb | Affiliation | Located |
|---|---|---|---|
| (John) J.A.W.H. van Oorschot, MSc. (ed.) | ZUYD | ZUYD University of Applied Science | Heerlen, The Netherlands |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

## TABLE OF CONTENT

## CHAPTER 1: SHORT INTRODUCTION

### 1.1 Aim of the report

This report links to Work package 3: System integration of the H2020 project MORE-CONNECT. In particular, this report aims to outline a deep renovation concept based on modular prefabricated façade and roof panels, both addressing the technological design and the practical application conditions. In this respect, this report builds upon deep renovation projects completed in the Netherlands in which modular, prefabricated façade and roof elements have been applied. This deep renovation approach have been stimulated by governmental deep renovation policies and a covenant (‘De Stroomversnelling) signed by housing associations and contractors to retrofit at least 10,000 dwellings. Doing so, three research questions will be addressed:

1) What drives the develop of the ‘Stroomversnelling’ deep renovation approach in the Netherlands (chapter 2)?
2) What are the key cornerstones of the ‘Stroomversnelling’ deep renovation approach (chapter 3-7)?
3) Which mechanisms affect the adoption and uptake of the ‘Stroomversnelling’ deep renovation approach in (social housing) projects (chapter 8)?

It has to be emphasized that deep-retrofitting toward zero energy housing not only gained attention in the Netherlands. Across Europe state-of-the-art projects contributes to this goal. A short overview is presented in Appendix B.

### 1.2 Methodology

Two methodologies have been applied to develop this report. First, desk research have been conducted to assess the policies which stimulated the development of the deep renovation solutions in the Netherlands. The covenant which emerged from policy development and experiments in the market has resulted in the development of a dominant design for deep renovation in the social housing sector. In addition to the desk research, a case study approach have been followed to assess several deep renovation projects which have been completed in accordance (‘De with the dominant design. Besides extensively assessing the case projects it has also been assessed which mechanisms affect the adoption and uptake of deep renovation in the Netherlands.

### 1.3 Structure of the report

This report is structured as follows. In the next chapter an chronological overview of energy efficiency policies in the Netherlands is presented. In chapter 3 deep renovation approaches are discussed as well as how the dominant design was established in accordance with the covenant ‘De Stroomversnelling’. In the subsequent chapters several exemplary pilots are discussed which have been renovated in accordance with the ‘Stroomversnelling’ deep renovation approach. More specifically, in chapter 4-7 four key (demonstration) projects will be presented in chronological order and it will specifically addressed how the ‘Stroomvernelling’ matured in contrast to the previous project. Next, the mechanisms which stimulate or inhibit the uptake of deep renovation are discussed in chapter 8.

## CHAPTER 2: CHRONOLOGICAL OVERVIEW OF ENERGY EFFICIENCY POLICIES IN THE NETHERLANDS

This chapter provides a historical overview of the energy efficiency policies for the Dutch residential sector. This overview points out the rise and expected results for the energetic home improvements in the past (1973-2004), present (1997-2016) and (near) future (up to 2050).

### 2.1 National Insulation Program (NIP) & National Environmental policy (NMP) 1973-2004

In response to a series of events including a growing energy consumption, social resistance to nuclear power, declining gas reserves, dependence on foreign energy, the report of the Club of Rome (1972) and the oil crisis (1973), Prime Minister Lubbers (1982-1994) introduced for the first time an energy policy: The Energy Bill 1974 (Bais, 1990; De Jong & Borger, 2003). Between 1975 and 1983, thermal insulation with respect to roofs, cavity walls, windows and floors were included in the building codes for new housing. In 1974 the Ministry of Environment Affairs launched the first subsidy scheme for energy saving (Decision Pecuniary Aid Heat Insulation, BGSWI) (VROM, 2002). Employment Funds were used for post-insulation of 400,000 homes that the Ministries of Environment and Economic Affairs (EZ) and from this the National Insulation Program (NIP) was introduced in 1978 ((SNIP), 1988). In the period 1978-1988, 1.8 million homes were insulated according the NIP program. After the implementation of the NIP 1.15 million homes still had no form of insulation. From January 1987 housing improvements in the social and public rental sector were funded with 'clim loan' (in Dutch: klimlening) in accordance with the Scheme Pecuniary Support Services Rentals (RGSVH) (VROM, 2002). The development of the energy is reflected in the period 1973-2004.

From January 1991 the post-insulation of existing homes intensified according NMP+, which emerged from the National Environmental Policy (NMP) from 1989. This program aimed at energy savings of 2% per year (De Jong & Borger, 2003). In addition to improving energy efficiency of buildings the NMP+ also stimulated the reduction of GHG emission. As a result the NMP+ supported the uptake of energy saving and Sustainable Construction (DUBO). As a result of lower economic growth, annual savings within the NPM2 (1993) was revised to 1.7 percent. It has to be emphasized that for the development of NMP policies the government consulted the industry upfront in order to stimulate more sustainable construction practices based on long term agreements that were laid down in covenants (De Jong & Borger, 2003). In compliance with NMP2, NPM3 (1998) and NPM4 (2001), an Energy Performance Standard (EPN) standard was developed for buildings in The Netherlands. The EPN include restrictions and guidelines for thermal insulation, air permeability of the building envelope (facade, roof and floor), active and passive solar energy, heating and cooling, ventilation and lighting (Bregman & Chao-Duivis, 2007).
The NMP has been adjusted several times over the years. In the early version the NMP (+) focused on the energy savings (i.e. improving insulation of the building envelope), while NMP4 mainly focuses on the sustainable power generation. Moreover, NPM4 in particular addresses (inter)national policies regarding the reduction of the environmental impact of built environment (RIVM, 2001). The fourth environmental plan (NEP4) specifically aims at initiating sustainable building through transition management, which can be seen as the third generation of environmental policy (Grin, Earl, & Vergragt, 2003; Van der Vlist, 2003).
On October 15, 2004, the Ministry of Economic Affairs (EZ) introduced the program "EOS: demo and transition experiments". The main goal of this program was to support demonstration projects. In this way firm were able to demonstrate the performance of new sustainable technologies (NL Agency, 2010b; EZ, 2009). In compliance with the EOS demo a subsidy program was introduced of 4.5 million Euros to support demonstration projects (the 'Unique Opportunities Scheme (UKR) - Energy neutral housing' (2008-2011)).
As a result of the NIP and NMP the Dutch housing stock has been improved by means of new build housing and renovation. Furthermore, based on the year of construction and taking into account the prevailing building codes the energy performance of the Dutch housing stock can be estimated relatively easy (Liebregts, 2011; Smart Building, 2004). However, while the energy performance of the existing housing stock have been improved gradually over the years it is hard to predict accurately the energy performance of housing constructed before 1983.

The NIP program has resulted in the improvement of the energy efficiency of about 1.8 million housing units and from a quantitative perspective relatively successful (i.e. 1.8 out of total building stock of 7.5 housing units). However, qualitatively, these housing units are mostly partially insulation (coverage of about 25 percent of primary energy demand) which is insufficient considering a (near) energy zero built environment (Bais, 1990).

Until the introduction of the Energy Performance Standard (EPN) for new constructed housing (introduced in 1995) insulation measures were regarded as separate interventions that contribute to reducing energy consumption (PeGO, 2007). Since the introduction of EPN insulation is part of an integral approach to achieve the required energy performance of buildings. During the introduction of the EPN the existing building stock was not yet addressed with respect to energy efficiency. In the period 1980-1996, the costs of gas and electricity consumption decreased by 29 percent and as a result the available subsidies hardly stimulated housing associations to improve the energy efficiency of housing (Jeeninga, 1997).
With respect to the energy efficiency performance of dwellings owned by social housing associations (owning 30% of the housing units in The Netherlands), the NIP and NMP resulted in:

1. Housing build before 1975, originally are constructed without any insulation. However, housing constructed in the post war period are often (partially) renovated (roof, crawl space and cavity wall have been insulated and the dwelling has been improved by double glazing);
2. Houses built between 1975 and 1983, depending on the year of manufacture, are often equipped with a number of the above measures, and optionally enhanced with extra insulation;
3. Properties of the construction period from 1983 to 1995 are equipped with several energy efficiency measures without taking into account the consistency of these measures.
4. Houses built after 1995 have a fully insulated building envelope in order to comply with the imposed energy performance.

Due to the missing or limited insulation of the building envelope, properties constructed before 1979 require a radical approach to comply with current energy efficiency policies. In the period 1973-2004, the government has subsidized the distribution of insulation measures in the Dutch residential sector. Since 2004 the government in particular provide funding to the demonstration of new technologies until the end of the program in 2011.

### 2.2. Kyoto agreement, the Clean and Green program and energy efficiency covenants (1997-2016)

In 1997, in compliance with the Kyoto agreement, 55 countries of the United Nations (UN), including the Netherlands, declared that they will reduce greenhouse gas emissions to reduce global warming in 2050 by two degrees compared to 1990 (Netherlands Environmental Assessment Agency, 2011) . Moreover, the European Commission (EC) aims at a reduction GHG emission of 80 per cent by 2050 compared to 1990 to comply with the Kyoto Protocol. In the European Union (EU), the built environment is responsible for 30% of the total GHG emissions. To achieve the climate target from the Kyoto Protocol in 2050, the Energy Performance of Buildings Directive (EPBD) requires all EU Member States to reduce GHG emissions by 20 percent before 2021 compared to the situation back in 1990.
In May 2006, targeting the residential sector at large, the Energy Transition Platform for the Built Environment (PeGO) contributed actively to the development of new energy policy, which resulted into the "Clean and Green" program. The "Clean and Green" program was introduced in 2007 and in particular builds upon the previous NMP programs. The "Clean and Green" program in particular directs the efforts of the construction industry to further improve the energy efficiency of the Dutch built environment (Ecofys, 2010). The "Clean and Green" program operationalizes the Kyoto agreement and the ensuing European policies (i.e. the 2002 and 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive) into concrete objectives. Based on the EPBD and the Kyoto agreement, the Dutch government aims at the following three goals with the "Clean and Green" program (Ecofys, 2010):

1. Greenhouse gas emissions in 2020 reduced by 30% compared to 1990;
2. The rate of energy reduction doubles from 1 to 2 percent per year;
3. The share of renewable energy in 2020 is now raising about 1% to 20% of total energy;
4. Tightening of the EPC for new homes to 0.6 in 2011 and 0.4 in 2015;
5. Realization of (fossil) energy neutral (newly built) homes in 2020;
6. New commercial and industrial buildings in 2017 to 50% better energy performance compared to the current situation;
7. Reduction total energy use in the built environment of 50% by 2030.

To implement the "Clean and Green", the Ministry of Housing, Spatial Planning and the Environment (VROM) established multiple covenants, the most important covenant include:

- In 2007 several ministries and the Association of Dutch Municipalities (VNG) developed the "Climate Agreement City and State 2007-2011" which simulates municipalities to transform, revitalize and renovate specific districts. No concrete reduction goals are included in this covenant.
- On January 23, 2008 the Ministry of Housing, Spatial Planning and the Environment (VROM), the Ministry of Economy and industry associations Bouwend Nederland (contractors) , UNETO-VNI (service installation companies), EnergieNed and VME (energy companies) signed the covenant "More with Less" (VROM, 2008). This covenant focuses on the development and promotion of energy conservation in the built environment and aims at 100 PJ energy reduction within the existing building stock before 2020. Therefore, at least 300.000 existing dwellings and buildings need to be transformed into energy efficient buildings.
- On October 10, 2008 VROM, Aedes (industry association for social housing corporations) and Woonbond (representing the residents) established the 'Covenant energy sector corporation'. Based on this agreement, renovation projects of social housing associations should improve existing housing towards energy label B or at least two label steps.
- On June 28, 2012, the covenant "More with Less" is replaced by a more comprehensive covenant "Built environment" and the covenant "Energy reduction social housing sector" is replaced by the covenant "Energy reduction rental sector". The covenant "Built Environment" aims an energy reduction From 617 PJ in 2008 to a maximum consumption of 507 PJ in 2020 (540 PJ in 2015). Moreover, energy labels become mandatory. Next, the covenant "Energy reduction social housing sector" aims at 33% savings on the building-related energy consumption in the period 2008-2020. As a result of the policy changes, for the first time, also the private rental sector is included. However the ambition with respect to energy efficiency is somewhat lower (80% of the housing owned by the commercial rental sector need to be improved to label C) in contrast to the social housing sector (label B). More specifically, social housing associations need to improve their total housing stock to an average level of label B (in contrast to the 2008 policy which only addressed renovation projects which aim at energy efficiency improvement). In the end, 2.4 million housing units owned by social housing associations need to be improved in this respect.
- For new constructed housing the most important energy efficiency goals are confined in the Spring Agreement of 2012. This agreement include that the energy efficiency of new constructed housing need to be improved by 25% in 2011 and 50% in 2015 compared to the situation in 2008. Next, the energy ambition of about 5-10% of new constructed housing is set 25% higher than is required by law. From 2020 onwards all new constructed dwellings are (near) energy-neutral (the appointed goals are relate to building-related energy consumption).

In line with the "Clean and Green" program the Ministry of Internal Affairs developed the innovation agenda "Energy and the Built Environment". The "Energy Leap" (in Dutch: Energiesprong) was established in 2010 as part of the innovation agenda (as part of Platform 31). The goal of "Energy Leap" was to save 45% to 90% on energy consumption of about 2,500 homes by the end of 2016. Meanwhile, during the period 2010-2016, the focus of energy efficiency improvement in housing have been shifted from 60 to 80% energy reduction towards "zero on the meter". The "Energy Leap" program in particular stimulated the development, adoption and implementation of innovations necessary to achieve very energy efficient housing. After the completion of some pioneering projects, in 2013 a covenant, "The accelerator" (in Dutch: Stroomversnelling), was signed by 4 contractors and 6 social housing associations to renovate 11,000 single family homes towards "Zero on the Meter". Its primary goal was to diffuse deep renovation toward zero energy at a large scale and beyond the level of pilot projects. Moreover, "The accelerator" contributes to the feasibility and affordability of deep renovation and creates awareness within the Dutch residential market.

Despite public and private efforts, interim reports showed that the achievements of the Dutch housing sector fall behind with respect to the energy efficiency goals included in these covenants and governmental programs (Ecofys, 2010).

### 2.3 Towards a circular economy in 2050

On June 25, 2009, the European Parliament replaced the Renewable Energy Directives from 2001 and 2003 by "RED 2009/28 / EC". Based on this policy all Member States were required to develop energy policies up to 2050 (EC, 2009). Then the Dutch government (PBL) asked consultant ECN to develop a roadmap "to an energy-efficient economy by 2050".

In order to reduce GHG emissions by 80 percent in 2050, only "near-zero energy buildings" are constructed from 2020 onwards (NL Agency, 2010a). However, a large part of the building stock in 2050 consist of existing dwellings (Netherlands Environmental Assessment Agency, 2011). Building often have a life cycle over 100 years. De Bruijn and Fox (2012) indicated that, on the basis of available building capacity of 1.06 percent, that a house should have a minimum lifespan of 95 years. Thus, 75% of the expected housing stock in 2050 consists of dwellings constructed before 2010 (PBL, 2011, p. 62). The Dutch Environmental Assessment Agency (PBL) recommends to further reduce the (primary) energy needs of housing. Passive House is named as an appropriate approach to do so. For the remaining energy needs the agency recommends to apply heat pumps and PV.

More recently, 2016, the Paris Agreement has been signed by 195 countries including the Netherlands. The primary goal of the Paris Agreement to limit global warming to 2 degrees Celsius. Moreover, countries try to limit the temperature rise to a maximum of 1.5 degrees Celsius. The Paris Agreement has not yet resulted in working programs to contribute to this goal and improve the uptake of practices which reduces the environmental impact of the built environment.

Moreover, while the Dutch government aims at a circular economy in 2050 it has introduced Green Deals with large firms to stimulate the separation of waste streams. Next, on January 24, 2017 the Commodity Agreement was introduced and signed by 180 stakeholders. This Commodity Agreement stimulates the Dutch economy to run circular on renewable raw materials in 2050. 180 parties signed the National Commodities Agreement. However, already in 2030, the Netherlands should use 50% fewer raw materials (minerals, metals and fossil). Circular construction is still in its infancy and yet there is a lack of exemplary circular buildings.

## CHAPTER 3: KEY CORNERSTONES OF THE 'STROOMVERSNELLING' DEEP RENOVATION APPROACHES

Chapter 3 will address the key cornerstones of the 'Stroomversnelling' deep renovation approach. Within the first 5 sections the background of the key cornerstones will be addressed by assessing different deep renovation approaches. In the final section the key cornerstones of the 'stroomversnelling' will be discussed by presenting the development of the deep renovation market since the introduction of the Energy Performance of Buildings Directive (chapter 2).

### 3.1 Anyway renovation

When adapting existing homes, Liebregts and Persoon (2011b) distinguish two extremes: only one or more components must be corrected or only the existing structure is preserved and all other components, including the entire building envelope, is replaced 'as new'. Current practice with respect to renovation is dominated by preserving the existing quality of housing (M. Liebregts & Person, 2009). Measures are still focused on repairing and replacing bad parts, but does not necessarily improve the indoor climate or energy efficiency of the dwelling. The aim of anyway renovation is an energy index score of at least 1.25 or lower and a lifetime extension increase of 15 years. This is done by using conventional renovation methods and frequently used renovation materials. In general this includes the replacement of single glazing by double glazing, insulating the cavity walls, insulating the roof from the insite and replacing inefficient central heating (gas). The anyway renovations are motivated by the "Meer met Minder" and "Huurconvenant" covenants. Moreover, the "Huurconvenant" states that the entire Dutch housing corporations housing stock should at least have an energy index of 1.25 (energy B label) or lower in 2020. The same energy index requirement of ≤1.25 is used for the low ambition level renovation. Besides an energy performance increase the renovation should also extend the functional lifetime of the dwelling with 15 years (Dijkstra, 2013).
In contrast to the low ambition 'anyway renovation' also high high ambition renovation solutions can be selected. High ambition renovation (or deep renovation or nZEB renovation) solutions are primarily motivated by 'de Stroomversnelling' covenants which have emerged out of two innovative deep renovation projects ("de Kroeven" and "de bestaande wijk van Morgen"). The requirements for both projects were at least an energy A label or higher and a functional lifetime extension of approximately 50 years (Dijkstra, 2013). High ambition renovation projects in particular build upon passive and active house principles as will be discussed below.

### 3.2 Passive house renovation

The passive housing construction method can make an important contribution to both national and European energy conservation objectives in the built environment (De Boer, Kondratenko, Jansen, Joosten, & Boonstra, 2009). Passive houses are extremely well-insulated dwellings with exceptionally low infiltration losses and minimal energy use for space heating. A passive house is heated to a large extent by passive solar utilization and by the internal heat development of persons, installations and household appliances. The remaining heat demand has become so low that in order to achieve a comfortable and healthy indoor climate, a limited heating capacity can be provided that can be delivered through the ventilation air. The purpose of a passive house is to achieve high energy efficiency using a high-quality airtight building shelf and a simple installation concept and building management system (Nieminen et al., 2007). Bo Adamson, Robert Hastings and Wolfgang Feist have developed the passive house construction and calculation method between 1989 and 1992 and tested in a newly built complex at Darmstadt (Passivhaus Institute, 2012). For the development of the passive housing method, the researchers established the Passivhaus Institute in 1996 which provides the calculation software PassivHaus Planungs Package (PHPP). Passive houses apply a maximum annual primary energy consumption for space heating and 15kWh / m2 hot water production at new construction and 25kWh / m2 for renovation. In addition, a maximum heating capacity of 10W / m / m2 and a maximum primary energy consumption of 120 kWh / m2 applies to new buildings and 130 kWh / m2 for renovation. In the "Promotion of European Passive Houses" (PEP) project, the renovation standard has been established after analysing various renovation projects. Due to deviations in existing construction, it is often not possible to meet the norm of 15kWh / m2 in an economically sound manner. PEP projects have demonstrated that passive housing renovation within a deviation of 10kWh / m2 is economically sound, resulting in the renovation standard of 25kWh / m2 per year (Ploss, 2008). The energy performance for Passive House New Construction and Renovation is achieved with the continuation of a series of design steps as Sintef describes in the Kyoto Pyramid (Figure 2.15) (Boonstra, Clocquet, & Joosten, 2006).

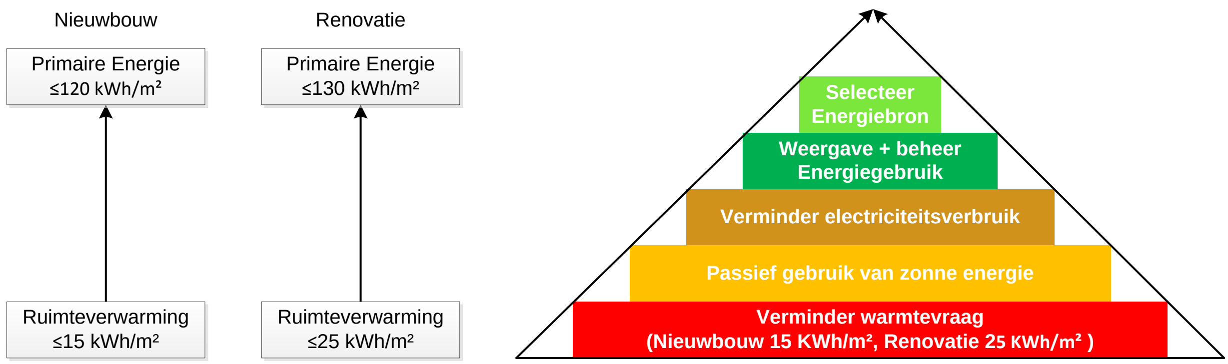



*Figure 3.1: The Kyoto pyramid and the passive house design process (based on Sintef) (Boonstra et al., 2006).*

The adoption of the passive housing construction method was largely hampered by the high initial investment costs in 2008 compared to traditional construction methods, and to a lesser extent due to lack of practical knowledge and availability of building elements (Elswijk & Kaan, 2008). The packaging of brick facades with insulation material can obstruct the uptake of passive house renovation in the Netherlands and Belgium while it drastically changes the aesthetic appearance of the building (Elswijk & Kaan, 2008). In Germany, the packing of facades is more accepted because stucco is a usual form of facade finishing. In addition, the PHPP calculation in the Netherlands is not accepted as a replacement for the Dutch energy performance (EPN) calculation, which means that the energy performance must be calculated twice for the application of a building permit. The passive house EPC is about 0.4 equal to an A++ Energy Label. In the Netherlands passive housing inspection, testing and certification of projects are organized by the Passiefbouwen.nl (2012) foundation. As discussed in the previous chapter, the deep renovation approach included in the covenant ‘De Stroomversnelling’ builds upon the passive house approaches and the Kyoto pyramid design guide.

## 3.3 Active house renovation

According to Rovers (2008), the passive approach to energy saving is not always automatically the best method because airtight housing requires an abundance of materials. The production of construction materials contributes to the depletion of natural resources and climate change resulting from GHG emissions (emanating from the production of the materials). Therefore, considering deep renovation, designers should not only take into account the operational energy of buildings but also the embodied energy of construction materials included in the design. Thus, a careful balance between active and passive measures is required. In addition to energy saving, energy generation is necessary to make the housing stock in 2050 energy neutral. Van Nunen and Van Bergen (2011) contributed to the development of "Active House" which builds upon the basic principle to include renewable energy in the design like solar thermal heating (4.6m2) and photovoltaic (PV) solar panels (18.6m2). The "Active House" provides itself completely of energy produced by renewable sources for space heating, domestic hot water and (household) electricity. In the construction sector today it is actively debated or the active or passive house concept should be applied. This discussion is not described here because while it is beyond the scope of this report. While the government and the residential construction industry supports the covenant ‘De Stroomversnelling’, other deep renovation approaches (like active house) are not explored as extensively as passive house.

## 3.4 Energy reduction measures

An important measure to reduce the heat demand of a home is to improve the insulation value of the building shelf. Solving thermal bridges (interruptions in the insulation gap) requires a lot of attention because they lead to heat loss and can cause problems with moisture and fungus. In addition, airtightness is an important issue. Airtightness of a dwelling contributes to an energy reduction of 20%, and continuous functioning ventilation is required to prevent moisture problems (Senternovem, 2009). In the existing building, insulation can be added inside or outside (Senternovem, 2009), table 1 shows the characteristics of these two methods.

*Table 3.1: Overview features energy reduction measures*

| Energy reduction measures | External insulation (building envelope renovation) | Internal insulation (box-in-box renovation) |
|---|---|---|
| ***Effect on internal building dimensions (floor space)*** | None | Floor space diminishes due to the insulation |
| ***Effect on internal building dimensions*** | Extension of building dimensions due to the addition of insulation; not applicable when the building dimensions exceed the plot boundaries, also not applicable for monumental buildings | None |
| ***Thermal bridge*** | Wrapping or removing balconies or hanging cold bridges or putting them in a detached construction. | Floors and walls that pass through the exterior are disconnected or packed with insulation. |
| ***Application*** | Low (aesthetic) quality building facade | Monumental buildings; sufficient internal building dimensions |

In case of a passive house renovation, extra attention is paid to the windows, doors, and the connection of these elements to the facade. For example, passive house doors have two stops with double sealing so that airtight closure is possible. Passive housing cages have a built-in cold bridge interruption that often consists of an enclosed air chamber and usually also includes two stops with a double core seal. In the passenger compartment cushions, triple glazing is fitted, the outer windows of which are fitted with a (sun-resistant) coating and the cavity is filled with argon that is better insulated than air (Cobbaert, 2003). Senternovem (2009) describes that traditional building methods accept a cold bridge between the window frame and the facade. Cobbaert (2003) describes that the cold bridge between the frame and the facade can be eliminated by completely enclosing the frame with insulation material. In addition to the structural elements, the shape and orientation of the building plays an important role in energy consumption. Senternovem (2009) indicates that the compact renovation of houses by removing jumps or protrusions from the façade results in a smaller outside surface with a consequent reduction of heat loss. In addition, in some cases it is possible to increase the zone entry by providing additional windows in the south-facade combined with an adjustment of the housing layout. The window surface of the north side can thereby be reduced to reduce heat loss. Overheating can occur in homes with large window surfaces and facades with a high insulation value. Senternovem (2009) recommends applying sun protection to prevent overheating.

### 3.5 Energy production measures

In addition to the insulated building shelf, the energy demand of a dwelling according to Senternovem (2009) can be reduced with the following installations:

- Balanced ventilation: extracts the heat of the outgoing ventilation air to preheat the fresh incoming ventilation air, with high efficiency recovery of up to 95% of the energy. During renovation, the balances for balanced ventilation must be integrated into the existing house. The Netherlands is the only country where there is discussion about the risks of balanced ventilation for public health after problems with incorrectly installed systems in the Vathorst district of Amersfoort. The balanced ventilation design requires careful tuning between the channels and the Warmth Back Win (WTW) unit to ensure the quality of the indoor air and to prevent noise. In addition, residents must be informed about changing the filters in the WTW unit.
- Low Temperature Heating System (LTV): The supply water temperature is not higher than 55° C, the temperature delivery system can consist of: floor or wall heating, LT radiators, LT convectors and LT air heater. By increasing the heating element, the same energy output can be achieved at a lower temperature, which means that a lower supply temperature is sufficient for space heating. By using LTV, the heat from natural sources such as solar boilers and heat pumps can be used directly for space heating. LTV increases thermal comfort and ensures a uniform temperature distribution in space. In combination with a heat pump, LTV also provides for active cooling.

- Photovoltaic cells in PV panels: Provide (decentralized) generation of electricity and can provide the energy needs of heat pumps, solar boilers and balance ventilation to further reduce the energy demand for hot water production and space heating. The above three types of common installations are part of the concepts in the research. In addition to these three types, there are even more systems that use, for example, residual heat from shower and sewage. It's too far to name all the systems.

### 3.6 Renovation approach of Stroomversnelling projects: a brief history

Inspired by the Kyoto Agreement which commits the countries to reduce CO2 by 8% by 2010, to 5.2% below 1990 levels, the European Union introduced the Directive on the energy performance of buildings (EPBD), in short directive 2002/91/EC. The Directive came into force in January 2003 and had to be implemented by the EU Member States at the latest in. Shortly after the introduction of energy efficiency policies the market started to experiment with deep renovation of housing. The industry in particular took into consideration social housing while social housing need to invest in energy efficiency of their properties as agreed in covenants with the Dutch government. Next, it was believed that social housing associations could contribute to momentum and price reduction resulting from repletion. The first large scale project completed in the Netherlands was a monumental building located in Rotterdam (Sleephellingstraat). The deep renovation project involved several on-site techniques in order reach passive house levels. Notably, the monumental front façade was insulated from the inside in contrast to the opposite façade which was insulated from the outside.

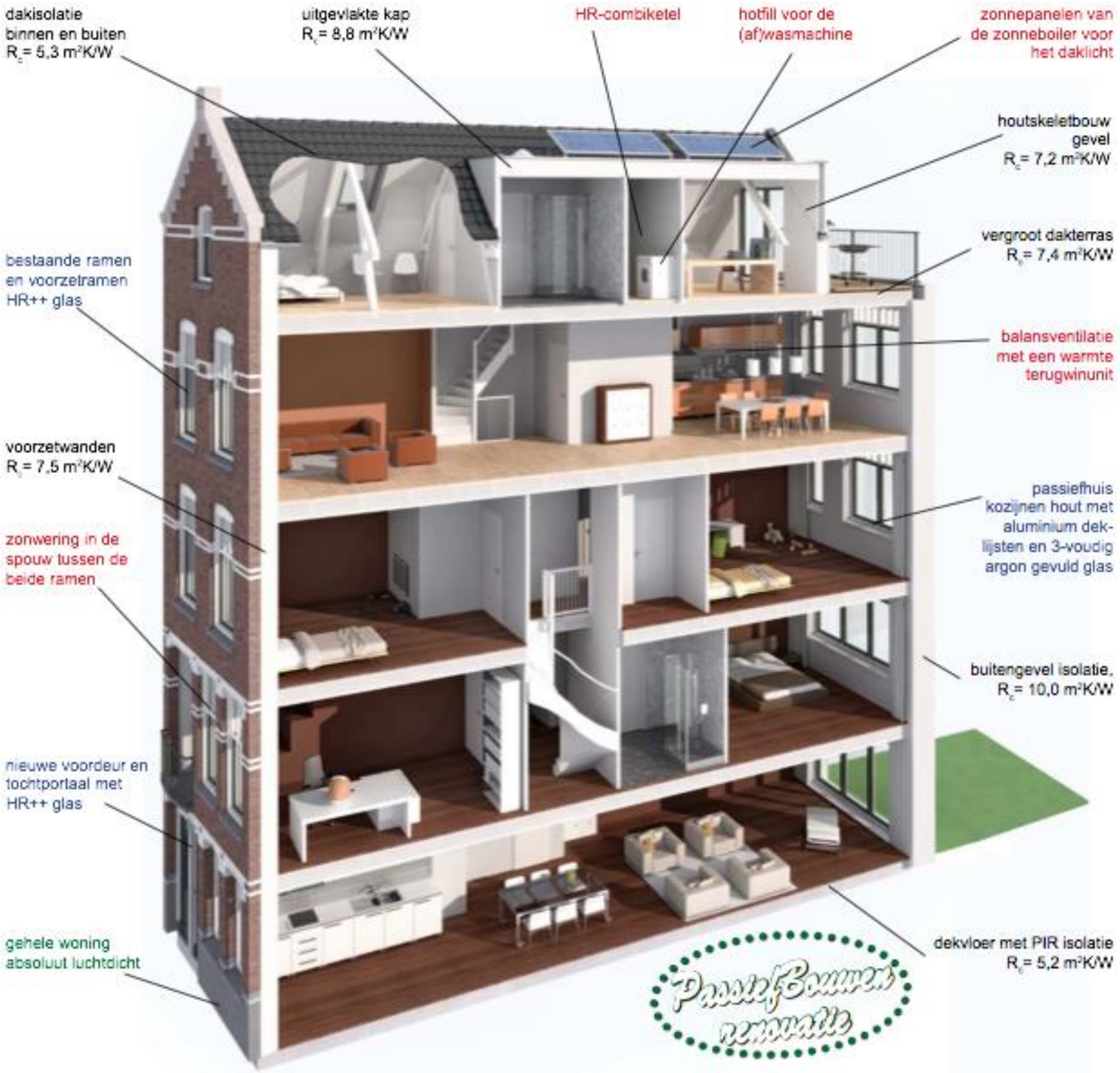



*Figure 3.2: First large scale deep renovation project (passive house) in the Netherlands (completed in 2009)*

It was learned that in particular single family dwellings – and to a lesser extend apartment buildings – constructed in the sixties and seventies have the potential to upscale deep renovation solutions. Single family dwellings are constructed at a large scale and share several commonalities which enables the replication of deep renovation solutions for this building typology. Next, benefiting from mass production and industrialization replication contributes to price optimization. As a result and inspired by Passive House principles, in 2010-2011 246 single family dwellings were renovated in the Kroeven region in Roosendaal. Two passive house renovation techniques were applied including an on-site added external façade insulation system finished with plaster and the installation of prefab panels (which were finished with slates on site, an exemplary case description can be found in the Appendix). Besides the improvement of the building façade (on-site or prefab), also Heat recovery ventilation and solar thermal collectors were installed. As a result only a small condensing gas boiler needed to be installed for space heating (an in-depth case description can be found in the next chapter). After close evaluation of the renovation solutions it was learned that installing prefab panels have some advantages over the on-site solution. First, the installation of off-site produced prefab panels is more quickly than an on-site solution. Second, it is less complex to ensure airtightness of the building façade. Subsequently, prefabricated façade and roof panels were successfully applied for retrofitting 153 dwellings in Kerkrade-West in 2012 (passive house). Inspired by the pilot projects in Roosendaal and Kerkrade and after closing the covenant 'De Stroomversnelling' in 2013, the application of prefab façade and roof element became the dominant design for deep renovation projects in the Netherlands. It need to be emphasized that since the introduction of 'De Stroomversnelling' deep renovation projects aim at reducing the operational energy consumption towards 'Zero-on-the-Meter' (in Dutch: Nul op de Meter, NOM). The building blocks of Zero-on-the-Meter renovations according 'De Stroomversnelling' standard are included in figure 3.4. In the next chapter several exemplary projects are discussed which are renovated in accordance with 'De Stroomversnelling' standard.


(1)


(2)


(3)

***Figure 3.3: Deep renovation of the Kroeven, Roosendaal (2010-2011): (1) The Kroeven before renovation, (2) The Kroeven 506 renovated with prefabricated panels, (3) The Kroeven 505 renovated on-site with an external façade insulation system and stucco.***

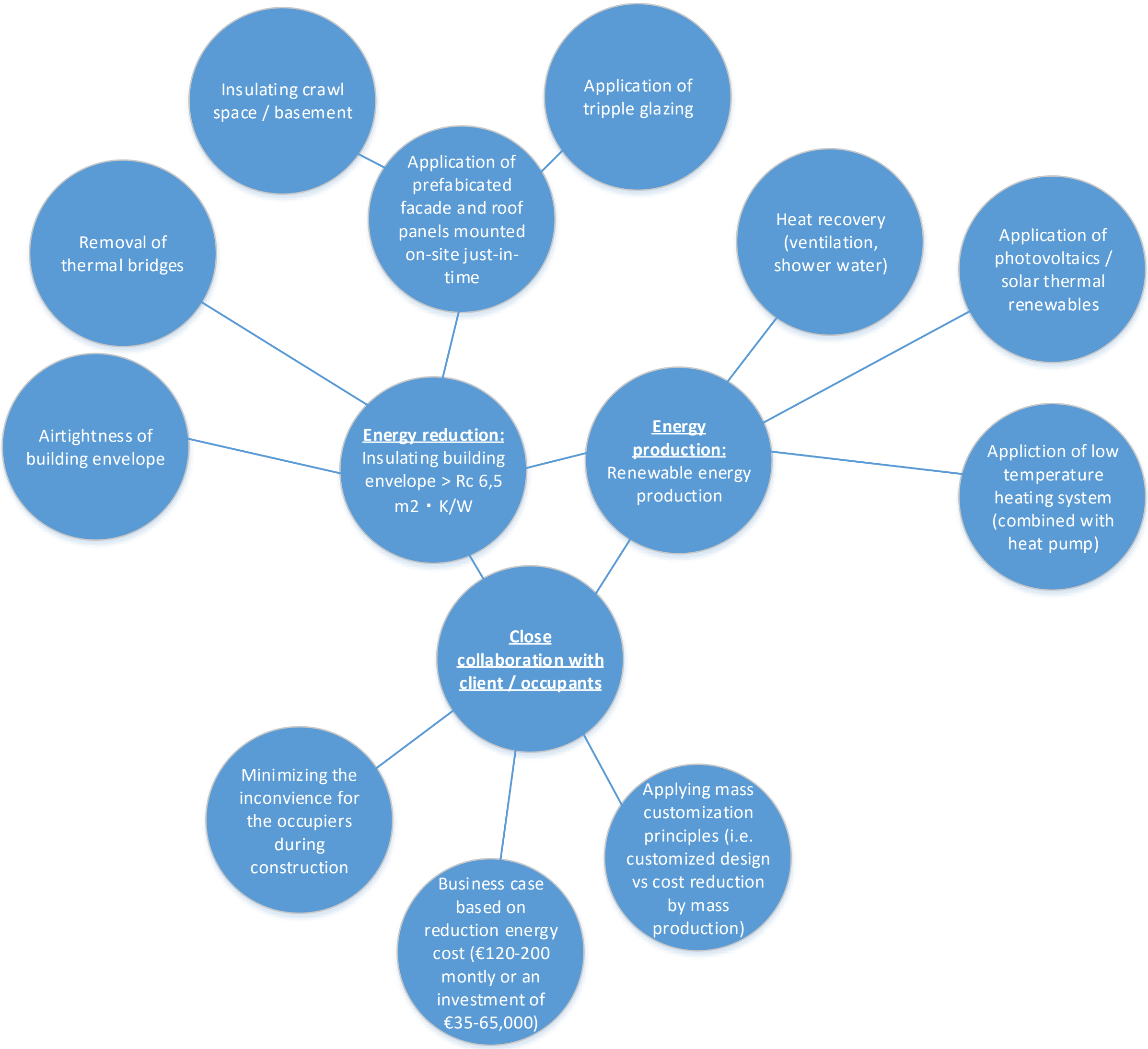



***Figure 3.4: Building blocks (dominants design) of Zero-on-the-Meter renovations as applied in 'De Stroomversnelling' projects.***

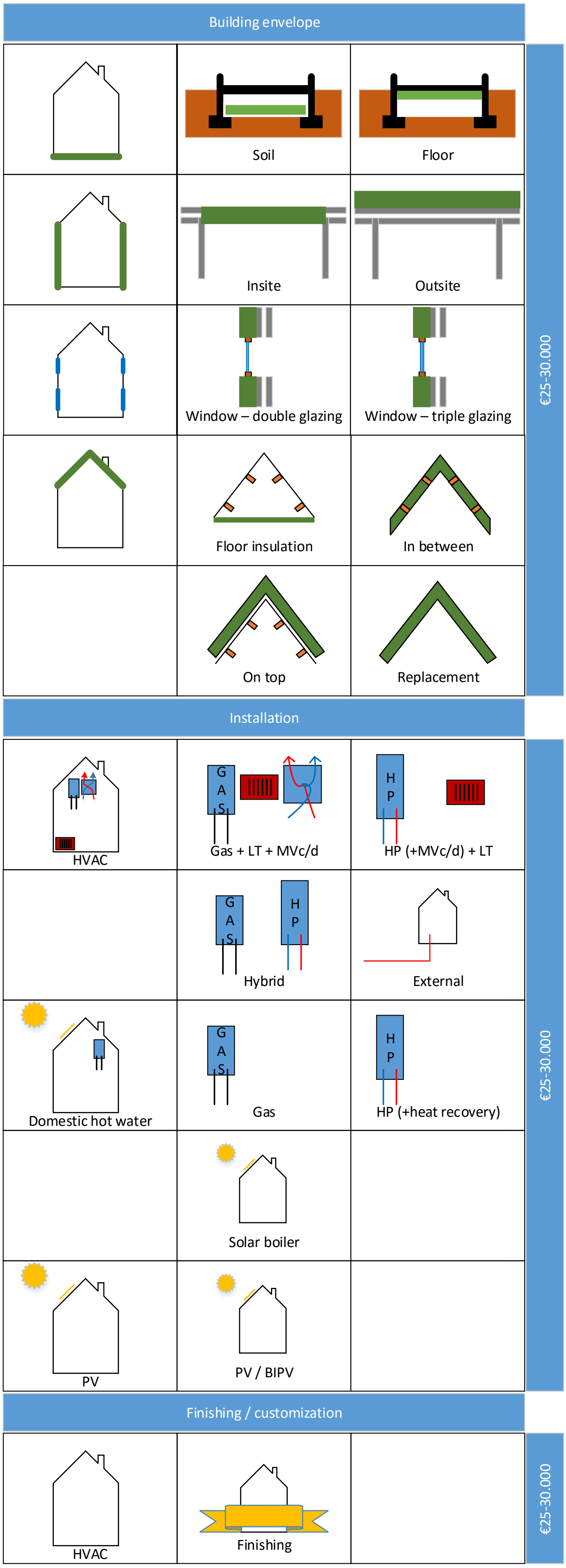



***Figure 3.5: Decomposition (dominants design) of Zero-on-the-Meter renovations as applied in 'De Stroomversnelling' projects.***

## CHAPTER 4: CASE STUDY 1 DE KROEVEN 505, ROOSENDAAL

### 4.1 General project description

Passive house renovation De Kroeven 505, Roosendaal, The Netherlands:

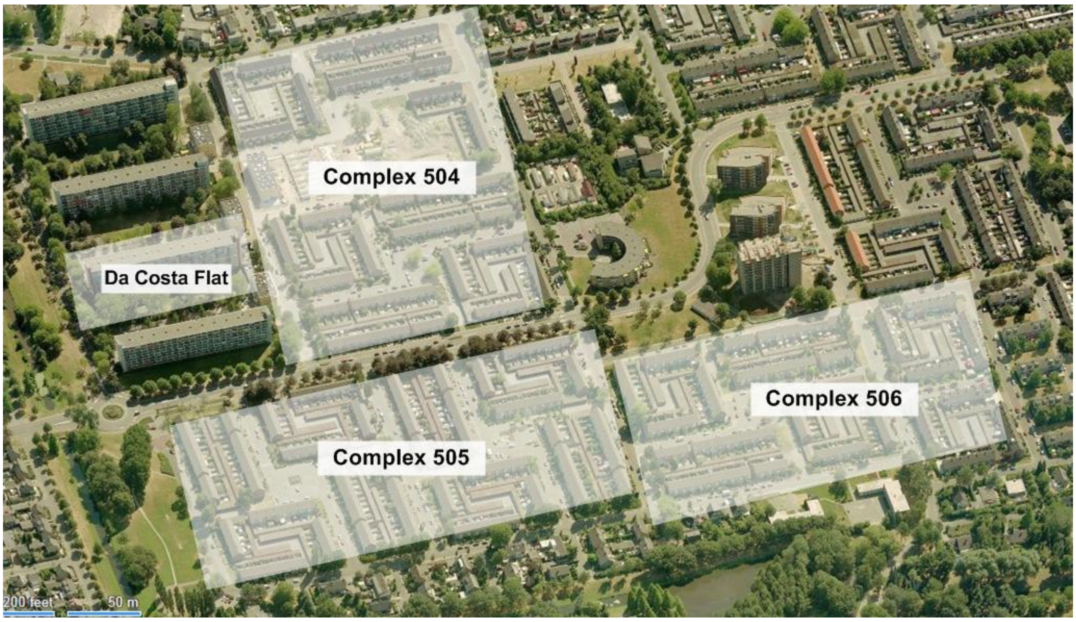
PROJECT CHARACTERISTICS
Owner:
Housing association (Aramis Allee Wonen)
Architect:
DAT architecten
Consultant:
Trecodome (PHPP)
Contractor / key suppliers:
Van Ieperen Groep, Kempair, Brink Climate Systems, VDM Woningen BV
Location:
De Kroeven (district), Roosendaal (NL)
Number of housing units:
134
Under construction:
2010-2011

KEY TECHNOLOGIES

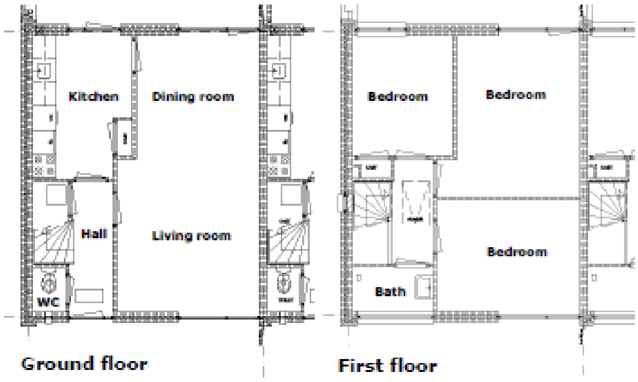
- Prefabricated timber facades and roofs
- Triple glazed windows
- Heat recovery ventilation
- Condensing gas boiler
- Solar thermal collectors

Housing company Aramis AlleeWonen transformed the "De Kroeven" district in Roosendaal by converting 246 residential buildings into passive houses and replacing 90 homes with 102 passive newly built homes (subdivided in three areas including 504, 505 and 506). Aramis AlleeWonen applied two passive housing renovation approaches to transform the dwellings constructed in the Kroeven district into passive houses. Aramis AlleeWonen selected two deep renovation solutions in order to test which approach has the most potential. For area '506' the social housing corporation selected an on-site approach by installing facade insulation finished with plaster while for area '505' a solution based on installing prefabricated (timber frame) panels was selected. In particular, the second approach was inspired by the transformation of area '504' were 90 dwellings were replaced with 102 newly build passive house dwellings. These dwellings were constructed with prefabricated timber frame panels.
Social housing association Allee Wonen owns about 19,000 housing units in the region Roosendaal and Breda. In 2001 Aramis AlleeWonen started the redevelopment of the southern part of the "Groot Kroeven" district in Roosendaal. Dwellings in the area's 504, 505 and 506 were in decline. The municipality of Roosendaal finds that the social quality of the district decreases and together with the social housing association it was decided to drastically upgrade and redesign/transform the 'Kroeven' district. The district was built in the period 1960-1970 and contains 896 almost identical single family dwellings in two variants with three or four bedrooms. In the period 1975-1990, only regular maintenance have been conducted and some gradual improvements have been installed (double glazing and / or cavity insulation (convenience improvement), energy efficient gas boiler). Although some of the 896 dwelling were sold, in the areas 504, 505 and 506 the housing association still owns most of the dwellings. Each area contains more than 100 identical dwellings. In 2005 Aramis AlleeWonen started with the transformation of complex 504. Aramis AlleeWonen instructed architect Han van Zwieten to completely re-design area 504 with a mix of renovation and replacement of existing dwelling. In short, 75 dwelling were replaced with 42 senior apartments, 13 bungalows (patio dwellings) and 46 single family homes. Next, 84 dwellings were cleaned and painted for conservation for another ten years. In addition, 62 homes are extensively renovated with bay windows, extensions to accommodate (larger) bathrooms (in Dutch: rugzakbadkamers), roof insulation and double glazed windows. Moreover, Aramis AlleeWonen participates within the European sustainability platforms "Treco" and "E2rebuild". During start-up, the project manager of Aramis AlleeWonen, who is responsible for the transition of De Kroeven, visited the passive housing project Lindås Gothenburg in Sweden. Passive house adviser Trécodome organized the excursion and convinced the Aramis AlleeWonen project manager of the passive house (renovation) method. As a result also three different passive houses were constructed in area 504.

The transformation of area 504  was followed by the transformation of areas 505 and 506. The social housing association intended to replace all dwelling from both areas with newly built dwellings. The occupants rebelled against the demolition plans. Aramis AlleeWonen decided to change plans and invest into both deep renovation and the replacement of some of the existing dwellings. A key assumption of the housing association was to renovate the dwellings while the dwellings remain occupied. This requires a fast, and nonintrusive renovation process. Two architect firms and energy consultants have been appointed to develop different approaches to passive renovation, and to ensure a variety in architectural and technical solutions, whilst aiming at the same low energy demand for space heating and domestic hot water.
For area 506 a passive house design was developed based on installing façade insulation on-site with plaster finishing. For area 505 DAT architects, Trecodome, Brink Climate Systems and Holzbau Brüggemann develop a passive housing design based on prefabricated timber frame panels. After 70% of residents agreed upon the deep renovation both areas 505 and 506 were completed. Based on the completion of these projects it was learned that the prefab construction approach is the most promising. Therefore, the completion of project 505 will be discussed in more detail below.



DESIGN DATA (before renovation)
Number of housing units [#]: 134
Heated floor area [m2]: 120
Energy consumption (heating + DHW) per housing unit per year [kWh]: 16500 (137kWh/m2)
Air tightness qv;10 [dm3/s] per m2 floor space: -
Installed heating capacity per housing unit [kW]: 20 (160W/m2)
Electricity consumption per housing unit per year (excl. heating) [kWh/y]: 3500 (29kWh/m2)



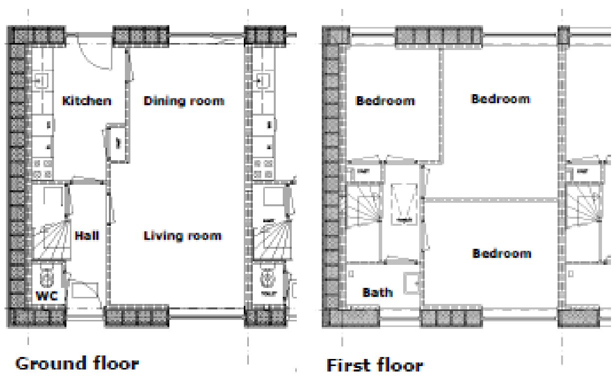

## 4.2 Renovation concept and notable features

The passive house renovation technology have been tested in a single test dwelling. It has been demonstrated how a dwelling can be insulated using a 350 mm timber frame element with cellulose insulation, with triple glazed passive house window frames, and prefabricated timber roof elements, filled with 350 mm insulation. For the external façade cladding natural slates have been applied. This approach has been implemented in 134 dwellings in area 505 in the 'Kroeven' district.

Key technologies for the 134 houses using prefab renovation elements:

- Prefabricated timber facades and roofs
- Triple glazed windows
- Prefabricated timber roofs
- Heat recovery ventilation
- Condensing gas boiler
- Solar thermal collectors

DESIGN DATA (after renovation)
Number of housing units [#]: 134
Heated floor area [m2]: 120
Energy consumption (heating + DHW) per housing unit per year [kWh]: 4500 (38kWh/m2)
Air tightness qv;10 [dm3/s] per m2 floor space: <0,15
Installed heating capacity per housing unit [kW]: 3,5 (30W/m2)
Electricity consumption per housing unit per year (excl. heating) [kWh/y]: 3500 (29kWh/m2)
Rent [€]: 565
Rent increase per month [€]: 65
Reduction energy costs per year [€]: 65



## 4.3 Energy related indicators

Characteristics Retrofit projects:

| | | | | | | |
|---|---|---|---|---|---|---|
| | Thermal insulation:<br>-Roof<br>-Facade<br>-Floor/foundation | Rc 1,0 – 2,5<br>○<br>○<br>○ | Rc 2,5 – 4,0<br>○<br>○<br>○ | Rc 4,0 – 5,5<br>○<br>○<br>○ | Rc 5,5 – 7,0<br>○<br>○<br>○ | Rc 7,0 – 12,0<br>●<br>●<br>● |
| | Measures airtightness | Present<br>● | Not present<br>○ | | | |
| | Glazing | Double<br>○ | Triple<br>● | | | |
| | PV panels<br>(m2 PV / dwelling) | 10 - 15<br>○ | 15 - 20<br>○ | 20 - 30<br>○ | 30 - 40<br>○ | >40<br>○ |
| | Heating | Gas-fired boiler (HR-107)<br>● | Heat pump (water)<br>○ | Heat pump (air)<br>○ | Hybrid<br>○ | External source<br>○ |
| | Domestic hot water | Gas-fired boiler (HR-107)<br>● | Heat pump<br>○ | External source<br>○ | Shower heat recovery<br>○ | Thermal solar boiler<br>● |
| | Ventilation system | Natural (C)<br>○ | Natural-controlled (C+)<br>○ | Mechanical (D)<br>● | Mechanical-controlled (D+)<br>○ | |
| | Energy supply | Gas + Electric<br>● | Electric<br>○ | External source (district heating)<br>○ | None (all-electric)<br>○ | |

The energy consumption of the dwellings is expected to change significantly after completion of the project. Space heating demand will reduce to a calculated figure of around 25 kWh/(m²·y) for a mid-row and around 30 kWh /(m²·y) for an end-row dwelling. The energy performance per square meter will drop by about 80%. Hot water demand will reduce by 50% to 60% due to the installed solar thermal boiler. Also a heat recovery ventilation system have been installed

The building related energy expenses is expected to reduce by 70%, whereas additional costs reduces by 40%, at constant energy prices. The significantly lower energy expenses (for heating) ensures that these dwellings remain affordable even when the energy prices go up.  After completion of the project blower door tests have been conducted to showing an airtightness figure of 1.0 air changes per hour at 50 Pa. Infrared imaging of the units did not show any anomalies.

### Heating, ventilation

***Heating & ventilation -*** Heating and ventilation is provided by a compact heating system, developed by Brink Climate Systems, which has all components included in single design:

- 150 litre storage tank
- Mechanical heat recovery ventilation
- Condensing gas boiler
- Connection to solar thermal collectors

Due to the limited available height (attic) the compact design of the HVAC and domestic hot water system has been divided in two parts, a heat recovery unit and the additional components, which are installed next to each other. The original heating system has been adjusted to the smaller heat demand, i.e. the living room has one new radiator to replace two large ones. Fresh air is provided through inlets installaed in the living room and bedrooms, and exhausts are installed within the toilet, bathroom and kitchen. To avoid discomfort at any time an additional heat loop is installed to post heat the ventilation air. This is done by manual operation and in addition to the thermostatic control of the radiator system.

***Domesitic hot water* -** Hot water is provided from the storage tank which is heated by the 5 m² solar thermal collectors and a tradional condensing gas boiler. Typical hot water use in residential buildings is around 35 liter/day of water at 60°C.


### 4.4 Technological design – retrofit design details

#### Façade solutions

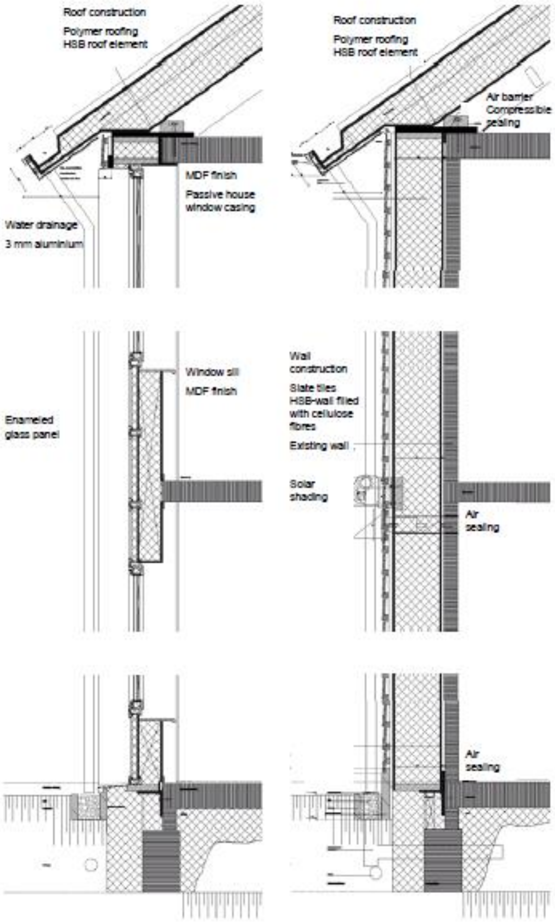
For the renovation of area 505 first the outer layer of the cavity wall was demolished. The next step was to insulate the perimeter (foundation) of the dwelling with EPS insulation, and to adjust the foundation for the installation of the timber frame panels. The new prefabricated timber frame modules (360 mm wide) are insulated with cellulose fibre with an U-value of 0.11 W/(m²·K). Moreover, triple glazed windows were already installed in the factory (U-value frame of about 0.87 W/(m²·K), U-value glass of about 0.5 W /(m²·K) with a g-value of 0.47). The new cavity between the inner leaf and the timber element is sealed around the window frames. The finishing of the prefab timber frames was installed on-site (slate tiles).

#### Roof solutions

The roof elements are also 360 mm wide (U-value of 0.10 W/(m²·K)) and are covered with PVC roofing material. Solar collectors for preheating domestic hot water were installed in the factory on top of the prefab panels.

#### Floor solutions

The ground floor is insulated using either PU spray underneath the floor or EPS chips to fill the crawl space under the floor.




## 4.5 Construction process

The prefabricated elements have been produced by VDM, a company that is based 250 km away from the renovation site in Roosendaal. The process of renovating 134 units has been streamlined in order to allow the renovation of 4 houses per week. The elements for one house have been transported on one truck load which travelled during the night and installed the next day.

Before the elements were mounted gardens were partially cleaned. Next, the outer skin of the cavity wall was demolished. The next step was to excavate and insulate the outside of the foundation with EPS (Expended Polystyrene) insulation blocks. The timber ground floor and the sides of the foundation were insulated with PU (Polyurethane) foam spray. The prefab timber frame façade elements were then placed against the still standing inside layer of the cavity wall. It has to be emphasized that the triple glazed windows with PVC frame were factory mounted in the prefab façade elements. Finally finishing of the façade (i.e. battens and slate tiles) were mounted on-site. Aluminium sheets were installed near façade openings. The same principle have been applied to the roof: the existing roof was removed and replaced by prefab timber frame roof panels. The prefab timber frame roof was also insulated with cellulose fibre. To minimise intrusion, the dwelling were only one day without roof and windows. Moreover, during the installation of the prefab panels, also the HVAC and domestic hot water system are installed on the top floor (attic).

It has to be emphasized that future improvements in the system are foreseen by integrating the ventilation ducts into the design of the prefabricated elements. Also alternative solutions for the new cavity between the existing wall and new prefabricated elements are being investigated.

### 4.6 Business model – renovation costs

#### Renovation costs

Compared to normal renovation costs for these fairly typical house types, the renovation to passive house level requires an additional investment of around € 25,000 per house. In Roosendaal, both an on-site external insulation concept and the prefab concept have been done at 112 and 134 houses. The prefab approach in this case turned out to be slightly cheaper. Also the renovation process is faster, and thus less intrusive to tenants. The tenants benefit by a lower heating bill, which in future is less sensitive to energy price increases.
The building owner has accepted a rent increase of € 65 per month, which equals the calculated energy saving at current energy prices. The owners has guaranteed that the cost of living for tenants will not increase. Added values are the long life time of the prefab renovation concept and in future the building owner may also expect a higher property value on the market.

#### Deep renovation cost:

| | |
|---|---|
| **Inducement renovation** | - Increasing energy cost forces housing association to invest in energy reduction<br>- Decay of the urban area motivated the housing association to invest in revitalization of the neighbourhood (i.e. deep-renovation while the occupiers did not agree with demolition) |
| **Housing typology** | Single family housing |
| **Year of construction** | 1967 |
| **Number of housing units before/after** | 134/134 |
| **Rent before/ after [monthly]** | €450-550,- / €515-516,- |
| **Energy label (NL) before/after** | F/A++ |
| **Under construction** | 2011 |
| **Investment installation per dwelling (total)** | €13.000,- |
| **Housing unit internally per dwelling** | €3.500,- |
| **Envelope housing unit per dwelling** | €73.500,- |
| **Cost outdoor per dwelling** | €10.975,60 |
| **Additional (organizational) cost per dwelling** | €40.000,- |
| **Total investment per dwelling** | €130.000,- |

| Cost & benefits per dwelling annually | Project | Project De Kroeven 505, 134 Single family housing | |
|---|---|---|---|
| | Measures | Ca. €130.000/dwelling incl VAT: prefab (passive house) facade and roof | |
| Stakeholder | Effect | Cost anually | Benefits anually |
| Social housing corporation | Investment comfort improvement | 281 | |
| | Investment cost energy efficiency | 562 | |
| | VAT | 160 | |
| | Overhead cost of SHC related to project | 37 | |
| | Subsidies | | |
| | Rent increase | | 158 |
| | Compensation inconvience | | |
| | Rent | | 3400 |
| | Overhead after renovation | 500 | |
| | Maintenance after renovation | 650 | |
| | Property (in Dutch: OZB) tax | 5 | |
| | Other | | |
| Occupants | Rent | 3400 | |
| | Rent increase | 158 | |
| | Housing fee for rent increase | | 25 |
| | Reduction energy bill | | 120 |
| | Comfort improvement | | 156 |
| | Inconvienence during project | 21 | |
| | Improvement indoor climate | | 26 |
| | Other | | |
| SHC | Total | 2195 | 3558 |
| Occupants | Totaal excl. rent | 179 | 327 |
| Total | | 2433 | 4263 |

# CHAPTER 5: CASE STUDY 2 DOLOMIETENLAAN, TILBURG

## 5.1 General project description

Passive house renovation 8 single family dwellings, Dolomietenlaan, Tilburg, The Netherlands:

PROJECT CHARACTERISTICS
Owner:
Housing association (TBV Wonen)
Architect:
Kuin en Kuin Architecten
Consultant:
Trecodome (PHPP)
Contractor / key suppliers:
Remmers Bouwgroep, Kempair, Brink Climate Systems, Gump & Maier
Location:
Dolomietenlaan, Tilburg (NL)
Number of housing units:
8
Under construction:
2011

KEY TECHNOLOGIES

- Prefabricated timber facades and roofs (airtight)
- Triple glazed windows
- Heat recovery ventilation
- Condensing gas boiler
- Solar thermal collectors

Social housing provider TBV Wonen owns 7,300 housing units in Tilburg, The Netherlands. In the Dolomietenlaan, 8 out of 60 single family houses have been retrofitted to passive house level as a demonstration project. These 8 dwellings, constructed in 1976, were selected because of its poor performance due its low quality window frames including single glazing and poorly functioning ventilation system. At first the occupants were not very enthusiastic, but after visiting the Kroeven project they agreed upon deep renovation. Next, while the building block of 8 dwellings was of low architectural quality the renovation provided the opportunity to improve the building aesthetics. During the renovation the dwellings remain occupied and thus this requires a fast, and nonintrusive renovation process.

DESIGN DATA (before renovation)
Number of housing units [#]: 8
Heated floor area [m2]: +/- 100
Energy consumption (heating + DHW) per housing unit per year [kWh]: 18.611 (186kWh/m2)
Air tightness qv;10 [dm3/s] per m2 floor space: -
Installed heating capacity per housing unit [kW]: - (-W/m2)
Electricity consumption per housing unit per year (excl. heating) [kWh/y]: - (-kWh/m2)

*Energy performance*
The energy performance has been improved from label D label A+. Spatial heating is no longer the biggest contributor to the annual energy use, but hot water use is.

## 5.2 Renovation concept and notable features

Characteristics Retrofit projects:

| | | | | | | |
|---|---|---|---|---|---|---|
| | Thermal insulation:<br>-Roof<br>-Facade<br>-Floor/foundation | Rc 1,0 – 2,5<br>○<br>○<br>● | Rc 2,5 – 4,0<br>○<br>○<br>○ | Rc 4,0 – 5,5<br>○<br>○<br>○ | Rc 5,5 – 7,0<br>○<br>○<br>○ | Rc 7,0 – 12,0<br>●<br>●<br>○ |
| | Measures airtightness | Present<br>● | Not present<br>○ | | | |
| | Glazing | Double<br>○ | Triple<br>● | | | |
| | PV panels (m2 PV / dwelling) | 10 - 15<br>○ | 15 - 20<br>○ | 20 - 30<br>○ | 30 - 40<br>○ | >40<br>○ |
| | Heating | Gas-fired boiler (HR-107)<br>● | Heat pump (water)<br>○ | Heat pump (air)<br>○ | Hybrid<br>○ | External source<br>○ |
| | Domestic hot water | Gas-fired boiler (HR-107)<br>● | Heat pump<br>○ | External source<br>○ | Shower heat recovery<br>○ | Thermal solar boiler<br>● |
| | Ventilation system | Natural (C)<br>○ | Natural-controlled (C+)<br>○ | Mechanical (D)<br>● | Mechanical-controlled (D+)<br>○ | |
| | Energy supply | Gas + Electric<br>● | Electric<br>○ | External source (district heating)<br>○ | None (all-electric)<br>○ | |

| | |
|---|---|
| DESIGN DATA (after renovation) | |
| Number of housing units [#]: | 8 |
| Heated floor area [m2]: | +/-100 |
| Energy consumption (heating + DHW) per housing unit per year [kWh]: | 3.635 (36kWh/m2) |
| Air tightness qv;10 [dm3/s] per m2 floor space: | 0,25 |
| Installed heating capacity per housing unit [kW]: | 3,5 (0,035W/m2) |
| Electricity consumption per housing unit per year (excl. heating) [kWh/y]: | - (-kWh/m2) |
| Rent [€]: | 585 |
| Rent increase per month [€]: | 45 |
| Reduction energy costs per year [€]: | 60 (gas) |

### 5.3 Energy related indicators

The energy consumption of the houses is expected to change significantly. Space heating demand will reduce to a calculated figure of below 25 kWh/(m²·y).

Key technologies:

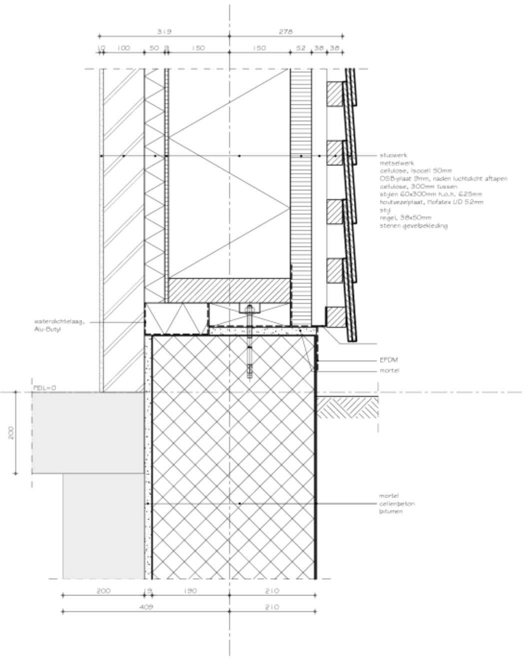
- Passive house insulation (EPS)
- Triple glazed windows
- Heat recovery ventilation
- Condensing gas boiler

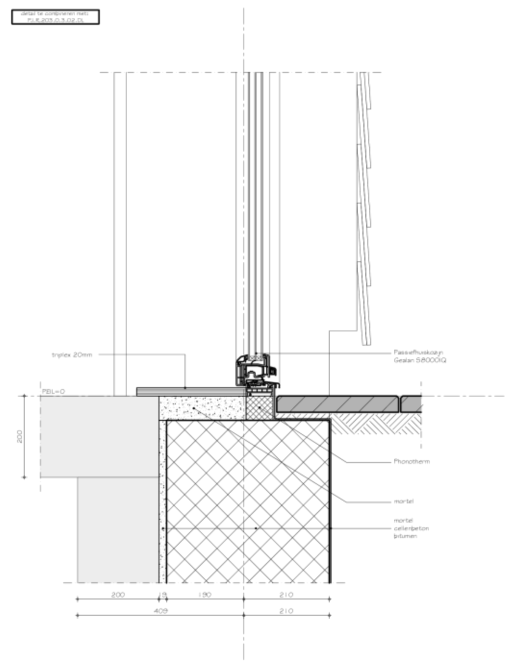
At completion of the renovation works blower door tests have been made resulting in an airtightness figure of below 1.0 air changes per hour at 50 Pa. Infrared imaging of the units did not show any anomalies.

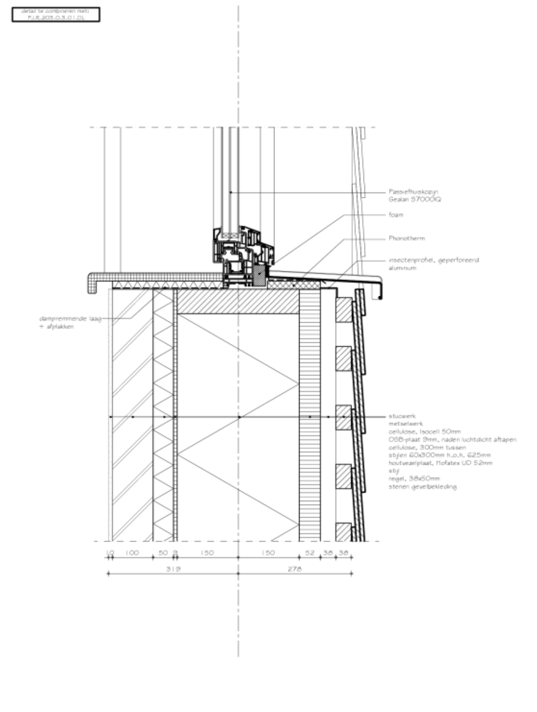
### 5.4 Technological design – retrofit design details

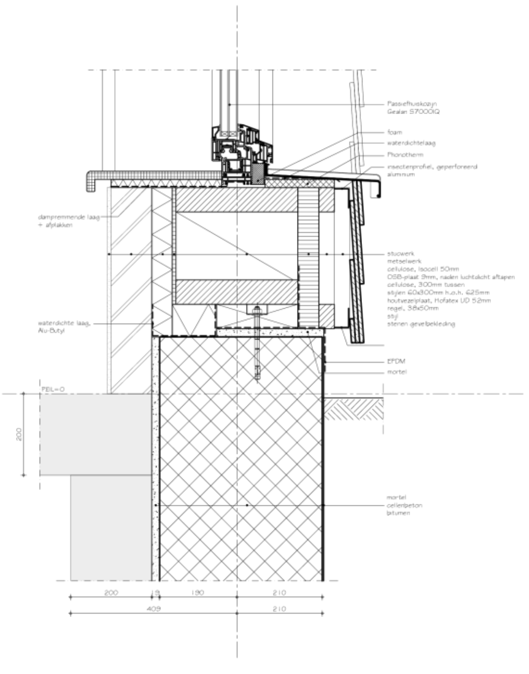
#### Building envelope

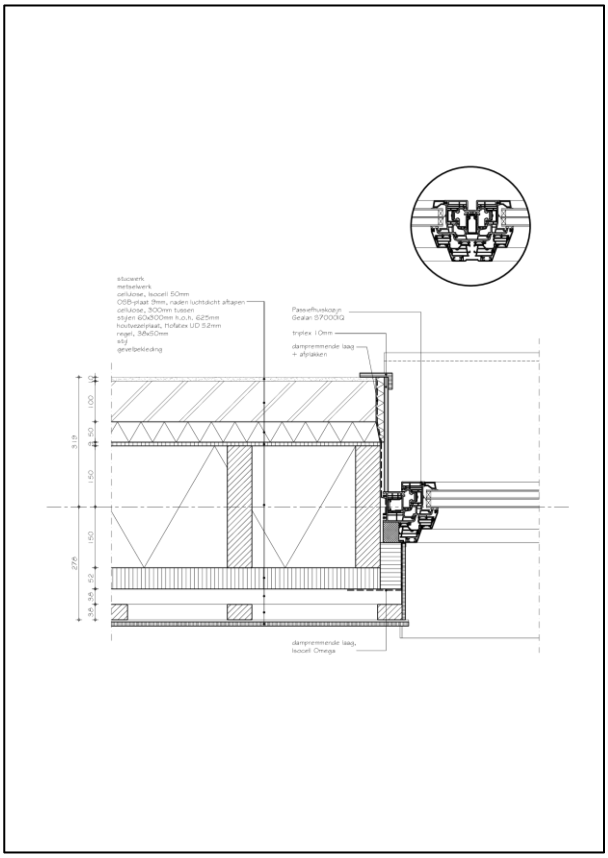
The same technical design have been applied as for 'De  Kroeven' project although some incremental improvements were introduced. The most important improvement is the installation of ducts and piping from the outside, i.e. after the outer leave of the cavity was removed ducts and piping were installed on the inner leave and the roof. The prefab modules were installed over the ducts and piping. Below the technical design details are included.

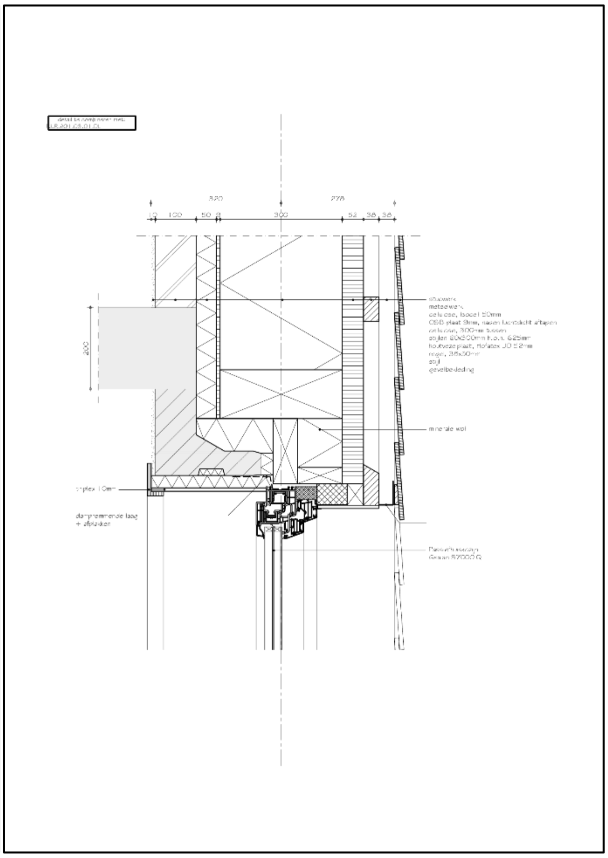

stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, naden luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
stijl
regel, 38x50mm
stenen gevelbekleding
waterdichtelaag,
Alu-Butyl
EPDM
mortel
PEIL=0
mortel
cellenbeton
bitumen

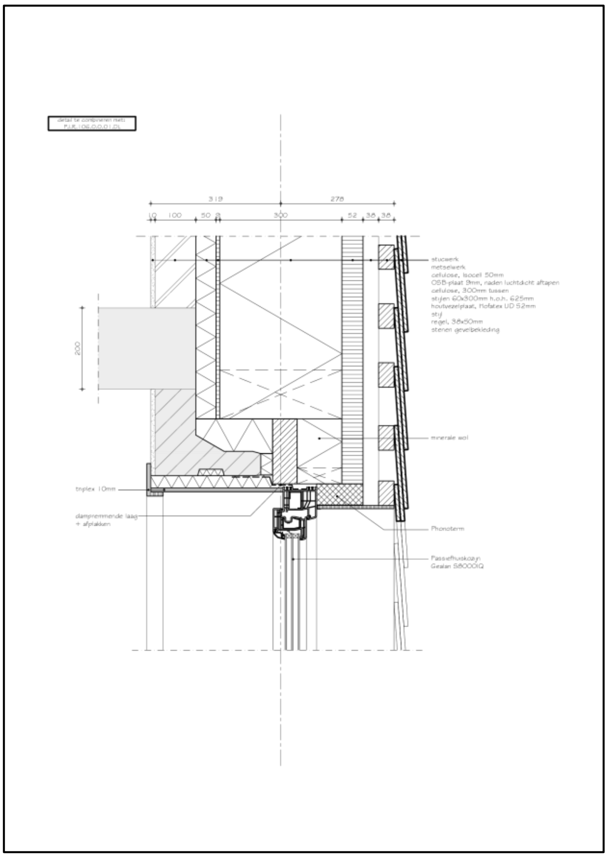

detail te combineren met:
triplex 20mm
Passiefhuiskozijn
Gealan S8000IQ
PEIL=0
Phonotherm
mortel
mortel
cellenbeton
bitumen

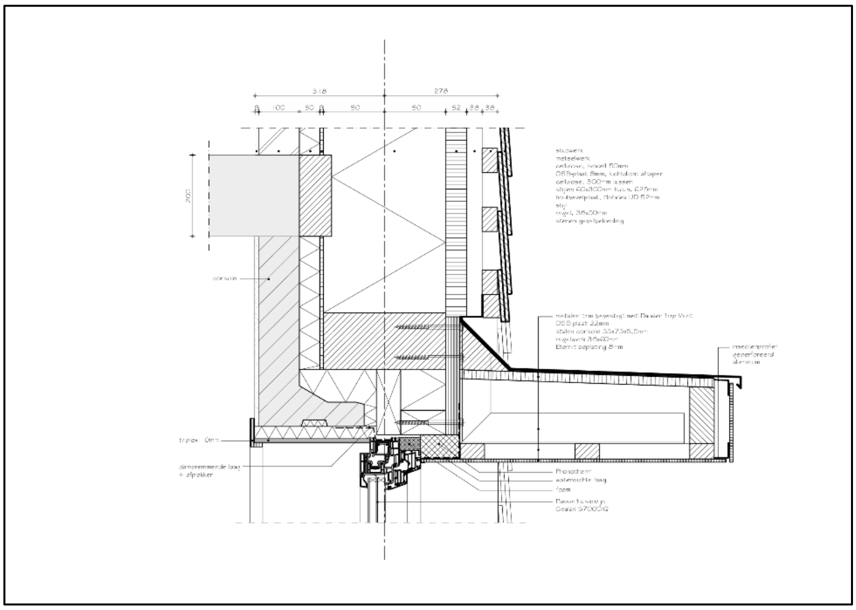

detail te combineren met:
Passiefhuiskozijn
Gealan S7000IQ
foam
Phonotherm
insectenprofiel, geperforeerd
aluminium
dampremmende laag
+ afplakken
stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, naden luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
stijl
regel, 38x50mm
stenen gevelbekleding

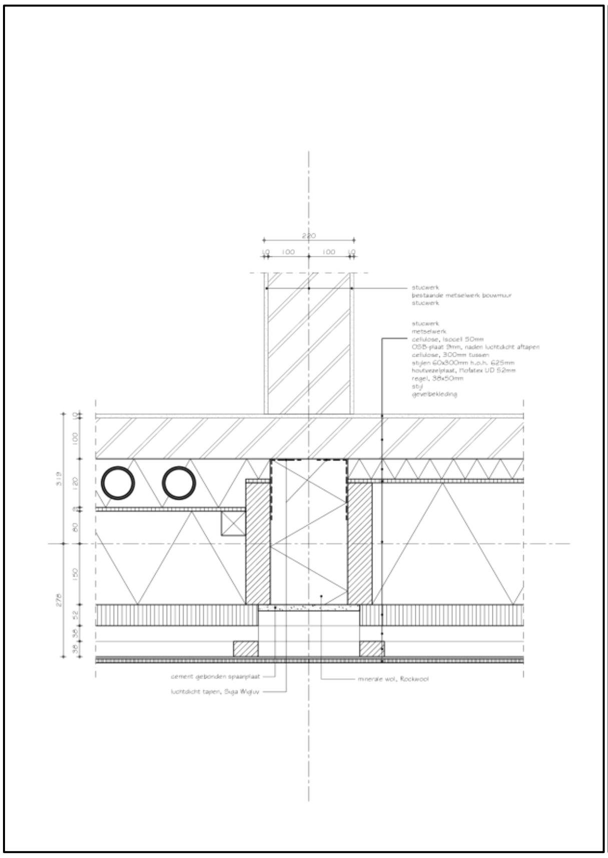

Passiefhuiskozijn
Gealan S7000IQ
foam
waterdichtelaag
Phonotherm
insectenprofiel, geperforeerd
aluminium
dampremmende laag
+ afplakken
stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, naden luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
regel, 38x50mm
stijl
stenen gevelbekleding
waterdichte laag,
Alu-Butyl
EPDM
mortel
PEIL=0
mortel
cellenbeton
bitumen

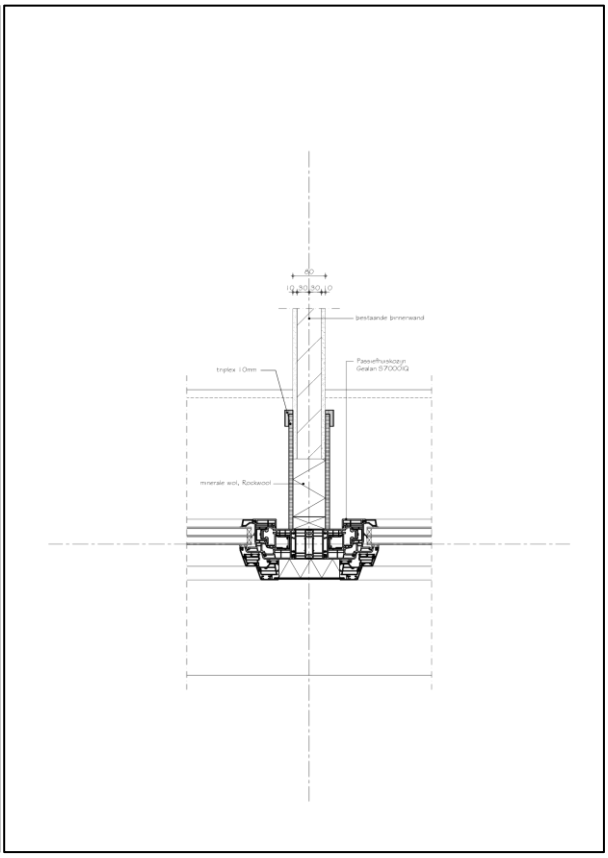

stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, naden luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
regel, 38x50mm
stijl
gevelbekleding
Passiefhuiskozijn
Gealan S7000IQ
triplex 10mm
dampremmende laag
+ afplakken
dampremmende laag,
Isocell Omega
10
100
50
9
319
150
150
278
52
38
38

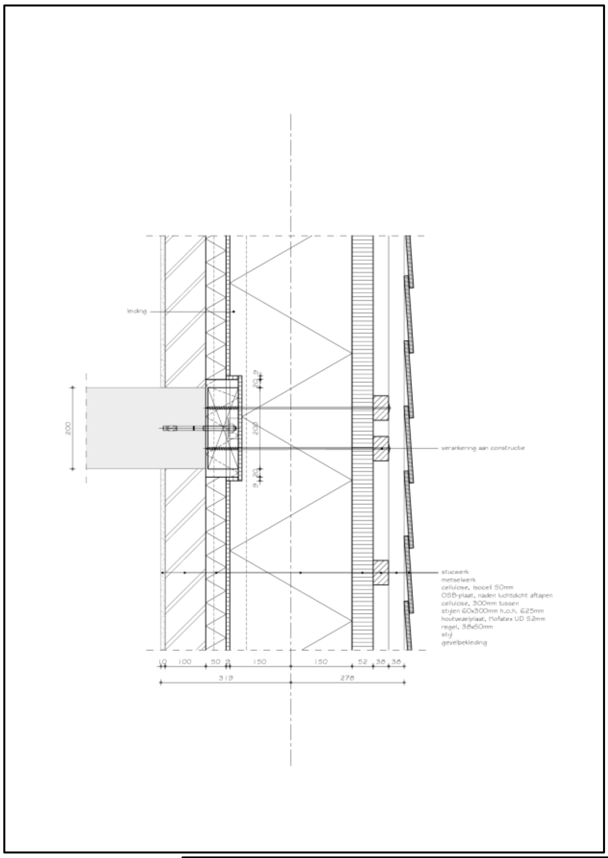

320
278
10
100
50
9
300
52
38
38
200
minerale wol
dampremmende laag
+ afplakken
metselwerk
OSB-plaat 9mm, naden luchtdicht aftapen
stijlen 60x300mm h.o.h. 625mm
gevelbekleding

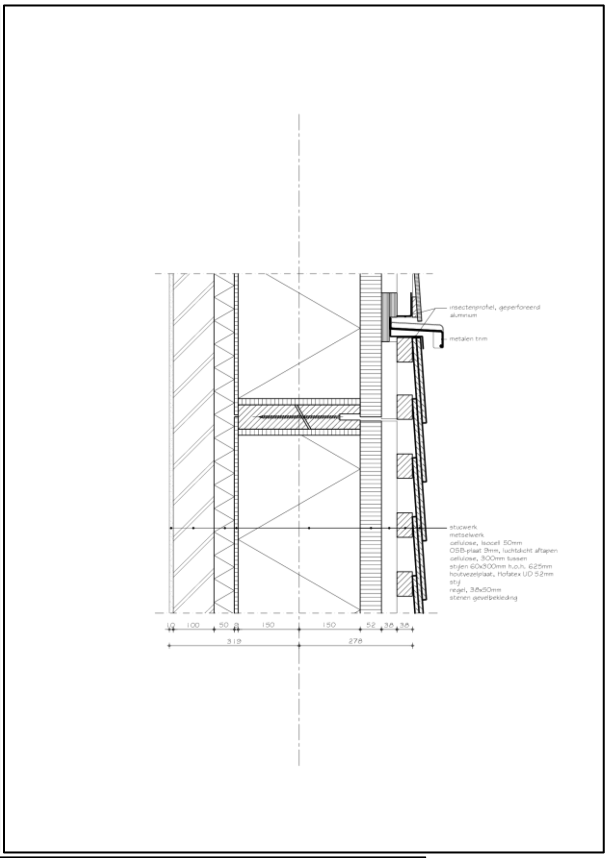

detail te combineren met:
319
278
10
100
50
9
300
52
38
38
200
stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, naden luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
stijl
regel, 38x50mm
stenen gevelbekleding
minerale wol
triplex 10mm
dampremmende laag
+ afplakken
Phonoterm
Passiefhuiskozijn
Gealan S8000IQ

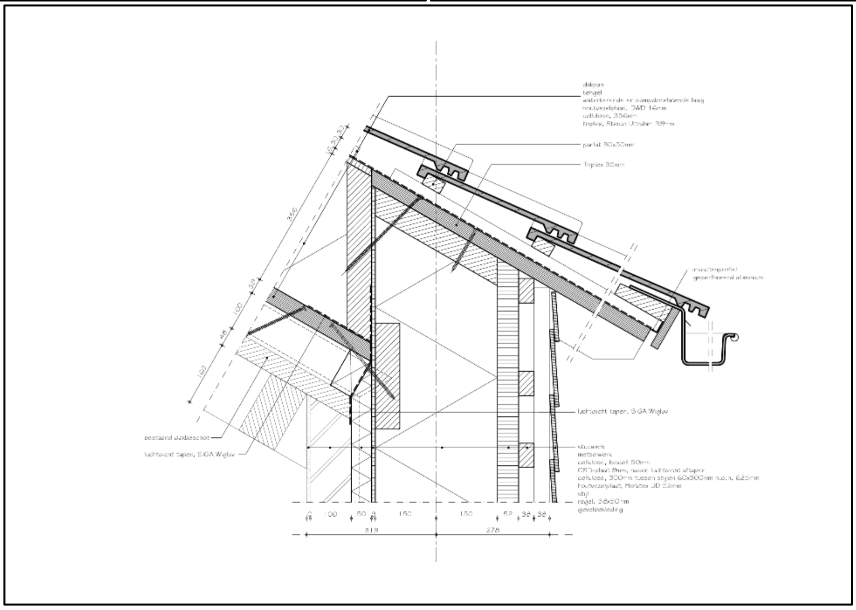

stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, luchtdicht aftapen
cellulose, 300mm tussen
regel, 38x50mm
Eternit beplating 8mm
Phonotherm
waterdichte laag
foam
Gealan S7000IQ

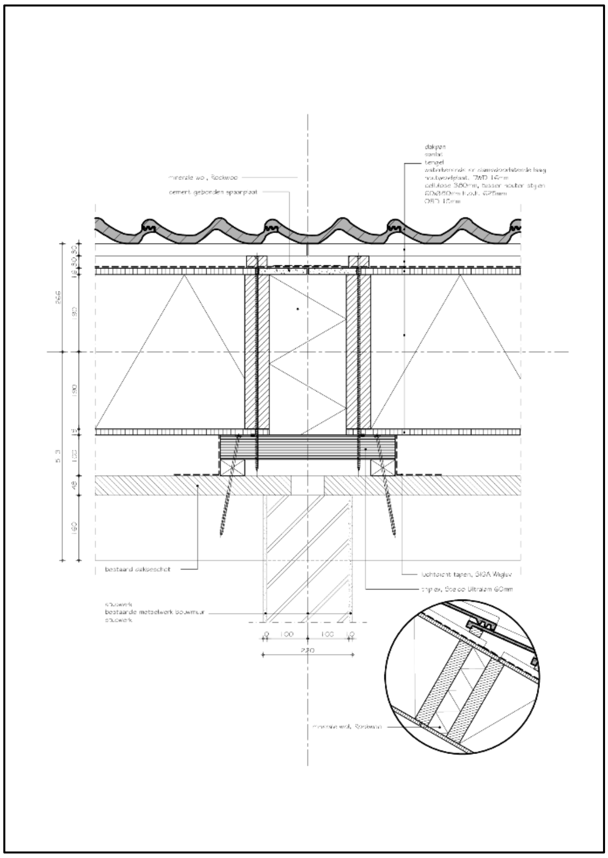
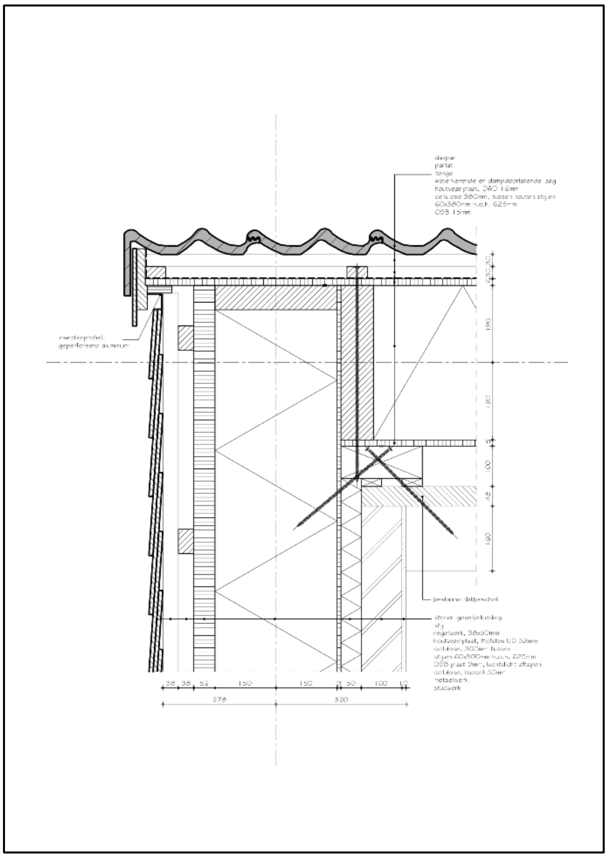

220
10
100
100
10
stucwerk
bestaande metselwerk bouwmuur
stucwerk
stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, naden luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
regel, 38x50mm
stijl
gevelbekleding
cement gebonden spaanplaat
luchtdicht tapen, Siga Wigluv
minerale wol, Rockwool


bestaande binnenwand
triplex 10mm
Passiefhuiskozijn
Gealan S7000IQ
minerale wol, Rockwool


leiding
verankering aan constructie
stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat, naden luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
regel, 38x50mm
stijl
gevelbekleding


insectenprofiel, geperforeerd
aluminium
metalen trim
stucwerk
metselwerk
cellulose, Isocell 50mm
OSB-plaat 9mm, luchtdicht aftapen
cellulose, 300mm tussen
stijlen 60x300mm h.o.h. 625mm
houtvezelplaat, Hofatex UD 52mm
stijl
regel, 38x50mm
stenen gevelbekleding


dakpan
tengel

## 5.5 Construction process

Renovation project ‘Dolomietenlaan’ was inspired by the exemplary project ‘De Kroeven’. In the projects following ‘De Kroeven’ it was learned how to renovate the dwellings while they were still occupied. In particular these projects attempted to reduce the level of inconvenience for the occupants by improving the construction efficiency on-site by means of prefabrication and through just-in-time, plug-and-play construction practices. First of all, the prefab panels were installed in a single day. Next, ventilation ducts were installed from the outside or included in the prefab panels. During the renovation of ‘De Kroeven’ residents still suffered from drilling for new pipelines for ventilation and installation ducts and piping. Because of this all new ducts and piping are mounted from the outside. More precisely, ducts an piping are attached to the original inner sheet after demolition of the outer sheet of the cavity wall. Cut outs, i.e. small cavities, were included in the factory to be able to install the prefab façade elements on-site. Moreover, on-site extra insulations is put in the cavity between the prefab modules and the original inner sheet of the cavity wall as well as around the ducts and piping optimal sealing. The same principle have been applied for the ducts and piping on the roof. This is also been done to reduce construction time and limit the level of inconvenience. More specifically, it have been concluded that dwellings internally were of sufficient quality and occupants adjusted the interior design by adding finishing and electrical works.

## 5.6 Business case – renovation costs

### Renovation costs

Although the renovation process is more efficient and is also less intrusive to the occupants compared to traditional construction practices, it comes at a price: €120.000/dwelling. The occupants benefit from a lower energy bill, which in future is less sensitive to energy price increases. Therefore, the tenants faced a rent increase of € xx per month, which equals the calculated energy saving at current energy prices. The owners has guaranteed that the cost of living for tenants will not increase. Added values are the long life time of the prefab renovation concept and in future the building owner may also expect a higher property value on the market.

### Deep renovation cost:

| | |
|---|---|
| **Inducement renovation** | Maintenance, low technical quality |
| **Housing typology** | Single family housing |
| **Year of construction** | 1976 |
| **Number of housing units before/after** | 8/8 |
| **Rent before/ after [monthly]** | €540,- / €585,- |
| **Energy label (NL) before/after** | D/A+ |
| **Under construction** | 2011 |
| **Investment installation per dwelling (total)** | €- |
| **Housing unit internally per dwelling** | €- |
| **Envelope housing unit per dwelling** | €- |
| **Cost outdoor per dwelling** | €- |
| **Additional (organizational) cost per dwelling** | €13.000 |
| **Total investment per dwelling** | €120.000,- |

## CHAPTER 6: CASE STUDY 3 THE EXISTING DISTRICT FOR TOMORROW, KERKRADE-WEST

### 6.1 General project description

Passive house renovation, the Existing District for Tomorrow, Kerkrade-West, The Netherlands:

PROJECT CHARACTERISTICS

Owner:
Housing association (Hestia groep/Heemwonen)

Architect:
TeekenBeckers Architects

Consultant:
Caubergh Huygen Consulting Engineers; ZUYD University of Applied Science

Contractor / key suppliers:
BAM, Brink Climate Systems, Stork

Location:
District of tomorrow Kerkrade-West (NL)

Number of housing units:
153

Under construction:
2012-2013

KEY TECHNOLOGIES

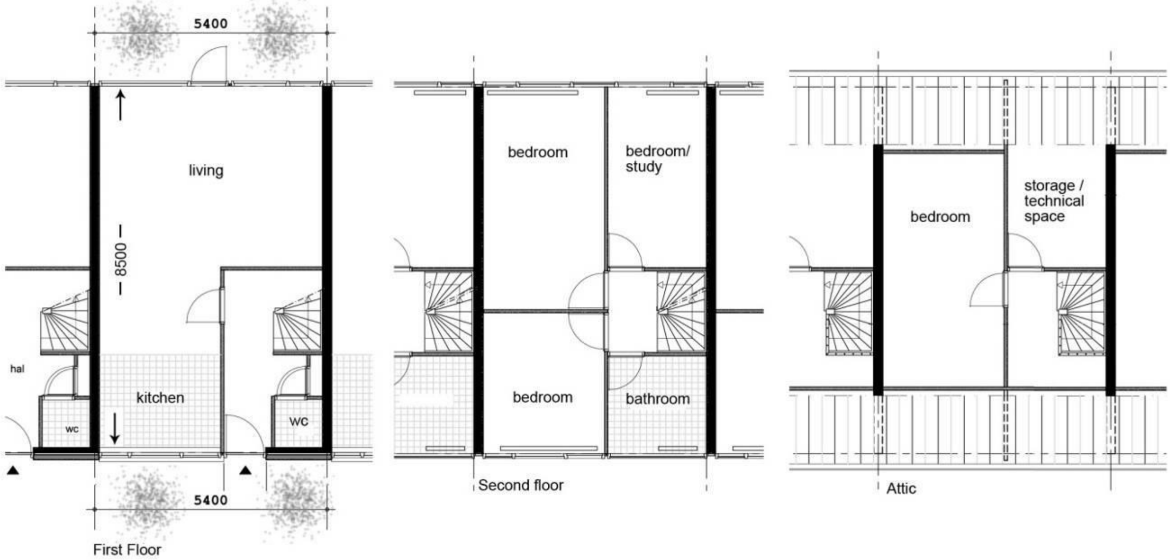
- Prefabricated timber facades and roofs
- Triple glazed windows
- Heat recovery ventilation
- Condensing gas boiler
- Building integrated PV
- Solar thermal collectors

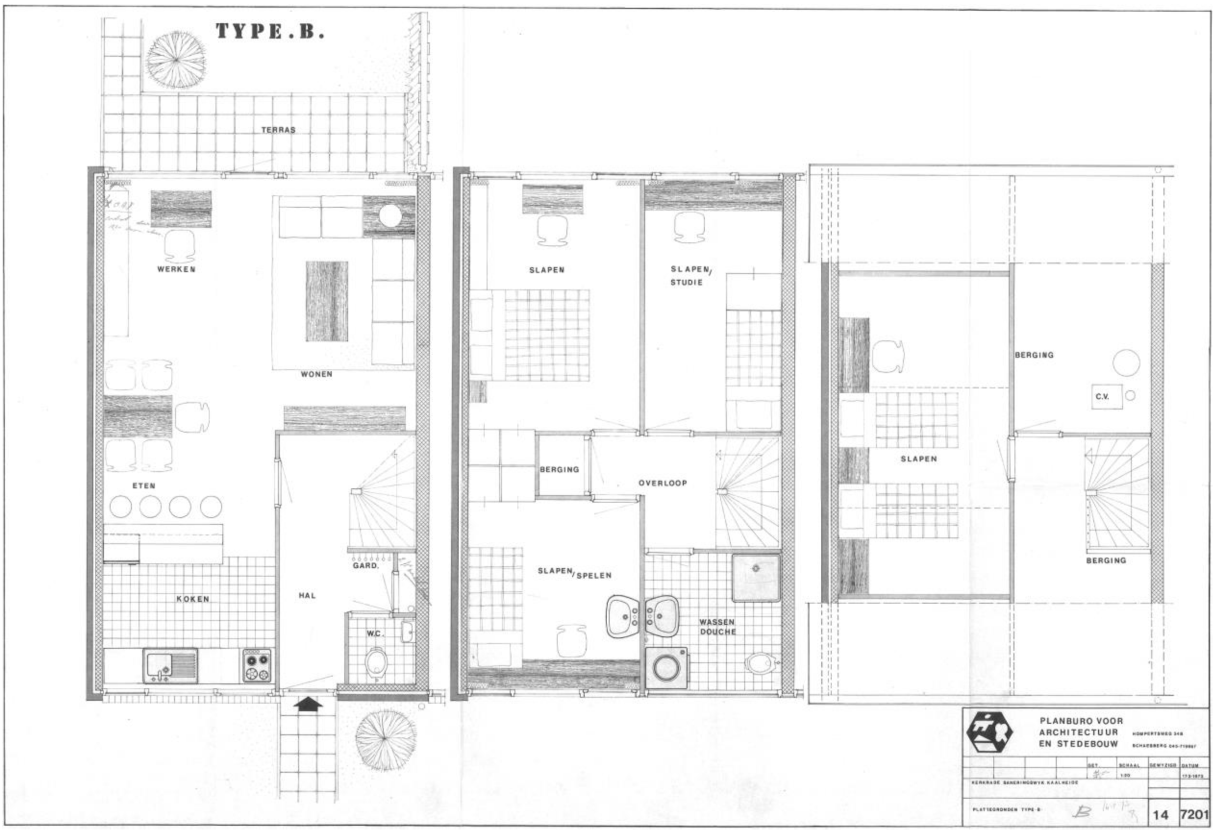
In the sustainable renovation project ‘The Existing District of Tomorrow,' 153 rental homes are being transformed into attractive and very energy-efficient houses that fully comply with the passive house standards. The project applies a unique and extremely fast renovation method that takes only ten working days to complete. The goal of the project is to create a passive neighbourhood that can serve as a symbol of how issues with existing housing are being dealt with in the Netherlands.

To ensure that the district of Kerkrade-West continues to be an attractive place to live in the future, 153 rental houses, built in 1974, will be renovated to very energy-efficient buildings (from label D to A++) and will comply with passive house standards. The houses are fitted with completely new outer walls, a new roof with an integrated solar energy system, a solar boiler, a high-efficiency combination boiler, new radiators, and a ventilation system with heat recovery The ground floor is also fitted with underfloor insulation. Thanks to an innovative, series-based approach, the total renovation takes place in 10 working days and occupants do not need to vacate their homes during the renovation activities. Approval of the residents had to be gained to be able to increase the monthly rental fee by an average of €65 per month to pay for the building renovation activities. However, the occupants will save as much as €100 per month on their total energy bill: €50 on natural gas and €50 on electricity. As part of their monthly rental fee, occupants will also pay a fee for use of the solar panels, which is equal to half of the value of the electricity expected to be produced by the house. HEEMwonen will monitor developments to check whether its projections are correct. If it turns out that the fee paid by the occupants is higher than the value of the electricity produced, HEEMwonen will repay the occupants the difference. This guarantee provision helped persuade residents to participate in the project. The first phase of the renovation project was launched in June 2012, and the first 95 houses have already been completely renovated. The remaining 58 will be completed in August 2013.

This project shows that fast renovation of existing homes to high energy efficiency standards is possible and that there is potential for upscaling since the renovation method can be replicated elsewhere. Also, with the knowledge gained during the process, the costs of the renovation method can be decreased with 10-20% in follow-up projects.

DESIGN DATA (before renovation)
Number of housing units [#]: 153
Heated floor area [m2]: -
Energy consumption per housing unit per year:
-Electricity [kWh]: 3970
-Gas [m3] 1600
Air tightness qv;10 [dm3/s] per m2 floor space: 3,3
Installed heating capacity per housing unit [kW]: -





TYPE . B .
TERRAS
WERKEN
WONEN
ETEN
KOKEN
HAL
GARD.
W.C.
SLAPEN
SLAPEN/
STUDIE
BERGING
OVERLOOP
SLAPEN/SPELEN
WASSEN
DOUCHE
BERGING
C.V.
SLAPEN
BERGING
PLANBURO VOOR
ARCHITECTUUR
EN STEDEBOUW
SCHAAL
DATUM
1:20
KERKRADE SANERINGSWYK KAALHEIDE
PLATTEGRONDEN TYPE B
14
7201

### 6.2 Renovation Concept and notable features

Characteristics Retrofit projects:

| | | | | | | |
|---|---|---|---|---|---|---|
| | Thermal insulation:<br>-Roof<br>-Facade<br>-Floor/foundation | Rc 1,0 – 2,5<br>○<br>○<br>○ | Rc 2,5 – 4,0<br>○<br>○<br>○ | Rc 4,0 – 5,5<br>○<br>○<br>● | Rc 5,5 – 7,0<br>●<br>○<br>○ | Rc 7,0 – 12,0<br>○<br>●<br>○ |
| | Measures airtightness | Present<br>○ | Not present<br>○ | | | |
| | Glazing | Double<br>○ | Triple<br>● | | | |
| | PV panels<br>(m2 PV / dwelling) | 10 - 15<br>○ | 15 - 20<br>● | 20 - 30<br>○ | 30 - 40<br>○ | >40<br>○ |
| | Heating | Gas-fired boiler (HR-107)<br>● | Heat pump (water)<br>○ | Heat pump (air)<br>○ | Hybrid<br>○ | External source<br>○ |
| | Domestic hot water | Gas-fired boiler (HR-107)<br>● | Heat pump<br>○ | External source<br>○ | Shower heat recovery<br>○ | Thermal solar boiler<br>● |
| | Ventilation system | Natural (C)<br>○ | Natural-controlled (C+)<br>○ | Mechanical (D)<br>● | Mechanical-controlled (D+)<br>○ | |
| | Energy supply | Gas + Electric<br>● | Electric<br>○ | External source (district heating)<br>○ | None (all-electric)<br>○ | |

This paper focuses on the passive house renovation of 153 ‘doorzon’ houses in Kerkrade West built in 1974. The aim of this project was to develop a quick and clean renovation concept based on prefab elements with integrated piping and wiring; renovation taking only a few days per house. During this works the house should stay inhabitable. Furthermore the costs of this renovation should be such that the increase in rent could be less than the savings on energy costs; per month the tenants should pay less for living in these houses.
Before renovation the exterior and surroundings of the houses where in a rather neglected state. The housing corporation hesitated for quite some years whether to demolish or renovate these houses. The wish for a sustainable and long term solution and the outcomes of a SWOT analysis made the housing corporation decide for an innovative passive house renovation. At the basis of this decision also lies an ongoing research project concerning the sustainable transition of Kerkrade West3. Main conclusion of this analysis was that the tenants appreciate the spaciousness of the houses, that the houses are structural solid and that the facade is relatively easy to replace by a new facade in order to improve insulation, comfort and aesthetics.

Criteria for renovation
In 2010 the decision was made to renovate the houses to the level of ‘passive house’. The housing corporation wanted to renovate on the basis of clear performance indicators.

- Renovation of exterior and installations only, not the interior
- Energy performance at passive house renovation
- Building speed of approximately 8 days per house (for exterior and installations)
- The houses should stay inhabited (inhabitable) during the renovation works
- Contractors should have an open and clear communication with the dwellers/tenants
- Aesthetic/architectural improvement

Key technologies:

- Timber frame prefab elements (half the width of one house, 2 storeys high) supported by studs resting on the existing foundation. Additional insulation (EPS) is added to the prefab elements. Insulation value of facade; R= 10 m2.K/W or U=0,1 W/(m².K))
- Passive house vinyl window frames with triple glazing, integrated in prefab facade elements (Uf+g = 0,8)
- Prefab timber frame roof elements (also half the width of one house) that are placed over the existing sub roof. R= 7 m2.K/W or U=0,14 W/(m².K)

- Insulation of bottom of ground floor (accessible by a crawling space) with PUR foam. (R= 5 m2.K/W or U=0,2 W/(m².K))
- Insulation of the foundation with XPS foam (R= 7 m2.K/W or U=0,14 W/(m².K))
- Roof with integrated PV panels (approx. 2800Wp per house) and solar panels.
- Mechanical ventilation with heat recovery.
- Small efficient gas furnace (hot water / heating) to supplement the solar panels.
- Heat distribution with low-temperature convector panels
- Night cooling with natural ventilation
- All piping for heating and ventilation is integrated in prefab facade elements, as well as roller shutters for the windows

### 6.3 Energy related indicators

Based on PHPP calculations the expected energy needed for heating the houses (both single family and 1-on1) is 17-20 kWh/m2 per year (depending on orientation) for a mid-terrace house (2 facades) and 21-22 kWh/m2 for a corner house (3 facades). One PHPP datasheet is given at the end of this paper. For cooling no energy is needed because of selective use of heat reflecting glass and night cooling with natural ventilation. The actual energy performance is being monitored in 65 houses with data from their digital energy meters. The housing corporation is in negotiation with the tenants about further, more detailed, monitoring and research on rebound effects etc. Unfortunately the tenants start to feel like 'lab-rats' and are reluctant to cooperate.

| DESIGN DATA (after renovation) | |
|---|---|
| Number of housing units [#]: | 153 |
| Heated floor area [m2]: | |
| Energy consumption per housing unit per year: | |
| -Electricity [kWh]: | 1200 |
| -Gas [m3] | 600 |
| Energy consumption (heating) [kWh/m2]: | 17 |
| Air tightness qv;10 [dm3/s] per m2 floor space: | <0,15 |
| Savings energy cost (electricity + gas) per month [€]: | 55-101 |
| Rent increase per month [€]: | 34-64 |

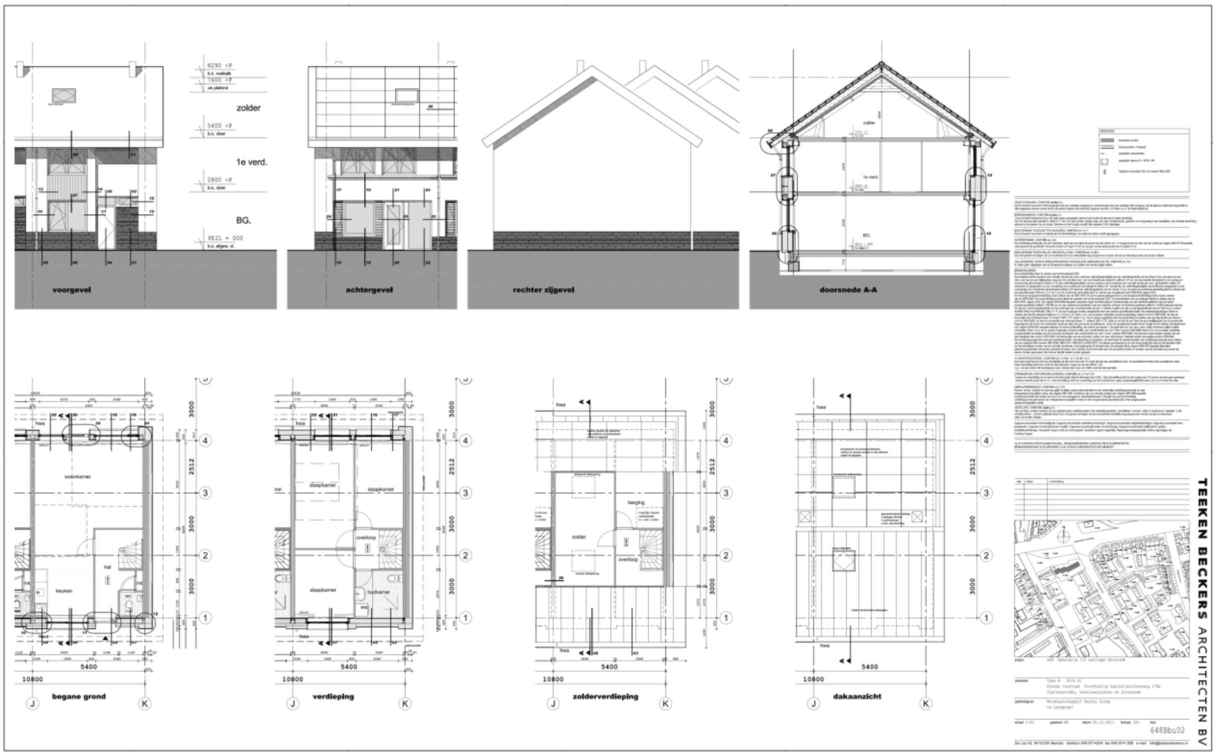
### 6.4 Technological design – retrofit design details

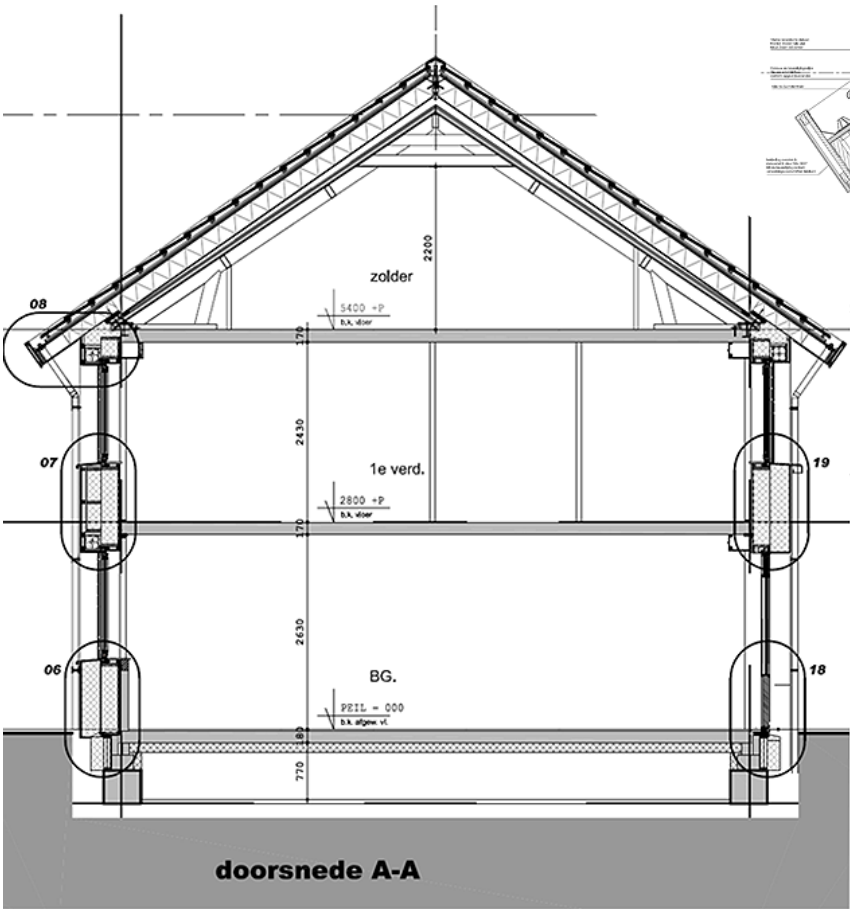
The prefab timber frame elements are 2,8m wide and 5,2m high. The elements are already closed on both sides and filled with 14cm of thermal insulation (glass wool). The elements come with window- and doorframes (including the triple glazing) already installed. This saves time on the building site and guarantees an airtight fixture. Besides doors and windows also roller shutters and piping for ventilation and heating is integrated in the prefab elements. The elements are supported by metal studs which are placed on the existing foundation. A new facade is installed on the same day that the old facade is removed. After installing the prefab facade elements an additional EPS insulation is added and the facades are finished with a white stucco. Renovation of the roof is also based on prefab timber frame elements. These roof elements are placed over the existing roof; only the roof tiles and battens are removed. These roof elements are placed on metal anchors which are connected to the concrete attic floor. The roofs are partially clad with roof tiles and partially with building integrated solar and PV panels; these also function as roofing. In the attic the original gas furnace is replaced by a combination of solar heated thermal storage tank and high efficiency furnace, also a ventilation unit with heat recovery is installed. Because the renovation concepts only involves facade and roof floor heating was not an option, wall heating was rejected because of the large % of glass in the facades. The heat distribution units therefore are low temperature heating convector panels.

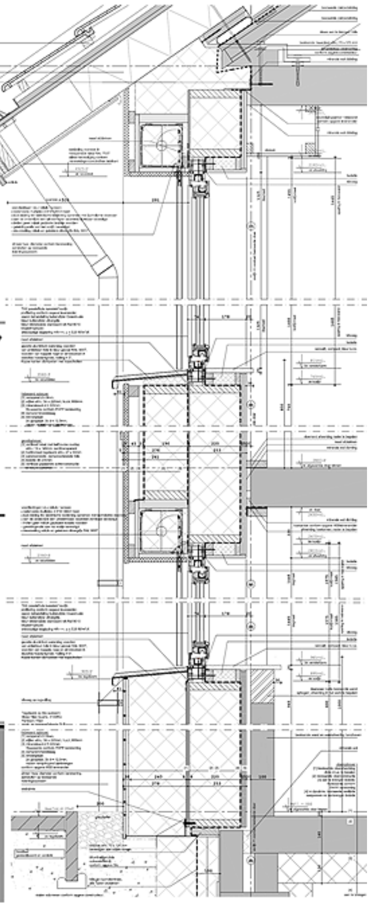

TEEKEN BECKERS ARCHITECTEN BV

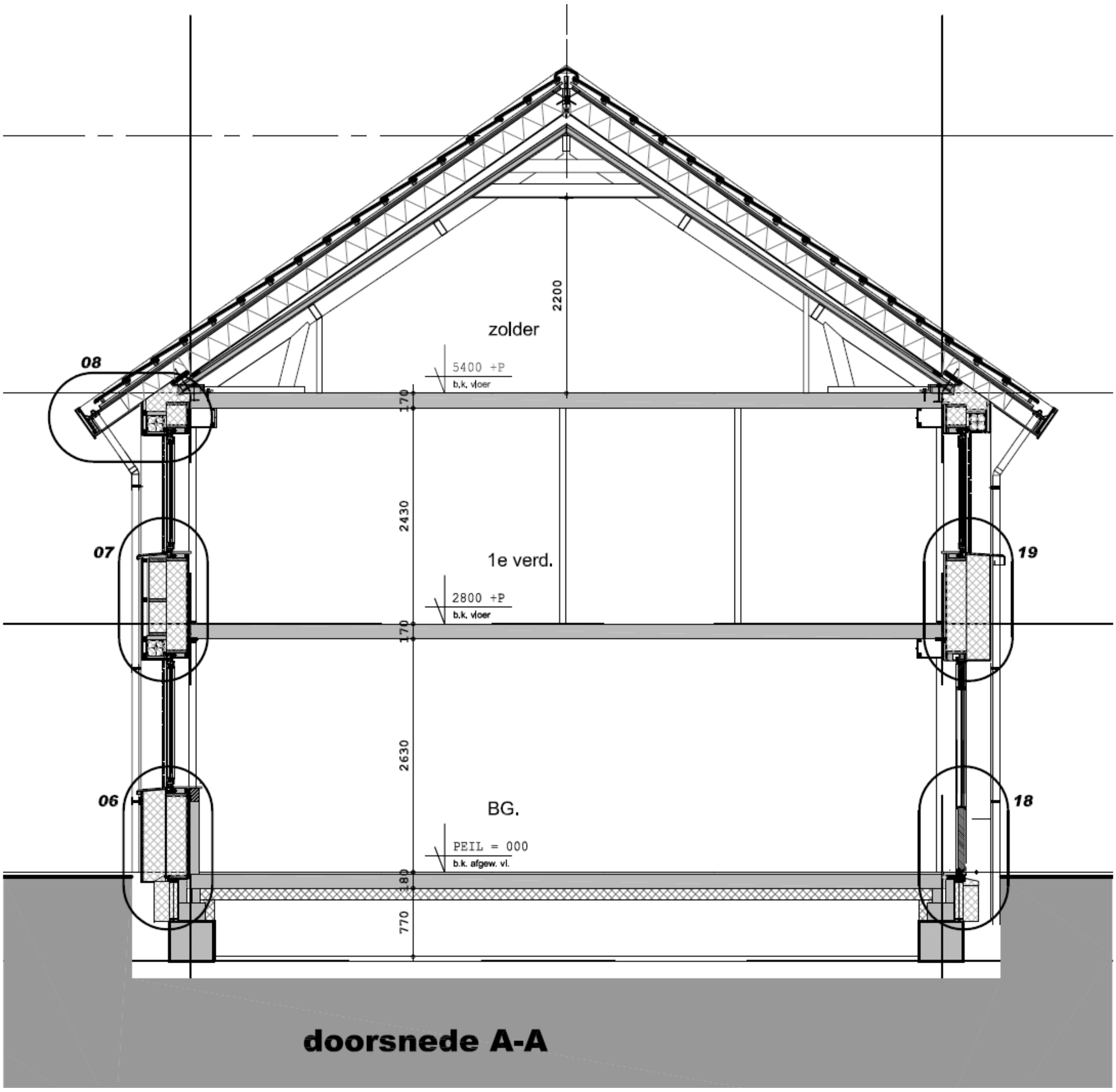

TEEKEN BECKERS ARCHITECTEN BV

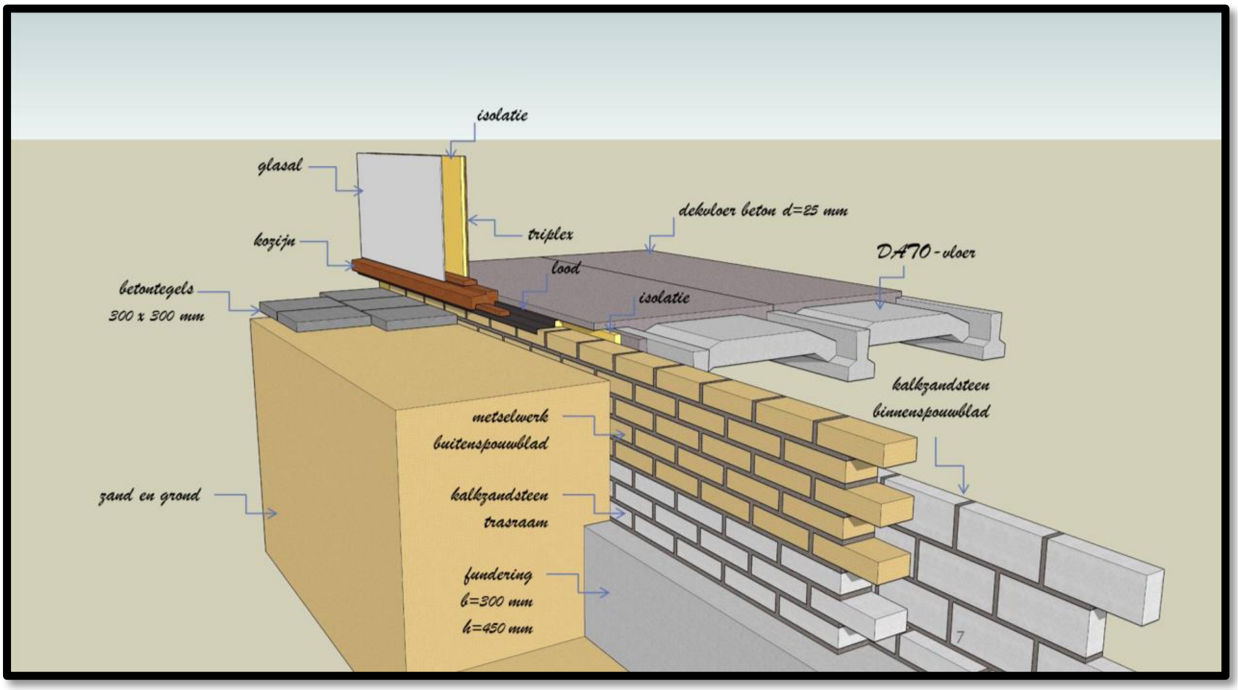

TEEKEN BECKERS ARCHITECTEN BV

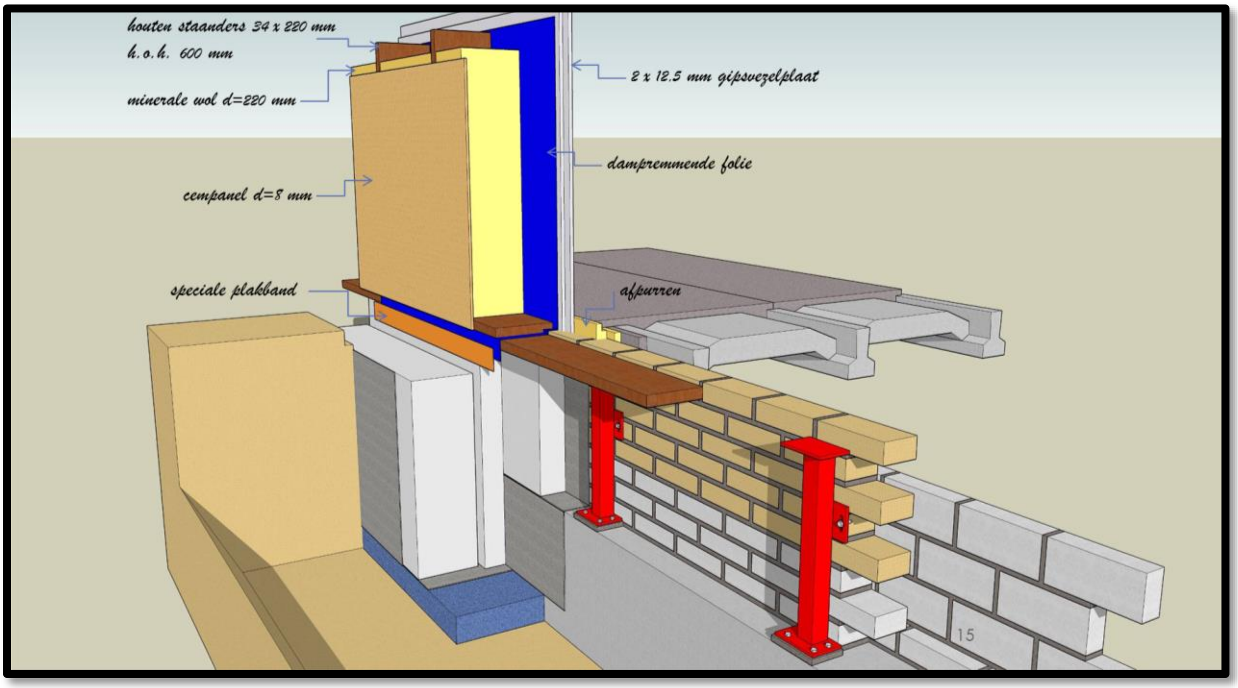

zolder
1e verd.
BG.
voorgevel
achtergevel
rechter zijgevel
doorsnede A-A
begane grond
verdieping
zolderverdieping
dakaanzicht
TEEKEN BECKERS ARCHITECTEN BV

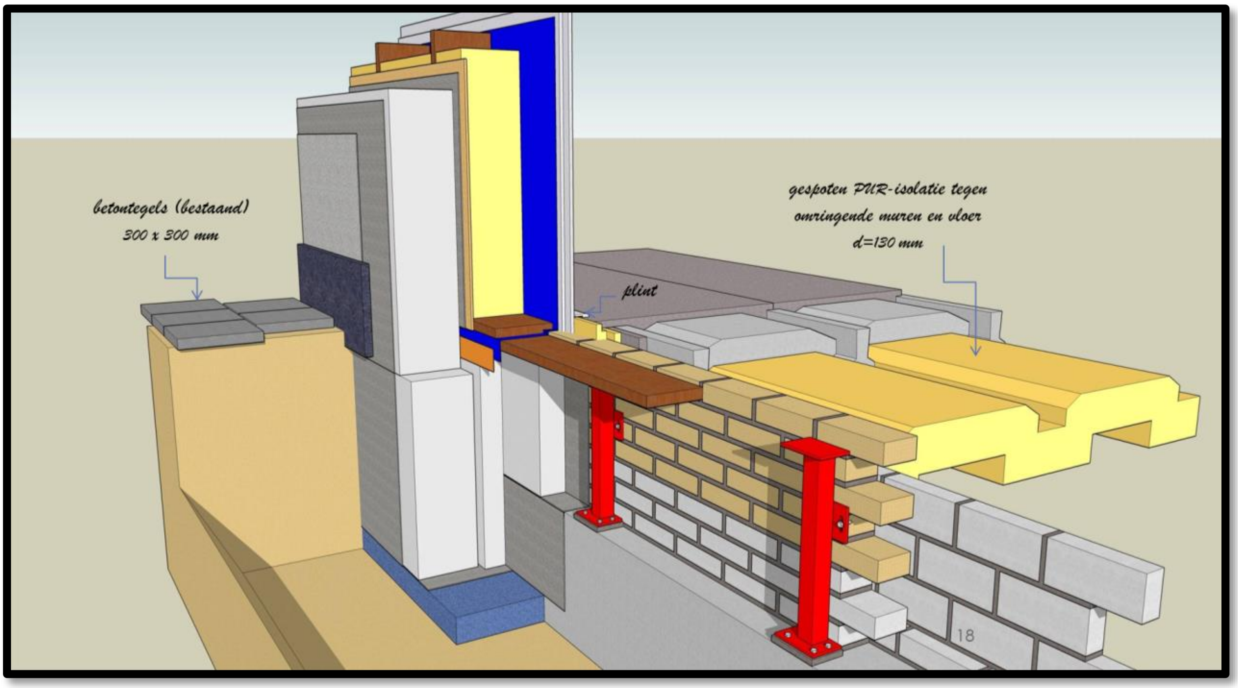

zolder
2200
08
5400 +P
b.k. vloer
170
2430
07
1e verd.
19
2800 +P
b.k. vloer
170
2630
06
BG.
18
PEIL = 000
b.k. afgew. vl.
80
770
doorsnede A-A

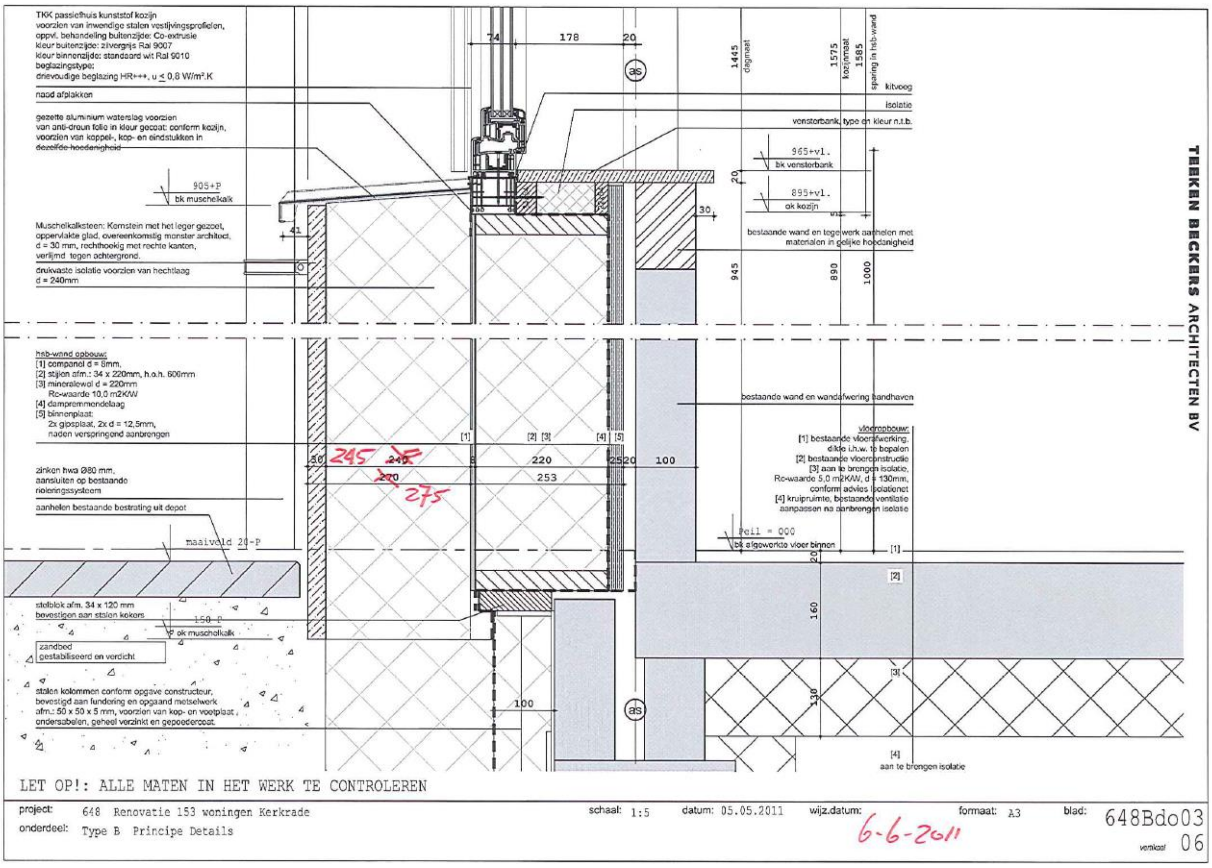


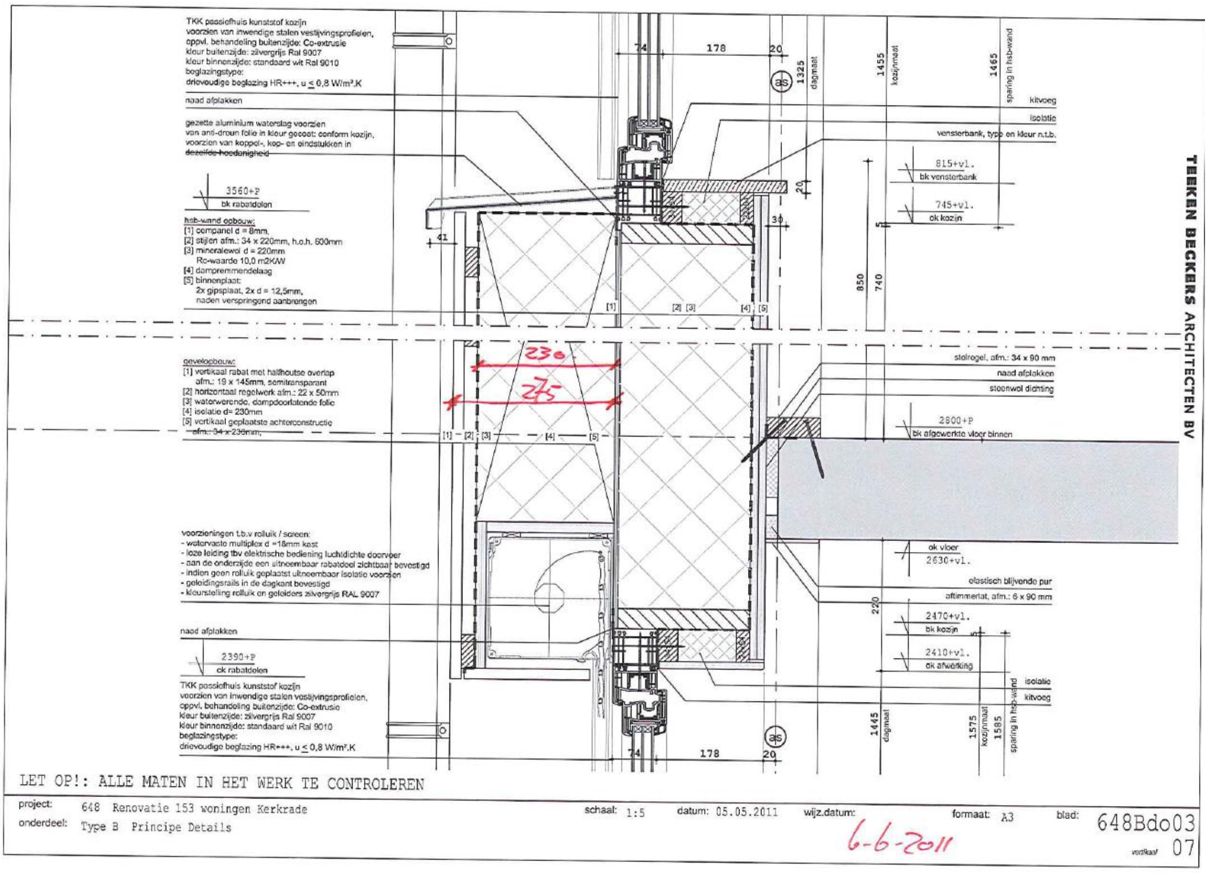

zolder
2200
5400 +P
b.k. vloer
08
170
2430
07
1e verd.
19
2800 +P
b.k. vloer
170
2630
06
BG.
18
PEIL = 000
b.k. afgew. vl.
180
770
doorsnede A-A


isolatie
glasal
triplex
dekvloer beton d=25 mm
kozijn
DATO-vloer
lood
betontegels
300 x 300 mm
isolatie
kalkzandsteen
binnenspouwblad
metselwerk
buitenspouwblad
zand en grond
kalkzandsteen
trasraam
fundering
b=300 mm
h=450 mm


houten staanders 34 x 220 mm
h.o.h. 600 mm
minerale wol d=220 mm
2 x 12.5 mm gipsvezelplaat
dampremmende folie
cempanel d=8 mm
speciale plakband
afpurren
15

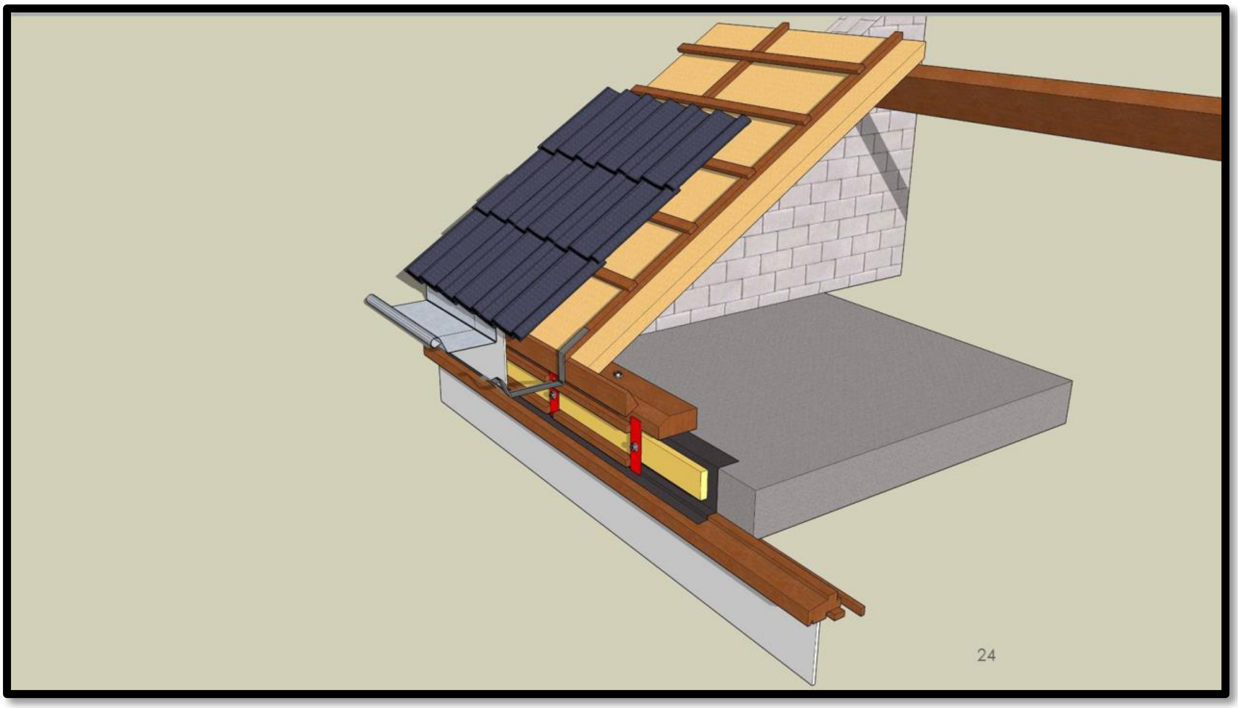

betontegels (bestaand)
300 x 300 mm
gespoten PUR-isolatie tegen
omringende muren en vloer
d=130 mm
plint
18

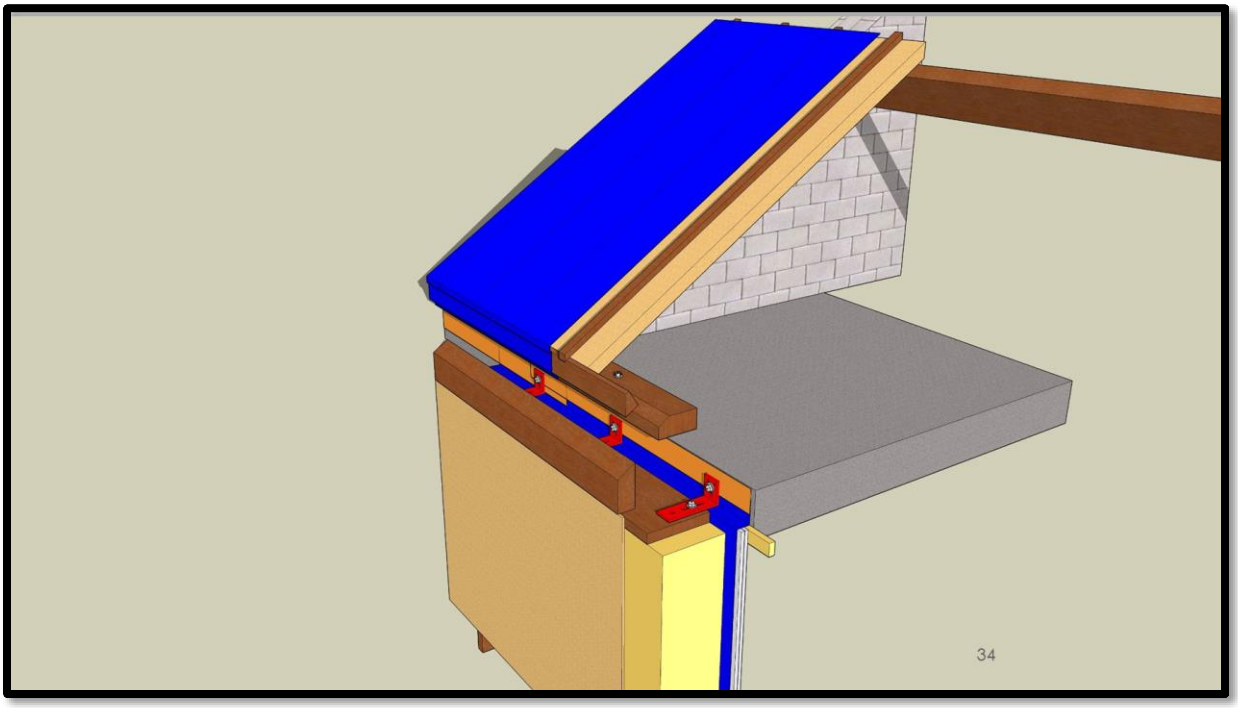

TKK passiefhuis kunststof kozijn
voorzien van inwendige stalen verstijvingsprofielen,
oppvl. behandeling buitenzijde: Co-extrusie
kleur buitenzijde: zilvergrijs Ral 9007
kleur binnenzijde: standaard wit Ral 9010
beglazingstype:
drievoudige beglazing HR+++, u ≤ 0,8 W/m².K
naad afplakken
gezette aluminium waterslag voorzien
van anti-dreun folie in kleur gecoat: conform kozijn,
voorzien van koppel-, kop- en eindstukken in
dezelfde hoedanigheid
905+P
bk muschelkalk
Muschelkalksteen: Kornstein met het leger gezet,
oppervlakte glad, overeenkomstig monster architect,
d = 30 mm, rechthoekig met rechte kanten,
verlijmd tegen achtergrond.
drukvaste isolatie voorzien van hechtlaag
d = 240mm
hsb-wand opbouw:
[1] cempanel d = 8mm,
[2] stijlen afm.: 34 x 220mm, h.o.h. 600mm
[3] mineralewol d = 220mm
Rc-waarde 10,0 m2K/W
[4] damprermmendelaag
[5] binnenplaat:
2x gipsplaat, 2x d = 12,5mm,
naden verspringend aanbrengen
zinken hwa Ø80 mm,
aansluiten op bestaande
rioleringssysteem
aanhelen bestaande bestrating uit depot
maaiveld 20-P
stelblok afm. 34 x 120 mm
bevestigen aan stalen kokers
150-P
ok muschelkalk
zandbed
gestabiliseerd en verdicht
stalen kolommen conform opgave constructeur,
bevestigd aan fundering en opgaand metselwerk
afm.: 50 x 50 x 5 mm, voorzien van kop- en voetplaat,
ondersabelen, geheel verzinkt en gepoedercoat.
74
178
20
as
1445
dagmaat
1575
kozijnmaat
1585
sparing in hsb-wand
kitvoeg
isolatie
vensterbank, type en kleur n.t.b.
965+vl.
bk vensterbank
895+vl.
ok kozijn
30
bestaande wand en tegelwerk aanhelen met
materialen in gelijke hoedanigheid
945
890
1000
bestaande wand en wandafwerking handhaven
vloeropbouw:
[1] bestaande vloerafwerking,
dikte i.h.w. te bepalen
[2] bestaande vloerconstructie
[3] aan te brengen isolatie,
Rc-waarde 5,0 m2K/W, d = 130mm,
conform advies isolatienet
[4] kruipruimte, bestaande ventilatie
aanpassen na aanbrengen isolatie
Peil = 000
bk afgewerkte vloer binnen
245
240
220
253
270
275
100
160
130
aan te brengen isolatie
LET OP!: ALLE MATEN IN HET WERK TE CONTROLEREN
project: 648 Renovatie 153 woningen Kerkrade
onderdeel: Type B Principe Details
schaal: 1:5
datum: 05.05.2011
wijz.datum: 6-6-2011
formaat: A3
blad: 648Bdo03
verdieping 06
TEEKEN BECKERS ARCHITECTEN BV

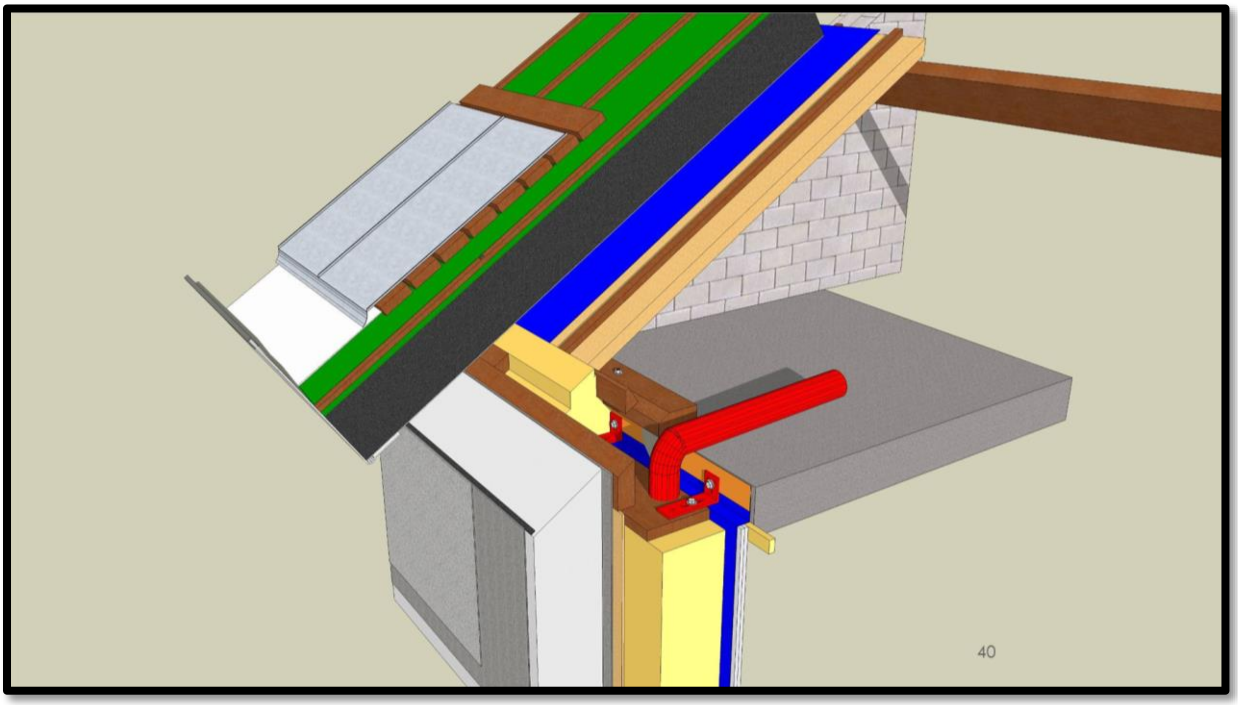

TKK passiefhuis kunststof kozijn
voorzien van inwendige stalen verstijvingsprofielen,
oppvl. behandeling buitenzijde: Co-extrusie
kleur buitenzijde: zilvergrijs Ral 9007
kleur binnenzijde: standaard wit Ral 9010
beglazingstype:
drievoudige beglazing HR+++, u ≤ 0,8 W/m².K
naad afplakken
gezette aluminium waterslag voorzien
van anti-dreun folie in kleur gecoat: conform kozijn,
voorzien van koppel-, kop- en eindstukken in
dezelfde hoedanigheid
3560+P
bk rabatdelen
hsb-wand opbouw:
[1] cempanel d = 8mm,
[2] stijlen afm.: 34 x 220mm, h.o.h. 600mm
[3] mineralewol d = 220mm
Rc-waarde 10,0 m2K/W
[4] damprermmendelaag
[5] binnenplaat:
2x gipsplaat, 2x d = 12,5mm,
naden verspringend aanbrengen
gevelopbouw:
[1] verticaal rabat met halfhoutse overlap
afm.: 19 x 145mm, semitransparant
[2] horizontaal regelwerk afm.: 22 x 50mm
[3] waterwerende, dampdoorlatende folie
[4] isolatie d= 230mm
[5] verticaal geplaatste achterconstructie
afm.: 34 x 230mm,
230
275
voorzieningen t.b.v rolluik / screen:
- watervaste multiplex d =18mm kast
- loze leiding tbv elektrische bediening luchtdichte doorvoer
- aan de onderzijde een uitneembaar rabatdeel zichtbaar bevestigd
- indien geen rolluik geplaatst uitneembaar isolatie voorzien
- geleidingsrails in de dagkant bevestigd
- kleurstelling rolluik en geleiders zilvergrijs RAL 9007
naad afplakken
2390+P
ok rabatdelen
74
178
20
as
1325
dagmaat
1455
kozijnmaat
1465
sparing in hsb-wand
kitvoeg
isolatie
vensterbank, type en kleur n.t.b.
815+vl.
bk vensterbank
745+vl.
ok kozijn
30
850
740
stelregel, afm.: 34 x 90 mm
naad afplakken
steenwol dichting
2800+P
bk afgewerkte vloer binnen
ok vloer
2630+vl.
elastisch blijvende pur
aftimmerlat, afm.: 6 x 90 mm
220
2470+vl.
bk kozijn
2410+vl.
ok afwerking
isolatie
kitvoeg
1445
dagmaat
1575
kozijnmaat
1585
sparing in hsb-wand
LET OP!: ALLE MATEN IN HET WERK TE CONTROLEREN
project: 648 Renovatie 153 woningen Kerkrade
onderdeel: Type B Principe Details
schaal: 1:5
datum: 05.05.2011
wijz.datum: 6-6-2011
formaat: A3
blad: 648Bdo03
verdieping 07
TEEKEN BECKERS ARCHITECTEN BV

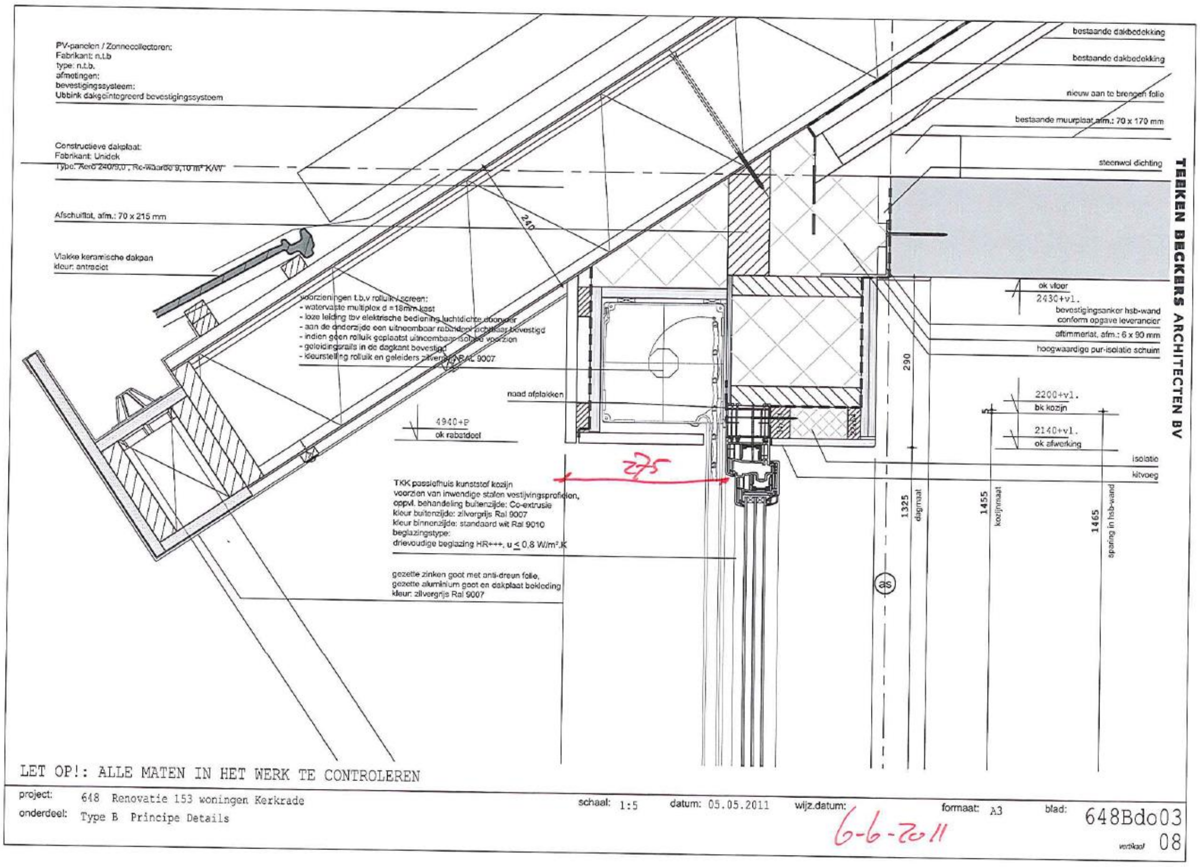


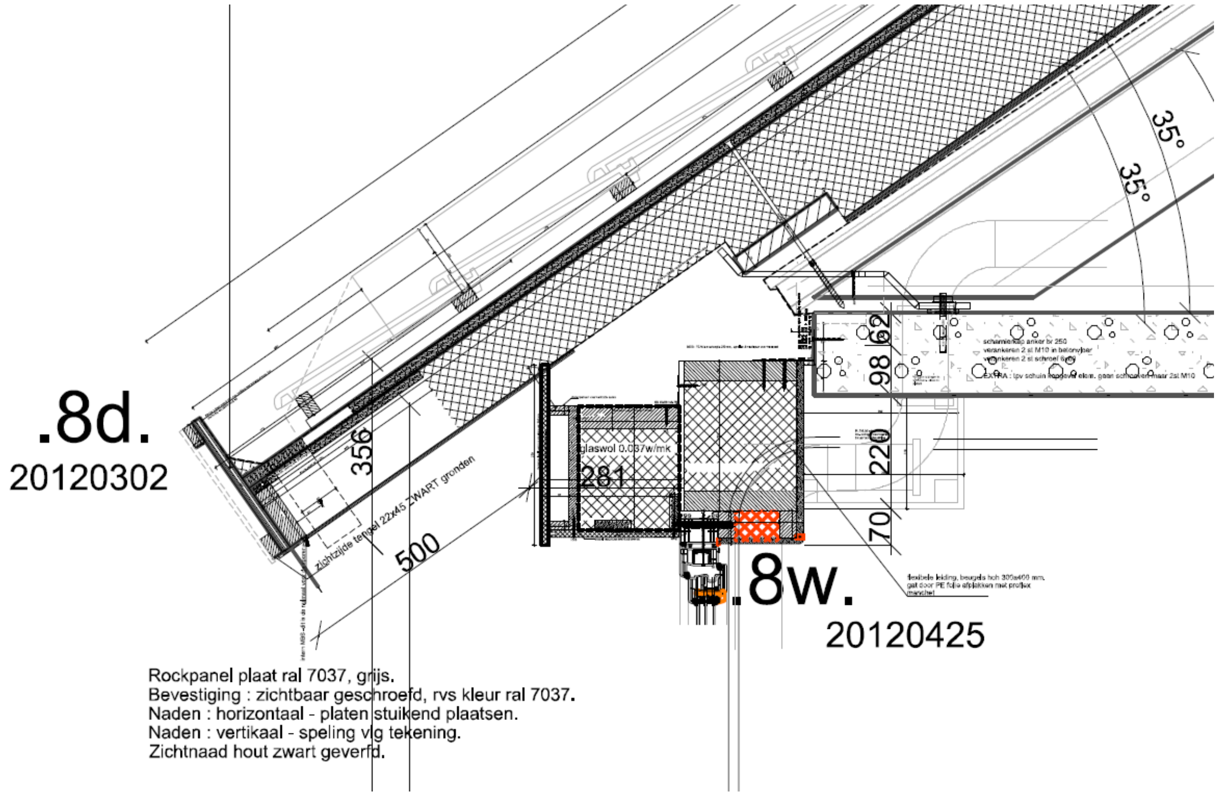


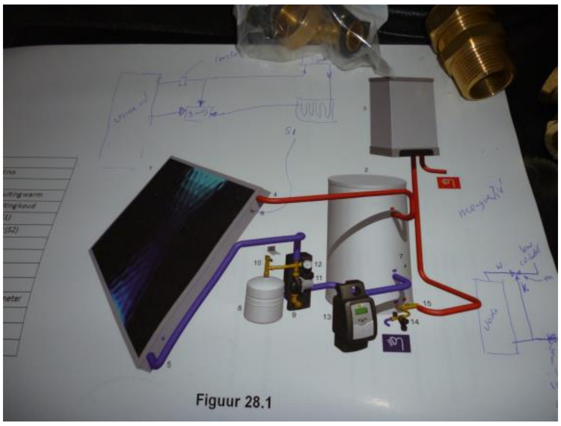

24


34


40


PV-panelen / Zonnecollectoren:
Fabrikant: n.t.b
type: n.t.b.
afmetingen:
bevestigingssysteem:
Ubbink dakgeïntegreerd bevestigingssysteem
Constructieve dakplaat:
Fabrikant: Unidek
Type: Aero 240/9,0 , Rc-waarde 9,10 m² K/W
Afschuiflat, afm.: 70 x 215 mm
Vlakke keramische dakpan
kleur: antraciet
240
voorzieningen t.b.v rolluik / screen:
- watervaste multiplex d =18mm kast
- loze leiding tbv elektrische bediening luchtdichte doorvoer
- aan de onderzijde een uitneembaar rabatdeel zichtbaar bevestigd
- indien geen rolluik geplaatst uitneembaar isolatie voorzien
- geleidingsrails in de dagkant bevestigd
- kleurstelling rolluik en geleiders zilvergrijs RAL 9007
naad afplakken
4940+P
ok rabatdeel
275
TKK passiefhuis kunststof kozijn
voorzien van inwendige stalen vestijvingsprofielen,
oppvl. behandeling buitenzijde: Co-extrusie
kleur buitenzijde: zilvergrijs Ral 9007
kleur binnenzijde: standaard wit Ral 9010
beglazingstype:
drievoudige beglazing HR+++, u ≤ 0,8 W/m².K
gezette zinken goot met anti-dreun folie,
gezette aluminium goot en dakplaat bekleding
kleur: zilvergrijs Ral 9007
bestaande dakbedekking
bestaande dakbedekking
nieuw aan te brengen folie
bestaande muurplaat afm.: 70 x 170 mm
steenwol dichting
ok vloer
2430+vl.
bevestigingsanker hsb-wand
conform opgave leverancier
aftimmerlat, afm.: 6 x 90 mm
hoogwaardige pur-isolatie schuim
290
2200+vl.
bk kozijn
2140+vl.
ok afwerking
isolatie
kitvoeg
1325
dagmaat
1455
kozijnmaat
1465
sparing in hsb-wand
as
TEBKEN BECKERS ARCHITECTEN BV
LET OP!: ALLE MATEN IN HET WERK TE CONTROLEREN
project: 648 Renovatie 153 woningen Kerkrade
onderdeel: Type B Principe Details
schaal: 1:5
datum: 05.05.2011
wijz.datum: 6-6-2011
formaat: A3
blad: 648Bdo03
vorblad 08


.8d.
20120302
356
zichtzijde tengel 22x45 ZWART gronden
500
glaswol 0.037w/mk
281
62
98
220
70
35°
35°
.8w.
20120425
Rockpanel plaat ral 7037, grijs.
Bevestiging : zichtbaar geschroefd, rvs kleur ral 7037.
Naden : horizontaal - platen stuikend plaatsen.
Naden : vertikaal - speling vlg tekening.
Zichtnaad hout zwart geverfd.


Figuur 28.1

### 6.5 Construction process

Day 1: Excavation of foundations, placing of supports for new facade
Day 2: Removal of the facade on the front and placing of the prefab facade elements
Day 3: Removal of the facade at the backside and placing of the prefab facade element
Day 4: Removal of roof covering and placing of the prefab roof elements
Day 5-8: Installing new installations, placing extra insulation on facade elements, cladding, roofing (including PV and solar heat panels).
In 2012 the renovation concept was tested on 2 houses. The renovation of these example houses was used to test the building system, building process and energy performance of the concept and it was a strong instrument to show the tenants how their new houses would look, feel and perform. After testing the concept on these houses the concept was further optimized. Main conclusions where; too much hinder (delay, noise, dust, dirt) for the inhabitants due to work on the installations inside the houses. The solution was found in integrating all the piping for the heating system in the prefab timber frame elements. The cladding and roofing took more time than initially planned (because the PV panels were not included in the initial plan) but since this is on the exterior and not hindering the inhabitants too much this was accepted; the average time it takes to renovate a complete house in this project / with this system turned out to be 10 working days.

### 6.6 Business case – renovation costs

The costs per house are on average € 100.000,- incl. PV panels, garden fencing and storage sheds. The municipality will invest in further improvement of the public space; public gardens, playgrounds, etc. This relatively large investment forms a drawback for this type of ambitious renovation. In order to justify this investment the houses are expected to last for the next 50 years and the rent was raised. This raise of the rent however is kept lower than the expected cost savings on energy of the tenants. The raise of the rent for a single family house is €64,- (incl. PV panels). The expected energy saving is € 101,- (based on current energy prices). Therefore a family saves expectantly € 37,- per month on costs for housing (rent + energy).

The solar energy system integrated into the roof is a new system in the Netherlands. The combination of solar collectors for hot water and solar panels for electricity is seamlessly integrated and linked to the electricity grid, which means that the occupant ends up paying only for the net consumption of energy. A single-family home produces about 2800 kWh per year, saving the occupant almost €50 per month on the electricity bill.

The energy label of the house improves dramatically from D to A++, which means that it becomes extremely energy-efficient. Thanks to the renovation, the occupants also save as much as €100 per month on their total energy bill: €50 on natural gas and €50 on electricity.
As part of their monthly rental fee, occupants will also pay a fee for use of the solar panels, which is equal to half of the value of the electricity expected to be produced by the house. HEEMwonen will monitor developments to check whether its projections are correct. If it turns out that the fee paid by the occupants is higher than the value of the electricity produced, HEEMwonen will repay the occupants the difference. This guarantee provision helped persuade residents to participate in the project. Rental rates for the renovated homes will also increase by an average of €35 per month to pay for the building renovation activities.

**Deep renovation cost:**

| | |
|---|---|
| **Inducement renovation** | |
| **Housing typology** | Single family housing |
| **Year of construction** | 1974 |
| **Number of housing units before/after** | 153/153 |
| **Rent before/ after [monthly]** | €450-550,- / €515-516,- |
| **Energy label (NL) before/after** | D/A++ |
| **Under construction** | 2012-2013 |
| **Investment installation per dwelling (total)** | €85.000,- |
| **Additional cost per dwelling** | €15.000,- |
| **-Housing unit internally per dwelling** | Incl. |
| **-Energy effiency per dwelling** | Incl. |
| **-Cost outdoor per dwelling** | Incl. |
| **-Additional (organizational) cost per dwelling** | Incl. |
| **Total investment per dwelling** | €100.000,- |

## CHAPTER 7: CASE STUDY 4 PRESIKHAAF, ARHNEM

### 7.1 General project description

Deep renovation apartment block Floriszstraat, Presikhaaf, Arhnem, The Netherlands:

PROJECT CHARACTERISTICS
Owner:
Housing association (Volkshuisvesting Arhnem)
Architect/Consultant:
Bouwnext, Ede
Contractor / key suppliers:
Vastbouw, WEBO
Location:
Presikhaaf (district), Arhnem (NL)
Number of housing units:
64
Under construction:
2015

KEY TECHNOLOGIES

- Prefabricated timber facades
- Triple glazed windows
- Heat recovery ventilation
- Condensing gas boiler??

Social housing association Volkshuisvesting Arhnem owns more than 700 housing units in Presikhaaf, Arhnem. Part of these 700 housing units consist of 64 apartments, constructed in 1963, located in the Stellingwerfstraat, Floriszstraat, Van Galenstraat and Hudsonstraat. These outdated and energy consuming housing units, are still heated by gas-fired boilers, and will be renovated towards Label A++. The energy efficiency improvement measures include triple glazing, a heat recovery system and mechanical ventilation.
The front and back balconies are partially added to the house, the facade is packed with 25 centimeter insulation and gives a fresh and fresh look. The entrees are also improved and residents get a new front door and videophone. Residents do not pay a rent increase for these improvements, and will subsequently save significantly on the energy costs. The relatively low housing costs will ultimately be even lower and the comfort increases. In addition, residents can choose extras for a rent increase, such as a soundproofing wall between the home and the neighbors. The 16 homes on the Hudson Street turn in 2016.
Due to the investments that can be made, the homes can be back in 50 years. The energy label makes multiple jumps to level A with several plus points! We will consult with a Soundboard group of six residents about the upcoming maintenance plan.

DESIGN DATA (before renovation)
Number of housing units [#]: 64
Heated floor area [m2]: xx
Energy consumption (heating + DHW) per housing unit per year [kWh]: xx (xxkWh/m2)
Air tightness qv;10 [dm3/s] per m2 floor space: xx
Installed heating capacity per housing unit [kW]: xx (xxW/m2)
Electricity consumption per housing unit per year (excl. heating) [kWh/y]: xx (xxkWh/m2)

The first step of the deep renovation project was the demolishing (of parts) of parts of the facade. The next step was to insulate the outer wall at the ground floor level (storage rooms of the apartments) with EPS insulation blocks. The prefab elements were made out of softwood and contain glass wool insulation. The triple glazed windows with wooden frames were factory mounted in the prefab façade elements. The finishing of the elements consist of brick slips (off-site) or plaster (on-site) installed on 60mm XPS added to the prefab element. The Rc value of the façade is 7.51 m2 ∙ K/W. For the roof an on-site system was applied by adding a layer of insulation on top of the existing roof.
The building services systems consists of several components. The HR100 condensing boiler was replaced by a new HR107 condensing boiler?? The original radiator system was adjusted to a smaller heat demand. Ventilation is provided by balance ventilation with heat recovery.

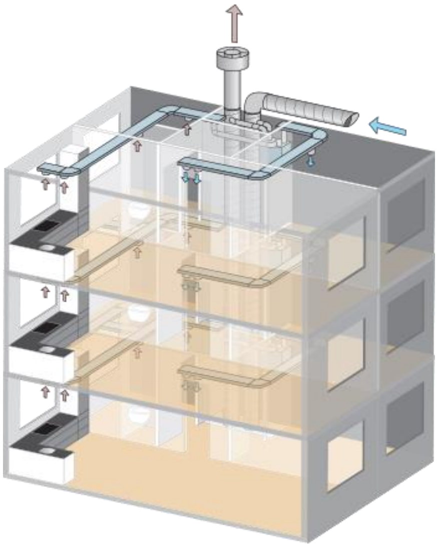
*Energy performance*
The energy index calculated with is 0.xx resulting in energy xx label. The total annual primary energy use is xx MJPrim.

## 7.2 Renovation concept and notable features

Characteristics Retrofit projects:

| | | | | | | |
|---|---|---|---|---|---|---|
| | Thermal insulation:<br>-Roof<br>-Facade<br>-Floor/foundation | Rc 1,0 – 2,5<br>○<br>○<br>○ | Rc 2,5 – 4,0<br>○<br>○<br>○ | Rc 4,0 – 5,5<br>○<br>○<br>○ | Rc 5,5 – 7,0<br>○<br>○<br>○ | Rc 7,0 – 12,0<br>○<br>●<br>● |
| | Measures airtightness | Present<br>● | Not present<br>○ | | | |
| | Glazing | Double<br>○ | Triple<br>● | | | |
| | PV panels<br>(m2 PV / dwelling) | 10 - 15<br>○ | 15 - 20<br>○ | 20 - 30<br>○ | 30 - 40<br>○ | >40<br>○ |
| | Heating | Gas-fired boiler (HR-107)<br>● | Heat pump (water)<br>○ | Heat pump (air)<br>○ | Hybrid<br>○ | External source<br>○ |
| | Domestic hot water | Gas-fired boiler (HR-107)<br>● | Heat pump<br>○ | External source<br>○ | Shower heat recovery<br>○ | Thermal solar boiler<br>● |
| | Ventilation system | Natural (C)<br>○ | Natural-controlled (C+)<br>○ | Mechanical (D)<br>● | Mechanical-controlled (D+)<br>○ | |
| | Energy supply | Gas + Electric<br>● | Electric<br>○ | External source (district heating)<br>○ | None (all-electric)<br>○ | |

- 3d design of renovation;
  - removing front and back walls (inner and outer wall)
  - placing new design walls front and back
  - adding insulation and new finish (brick-like tiles) to left and right wall
- demands to the the energy house hold
  - Rc 6 , which is NOM Renovation concept level based on BJW 'NOM-Keur' (Certificate of right design methodology and application)
  - Qv 10 value of 0,25, which is NOM Renovation concept level
  - Windows triple glazed which is NOM Renovation concept level
  - New ventilation system with heat exchange with practical performance of >74%



DESIGN DATA (after renovation)
Number of housing units [#]: 64
Heated floor area [m2]: ??
Energy consumption (heating + DHW) per housing unit per year [kWh]: ?? (??kWh/m2)
Air tightness qv;10 [dm3/s] per m2 floor space: 0,25
Installed heating capacity per housing unit [kW]: ?? (??W/m2)
Electricity consumption per housing unit per year (excl. heating) [kWh/y]: ?? (??kWh/m2)
Rent [€]: ??
Rent increase per month [€]: none
Reduction energy costs per year [€]: ??

### 7.3 Energy related indicators

The energy consumption of the houses is expected to change significantly. Space heating demand will reduce to a calculated figure of around xx kWh/($m^2$·y) for a mid-terrace and around xx kWh /($m^2$·y) for an end terrace. These figures are xx% better than the current performance. Hot water demand will reduce by xx% to xx% due to the installed solar thermal collectors and the high efficiency of hot water production by the compact system. Highly efficient fans are part of the compact system. But otherwise there are no building related electricity savings in the units.
The building related energy bill is expected to reduce by xx%, whereas the full bill for additional costs reduces by xx%, at constant energy prices. The significantly lower heating bills make the houses future proof and affordable, even if energy prices keep rising.

Key technologies:

- Prefabricated timber facades
- Triple glazed windows
- Heat recovery ventilation

The heating energy demand is expected to reduce by xx. The hot water demand decreases with xx%, thus resulting in a xx% lower building related energy demand. The significantly lower heating bills make the houses future proof and affordable, even if energy prices keep rising.
At completion of the renovation works blower door tests have been made resulting in an airtightness figure qv;10 of 0,25 dm3/s per m2. Infrared imaging of the units did not show any anomalies.

**Heating, ventilation**

***Heating & ventilation* -** Heating and ventilation is provided by a compact heating system, consisting of:

- Mechanical heat recovery ventilation
- Condensing gas boiler

The heating system has been installed on the top floor. The original radiator system has been adjusted to the smaller heat demand. This include xx. Fresh air is provided by the ventilation unit to the habitable spaces, i.e. living room and bedrooms, and exhausted via toilet, bathroom and kitchen.

***Domesitic hot water* -** xx

## 7.4 Technological design – retrofit design details

### Façade solutions

First, parts of the façade was demolished. The next step was to insulate the perimeter, the façade at the ground floor level were the storage rooms are located, around the apartment block with EPS insulation. The new prefabricated timber elements are 270 mm wide and contain glass wool insulation (Rc value of 7.51 m2 · K/W). The single story high prefab elements, are installed on a steel structure at the first floor level. The prefab elements on top are  connected to the building structure (floors) with plug-and-play connectors.

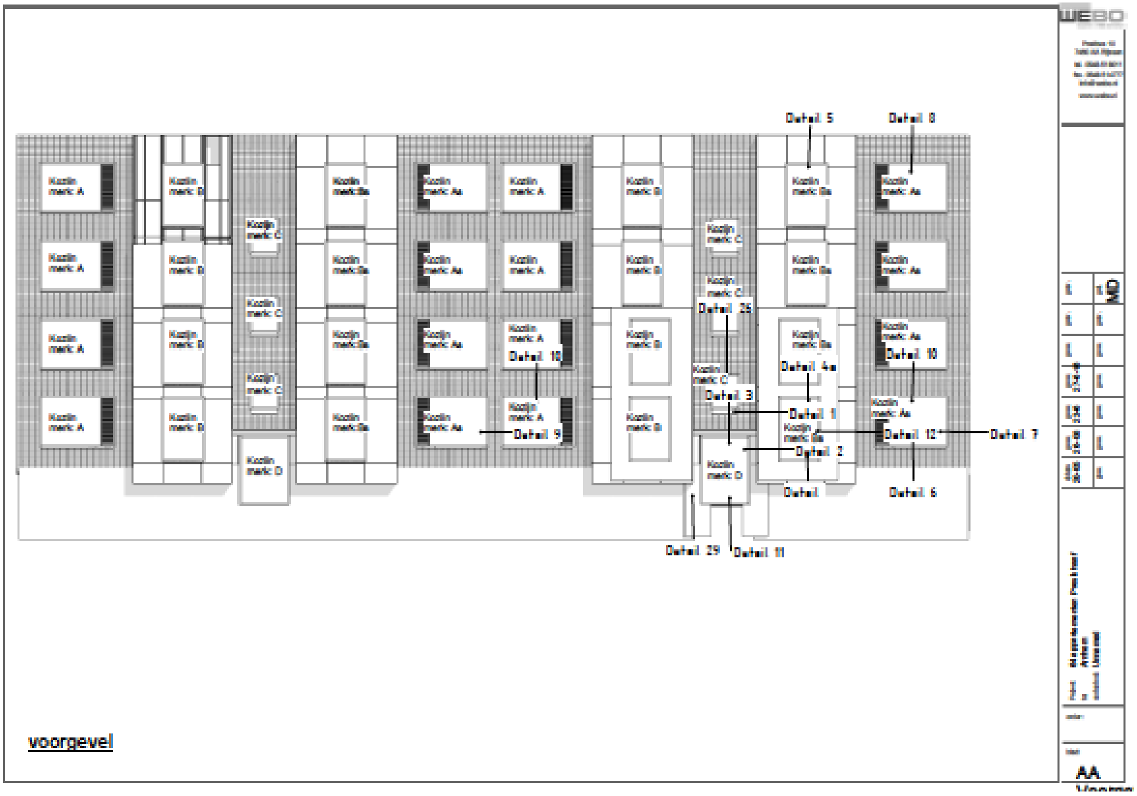
### Roof solutions

For the roof an on-site system was applied by adding a layer of insulation on top of the existing roof.

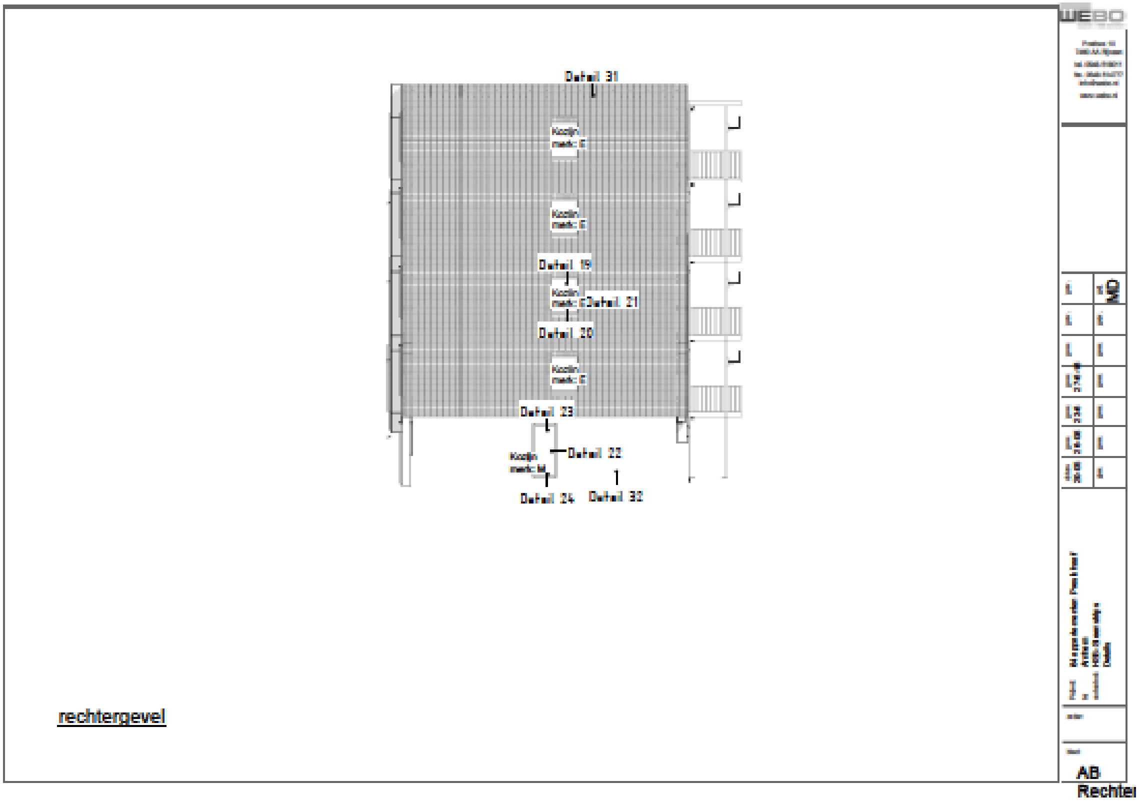
### (Ground) floor solutions

The façade at the ground floor level is insulated using EPS.

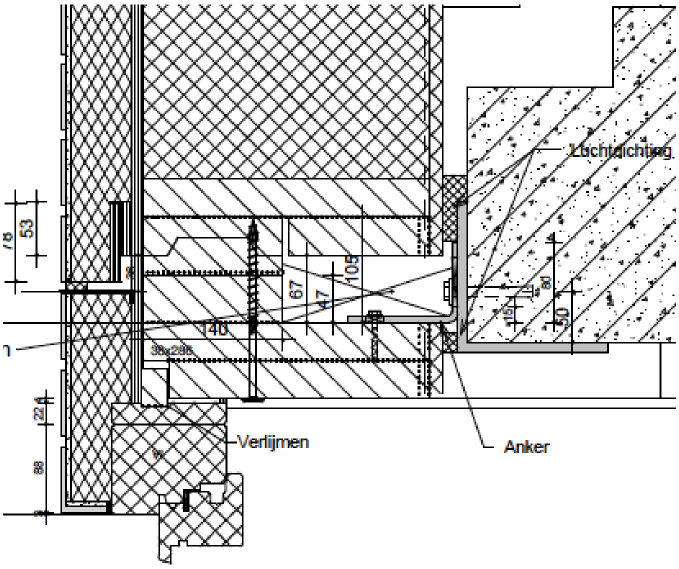
Demands met on insulation and airtightness (thermo pictures and blower test)



Overview of details front

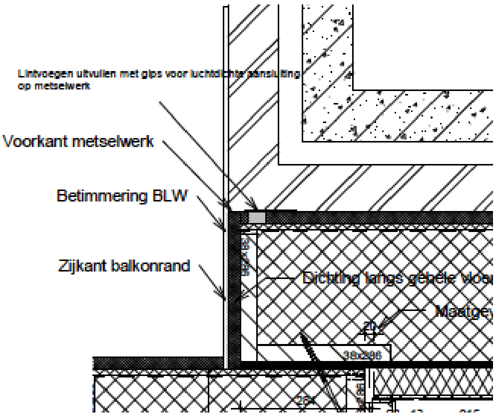



Overview of details side and back

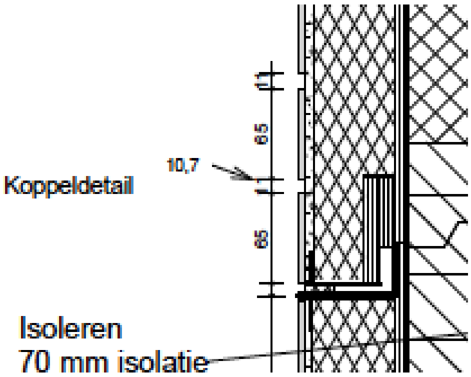



Improvements compared to previous project (project completed in the city of Zoetermeer);

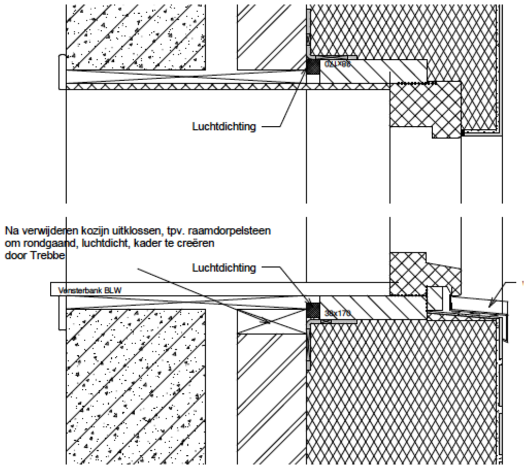
- Airtightness still organised on new elements
- Airtightness different types of compressed band used
    - Klick & Span plug-and-play mounting system applied; mounting from within the building (no scaffold needed)
- Connection between elements; different  types of compressible band used (water tightness)




Some preparation work done on the existing wall to ensure airtightness. Compressible band all around the existing floor edge.

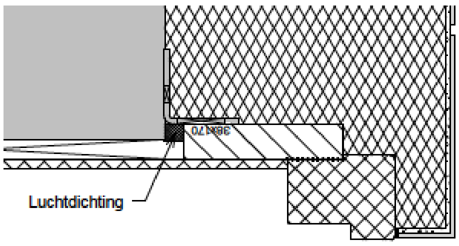


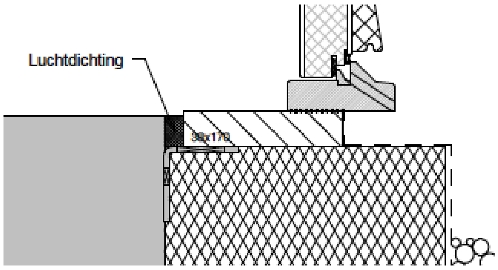

Connection detail; foil on both edges combined with compressible band.



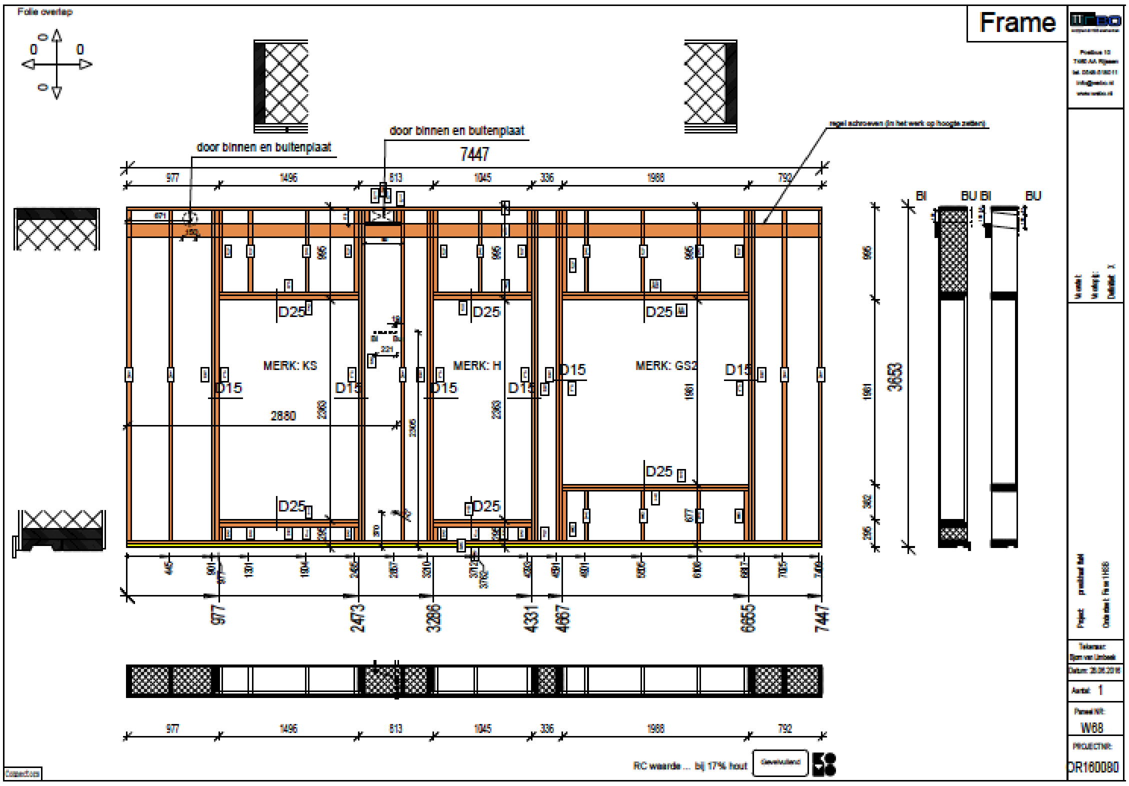

Connections detail window frames

- Old window frames removed
- New window frames installed in the façade module
- Airtightness around existing window openings



Steel bearing of walls; all weight directly to the foundation.




## 7.5 Construction process

The prefabricated elements have been produced by WEBO, a company that is based 75 km away from the renovation site in Presikhaaf, Arhnem. The elements are transported to the construction site by type (and thus not on based on the order of assembly). The window frames and outer finishing (brick slips) are already installed in the factory. Next the prefab façade elements are installed on site. An innovative connector has been developed to ease the mounting process. By applying the click-and-span connector, a typical plug-and-play solution, the prefab elements can be installed without scaffolding. After the installation of the elements the main contractor completed the internal finishing of the apartments. Notably, during construction period the apartments remained occupied.

## CHAPTER 8: THE ADOPTION AND UPTAKE OF 'DE STROOMVERSNELLING'

In this chapter the mechanisms which hinder or stimulate the adoption and uptake of deep renovation are assessed. More precisely, this chapter focusses on the mechanisms which affect the adoption of the deep renovation approach which have been developed for 'De Stroomversnelling'.

From the case studies it can be learned that the selection and adoption of suitable deep-renovation solutions depends on:

- Technical condition of the property (maintenance)
- Sustainability / energy efficiency of the property
- Housing comfort, i.e. personal living experience within the property
- (Social) living quality neighbourhood
- Area/neighbourhood/district development
- Developments (local) housing market
- Housing differentiation within the neighbourhood
- Financial and legal aspects (return on invest; operational and market value, rent/living expenses)
- Social aspects
- Organization renovation process

Below the various adoption mechanism will be discussed in more detail. While deep renovation according 'De Stroomversnelling' standard is mainly applied in social housing, this report focuses on the mechanism which affect the adoption decision of social housing association and the involved occupants. It need to be emphasized that the adoption mechanisms which affect the decision of occupants to agree upon deep innovation are only assessed indirectly, i.e. the occupants were not interviewed during the case studies and the adoption mechanisms were addressed by the representatives of the social housing association or contractors/suppliers. Moreover, the poor understanding of the mechanisms affecting the adoption of deep renovation by occupants is considered a lacuna in both renovation practice and literature (figure 8.1).

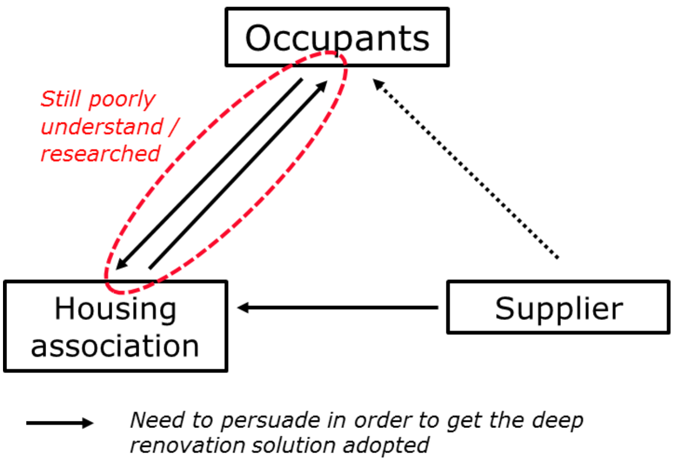



***Figure 8.1: Key stakeholders with respect to the adoption and uptake of deep renovation.***

### 8.1 Mechanisms affecting adoption by housing associations

**Energy Performance of Buildings Directive –** Governmental policies, in particular the Energy Performance of Buildings Directive (2010/31/EU) are stimulating deep renovation. In the Dutch case studies it was found that governmental policies, resulting from Directive 2010/31/EU and national programs as formalized in the covenants 'More with Less' (In Dutch: Meer met Minder) and 'De Stroomversnelling', are the driving forces with respect to the adoption of deep renovation. However, despite a government stimulating a transition towards a near energy zero build environment large investments are required which need to comply to strict institutionalized financial conditions.

**Civil Code: Occupant approval -** A key finding derived from the multiple case study reveals that adoption decision-making is highly institutionalized. Enforced by governmental regulation, Civil Code 7:220, adoption highly depends on a dual decision constituted by an investment decision of the social housing corporation and a go or no-go decision by occupants. This means that at least 70% of the involved occupants need to agree upon the suggested retrofit solution otherwise the housing association is not allowed to proceed.

**Social housing system and Housing Act: Services of General Economic Interest –** Housing associations are mandated to sustain the social housing system. The primary tasks of social housing associations are formalized as 'Services of General Economic Interest (in Dutch: DAEB). These services include (http://www.woningwet2015.nl/kennisbank/daeb; https://www.aedes.nl/artikelen/klant-en-wonen/huurbeleid/huurprijsbeleid/hoofdpunten-van-het-huurbeleid-2017-inkomens--en-huurgrenzen.html):

- A corporation preferably works within a specific housing market area and builds and rents social housing. In addition, a corporation may, at the request of municipalities, contribute to urban and village renewal, improvement of deprived areas and the construction of middle-class rental housing in areas neglected by commercial investors.
- Housing corporations allocate homes to households with an income up to the income limit of €35,739.-- annually (2016). The liberalization threshold (the threshold that determines whether a dwelling is assigned to the social or commercial markets) is as high as €710,68 monthly (2016). This mount is also the maximum rent limit to qualify for rent rebate. A small proportion of the vacant dwellings can be freely assigned, although priority rules apply. For *care-needers*, students and starters, exceptions apply. In addition, at least 95% of the housing stock owned by housing corporations should be rented to occupants who receive rent rebate. units with potential right to rented housing with a rent up to the limit of retirement. Housing corporations must have appreciated their real estate by 2016 at market value.
- Services that are primarily the task of other (commercial or social) organizations may not be offered by housing corporations. This also applies to services offered by market participants. Housing corporations would then compete improperly. For some services for the benefit of the tenants, such as housing preservation and energy efficiency, exceptions apply. These services may also be offered to all residents of a mixed residential building when the housing corporation is part of the Association of Owners.

Moreover, housing corporations need to apply to a strict financial regime when to invest in deep renovation. The investment may not weaken the financial position of the housing association. Next, recovering cost of investment primarily depends on rent income. However, rent may not exceed a certain threshold determined by a scoring system with a maximum of €710,68 per month (as constitutionalized in the Civil Code and Implementation act rental housing (In Dutch: Uitvoeringswet huurprijzen woonruimte). In this respect the business case depends on two key mechanism:

1. After deep renovation of the property tenants usually pay a higher rent. However, conform Civil Code 7:220 tenants have to agree upon the energy efficiency improvements prior to the execution of the project. Therefore, housing associations need to motivate the rent increase. This is normally done by (formally) guaranteeing that the overall living expenses reduces by savings on the energy bill (up to €120-200 monthly). In this respect, the rent increase should not exceed the savings on the energy bill.
2. In order to overcome the split-incentive problem Act on Energy Performance Compensation was instated on September 1, 2016. The Energy Performance Compensation (in Dutch: EPV) allows housing corporations to request an (additional) rent increase from tenants for almost (almost) Zero-on-the Meter homes. This Act allows social housing corporations to compensate their investments to renovate social housing to (near) zero energy homes. Within (near) zero energy housing, energy-saving measures are combined with power generating facilities, such as PV panels, thermal solar boilers or heat pumps. The deep renovated dwellings must meet some requirements, inculding (http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels-gebouwen/energieprestatievergoeding):
    - The dwelling is very well insulated;
    - The dwelling produces (sustainable) on average as much energy as the dwellings uses;
    - The building owner shows that the property meets the requirements for an Energy Performance Compensation;

- The dwelling must therefore be very well insulated, i.e. it has a very low heat demand. The heat demand is less than 50 kWh / m2 per year. The highest EPV is up to € 1.40 / m2 per month. For this, the heat demand must be below 30 kWh / m2 per year. The dwelling generates at least an equal amount of renewable energy. This allows them to fully meet the need for heat. In addition, the dwelling generates 15 kWh / m2 per year for hot tap water.
- The dwelling has enough 'help energy' (E-help). E-help is the building-related (electrical) energy for installations. Consider ventilation systems, (comfort) cooling systems and measurement and monitoring systems. Energy for lighting does not fall under E-help. In addition, the house needs to generate 26 kWh / m2 per year, it covers at least 1,800 kWh with a maximum of 2,600 kWh.

Because investments in social housing includes public money, housing associations are expected to be risk averse. A contradiction can be denoted; it is expected that housing associations only derive mature solutions from the market well deep renovation solutions applied in all three cases are still in its infancy. Moreover, in order to comply with long term deep renovation policy goals housing associations are 'forced' to invest in innovative, deep renovation solutions. Nevertheless, uncertainty avoidance is within the nature of housing association and we found that the perceived risk with respect to the retrofit concepts included in the case studies emanates from:

- The limited availability of pilot projects in order to gain knowledge about the maturity of both the retrofit technology and the retrofit process;
- The uncertainty about return-on-investment resulting from uncertainties regarding long-term exploitation and changing governmental policies;
- Uncertainties also emanates from the confidence housing associations have about convincing occupants to agree with large scale retrofitting well as rent increase;
- Uncertainty emerging from disintegrated building stock; how to invest in building or apartment blocks of which not all dwellings are owned by the housing association?
- (A) dominant design(s) of deep renovation solutions has not yet come to a closure. A severe battle for dominance has evolved between 'active and passive' solutions, i.e. the application of energy efficient heating, ventilation and air conditioning (HVAC) systems (often by using renewables) to cover the energy consumption versus passive house solutions which minimize energy loss by extremely insulating the building envelope;
- Uncertainties about 'no-regret' investments with respect to how current investments (in technological solutions) could hamper future investments.

**Property management –** From the cases it became eminent that the investment in deep renovation is not fully compatible with the institutional financial agenda. First, the concepts studied here are transforming outdated and energy consuming housing into near energy zero building of new build quality and thus depend on both a retrofit cost part (restoring building quality) and an investment cost part (improving building quality). Slack resources are made up by long term maintenance budgets which result from policies to sustain the specific asset at a certain (operational) level (the anyway renovation). Long-term maintenance plans were initially not designed to add extra functionalities and/or quality to the property. Improving an dwelling to an 0-energy asset is considered as a value adding endeavour and it is therefore challenging to find resources without extracting these resources from other assets. Thus, this kind of investment does not fit into traditional investment agenda's considering the depreciation period, i.e. new build housing are included in the balance sheet for 40 to 50 years while investments in retrofitting are included for less than 25 years. Considering that the investment mainly needs to be recovered by rent income within a specific period of time this has a detrimental effect on adoption, also while social housing rent is highly institutionalized. In addition, from the case it became clear that a decision to invest in deep renovation also depends on the book and operational value of the property. Property on the balance sheet with a high book and/or operational value will not be considered because the investment could threaten the financial position of the housing association (because investment decisions include public money housing associations are considered to be risk averse). Previous investments, for example the replacement of the heating system, could hamper adoption for the same reason.
Next, the adoption of the passive house transformation concept in case 1 could be legitimized while upgrading housing is considered as an meaningful improvement of deprived urban areas. From case 1 it follows that retrofit concepts not only could be improve housing in a specific area but could also be used to change the social setting of that area (for example by introducing housing for a specific target group).

It was also learned that deep renovations competes with each other but also have to compete with alternative investment decisions. Housing associations faces six types of investment alternatives:

1) Suspend investment in favour of the status quo;
2) Invest to preserve the property (for a period up to 10 years, the anyway renovation);
3) Invest to renovate the property (for a period up to 25 years);
4) Invest to transform the property according the principles of a near energy zero build environment (for a period up to 50 years);
5) Invest to replace the property, or;
6) To sell the property.

More precisely, in line with (short time) policy goals, deep renovations concepts compete with less radical investment decisions, like upgrading dwellings to label B; replacing dwellings (demolition and rebuilding) or selling properties (transferring responsibilities to private homeowners). At least, housing associations are reluctant to invest in Zero-on-the-Meter renovations at this point.

**Investment costs -** It became clear that deep renovation are considered as being too expensive. Particularly it became evident that considering deep renovation housing associations are forced to (re)consider how to invest in a more sustainable housing stock. From these case studies it has been derived that retrofitting budgets are falling in the range from €20,000,- to €45,000,- per single-family house. However the solutions provided by transformation concepts exceeds these budgets by far (table 1).
In addition, it was learned that besides the lack of availability of slack resources, some other investment related mechanisms inhibit the adoption of transformation concepts. First, it has to be taken into account that the overall slack resources of a housing association are normally equally divided between the assets and this socially principle inhibits 'extreme investments. Also, the nature of the social housing system enforces housing associations to avoid exceptional investments, in particular projects which are extremely risky and/or result in social inequality. Besides that, it is considered to be more efficient to spread renovation investments in for example the improved of insulation of a large number of dwelling than investing extremely in a small number of dwellings.

***Table 1: Deep renovation investments versus new-build investments (demolition cost and land cost not included)***

| Concept characteristics | Case 1 (De Kroeven, Roosendaal) | Case 2 (Dolomietenlaan, Tilburg) | Case 3 (District for tomorrow, Kerkrade-West) | Case 4 (Presikhaaf, Arhnem) | New-build |
|---|---|---|---|---|---|
| **Energy label (improvement)** | G/F --> A++ | | | | A++ |
| **€/dwelling (case study)** | €90,000,- | | | | |
| **€/dwelling (reference)** | €65,000,- | | | | €81,000 (average social housing market) |

**Series of one –** When a housing association does not own all the housing units within a building block the application of the deep renovation approach discussed in the report is challenging (i.e. the housing association own one or two dwellings within a block). Therefore they cannot benefit from repetition, referred to as the series-of-one problem. In addition, when repetition among the housing units included in the project is low, for example as a result from randomly added extensions, the application of prefabricated façade and roof panels is limited.

## 8.2 Mechanisms affecting adoption by occupants

**Communication -** In contrast to decision making by housing associations a different set of mechanisms affect the adoption of deep renovation by occupants. It was learned that occupants hold a key position in the dual decision-making process. As embedded within the Dutch Civil Code, without confirmation of occupants housing associations are not allowed to proceed with the project. Therefore, derived from all case projects it follows that communication with occupants is considered as one of the most complex parts of the project. In one of the projects included in the case study, communication with occupants was at first a responsibility of the contractor but later on taken over by the housing association. From another case it follows that the housing association used a variety of communication tools to inform occupants about the project. Communication turned out to be challenging while a diversity of ethnicities was involved in the project. The housing associations who participated in the interviews made clear that occupant communication should be regarded as a shared responsibility. Altogether it became eminent that housing associations are struggling with elucidating which factors thrives the adoption by occupants.

**Change agents -** We find strong evidence that the involvement of change agents, opinion leader and reference projects are meaningful tools to persuade occupants. From 'De Kroeven' case it became clear that building upon the early adopters among the occupants could be meaningful in order to convince laggards. It is emphasized that once occupants can experience the end result of the retrofit project it is easier to convince them, in particular because it is hard for inexperienced occupants to imagine how the dwelling will look like after construction. Therefore, reference projects could be helpful in persuading the involved families. However from the same case it became eminent that housing associations should take into account both positive and negative opinion leaders; negative opinion leaders could just have the opposite effect. Several respondents referred to the distrust of occupants about the housing associations intentions and therefore emphasizes the necessity of an independent change agent to persuade occupants. The involvement of independent change agents turned out to be highly successful in the projects incorporated in the case study. These change agent were particular successful in showing the financial effect of the retrofit project while they showed the occupants that despite the rent increase, living expenses decreases in the long run because energy cost diminishes.

**Rent increase and relative advantages -** An investment into deep renovation mostly will result in rent increase and therefore it is particular challenging to convince occupants about the relative advantage. Besides institutional thresholds with respect to rent and rent increase also social-economic threshold need to be taken into account. Particularly during the first deep renovation projects it was challenging to provide insight into 'quality improvement' and therefore it become problematic to justify rent increase. Because it is challenging to persuade occupants to participate in the project rent increase is often postponed until new occupants move into the dwelling as have been referred to in several instances. In several cases housing cost warranties or rent increase conditions were provided by the housing association to justify rent increase, i.e. the warranty ensures a certain living expense threshold based on energy cost reduction. It was also found that it is particularly hard to convince occupants who lives in low quality housing characterized by a low book value and a relatively low rent. These group of occupants are less willing to accept a severe rent increase. Thus, occupants tend to accept rent increase only if living conditions (comfort level) drastically improves but rent increase should be kept to a minimum level in order to persuade occupants of deep renovation.

**Living conditions and inconvenience during construction -** Two important prerequisites for adoption by occupants were found in the case studies; the level of inconvenience occupants face and the improvement of living conditions. The former have been addressed by both solution providers as housing associations while the latter have not yet been sufficiently taken into account by the deep renovation market. Construction work on site need to be kept on a minimum level in order to diminish the level of inconvenience. The level of inconvenience predominately depends on the nature of the construction work ranging from replacing single building components and elements up to replacing the complete building façade. Therefore construction on site should follow the principle of just-in-time assembly in order to limit lead time of construction. In this respect it turned out that it is important to avoid any construction work delays. Furthermore, several technological developments has resulted in a further reduction of labour inside the dwelling by means of including ducts and HVAC services within the prefabricated elements of the building façade. Also one should take into account that moving occupants to temporary accommodation is not considered to be desirable or pleasant.

Thus, during construction a certain level of privacy need to be ensured. It was also learned from that solving deficiencies and improving indoor climate problems, and thus reducing daily inconveniences, could provide meaningful arguments to persuade occupants.

The ‘Stroomversnelling’ renovation standard included in this multiple case study predominately focus on improving the building envelope and improving indoor climate while neglecting other aspects of the living conditions. Put it differently, the ‘Stroomversnelling’ standard focuses on the building exterior while neglecting the replacement of the often outdated, kitchen and bathroom and thus neglecting comfort level improvement as being perceived by occupants. Particularly it became eminent that these aspect are considered as more important than the energy efficiency improvements and thus provide both contractors and housing associations an important mechanism to persuade occupants. The lack of interest for energy efficiency improvements also result from the unawareness of effect energy costs on living expenses and the impact of energy efficiency measures on living expense reduction. This final causal mechanism does not apply in case 3 while the entire dwelling, and thus also the kitchen and bathroom, was replaced

## REFERENCES

References will be included here.

## APPENDIX A: CASE STUDY 5 2X 16 APARTMENTS, NIEUWKUIJK

### General project description

Passive house renovation two apartment blocks, Nieuwkuijk, The Netherlands:

PROJECT CHARACTERISTICS
Owner:
Housing association (Woonveste)
Architect:
KOW Architectuur Eindhoven
Consultant:
BuildDesk Benelux
Contractor
De Bonth van Hulten (Volker Wessels)
Key suppliers:
De Bonth van Hulten (Volker Wessels); Van Delftgroep
Location:
Acacia- and Magnoliastraat, Nieuwkuijk (NL)
Number of housing units:
2x16 apartment blocks
Under construction:
2010-2011

KEY TECHNOLOGIES

- Facade insulation with stucco
- Triple glazed windows
- Heat recovery ventilation
- Condensing gas boiler

Woonveste is a social housing corporation operating in the region Heusden, Haaren and 's-Hertogenbosch. They offer a wide variety of affordable housing with a total number of 5,500 housing units. The housing corporation decided to renovate 2 apartment buildings, constructed in 1970, consisting of 8 apartments each with an energy label F. This included the extension of the double room apartments from 47 m2 to 57 m2 and the extension of the 3-room apartments from 57 m2 to 67 m2. These apartment buildings were selected as a pilot in order to assess the feasibility to upgrade existing buildings towards nZEB (energy label A+, passive house level). From this pilot project Woonveste learned in which technologies to invest, how to organize the project and which conditions determine or a building is suitable to be renovated towards zero energy. Woonveste selected Nieuwkuijk as a pilot project because these building blocks were relatively small with a total 16 dwelling units (47-57m2). Next, there was almost no cavity wall insulation, single glazing, and an uninsulated roof. However, there were a number of points of concern. In order to insulate the ground floor het the crawl space need to be high enough. Further, the orientation of the living room should preferably be southern oriented.


Front and back façade of the apartment buildings before the renovation


The apartment buildings after renovation


Artist impression of the apartment buildings after renovation.

DESIGN DATA (before renovation)
Number of housing units [#]: 16
Heated floor area [m2]: 47-57
Energy consumption (heating + DHW) per housing unit per year [kWh]: xx (xx kWh/m2)
Air tightness qv;10 [dm3/s] per m2 floor space: xx
Installed heating capacity per housing unit [kW]: xx (xxW/m2)
Electricity consumption per housing unit per year (excl. heating) [kWh/y]: xx (xxkWh/m2)

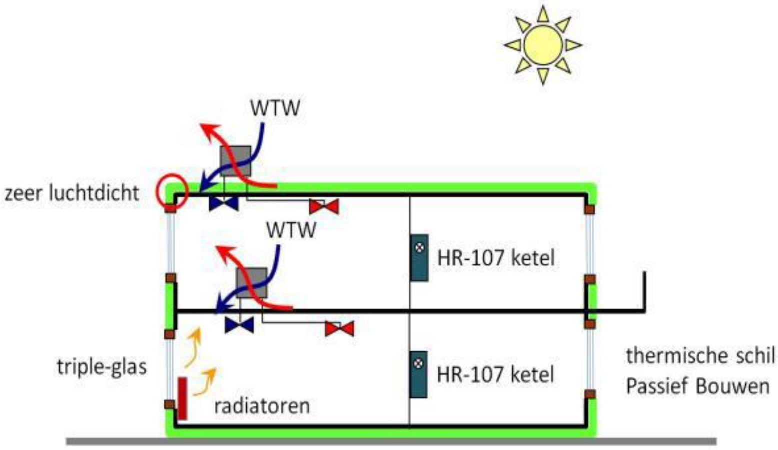
**Renovation concept and notable features**

Characteristics Retrofit projects:

| | | | | | | |
|---|---|---|---|---|---|---|
| | Thermal insulation:<br>-Roof<br>-Facade<br>-Floor/foundation | Rc 1,0 – 2,5<br>○<br>○<br>○ | Rc 2,5 – 4,0<br>○<br>○<br>○ | Rc 4,0 – 5,5<br>○<br>○<br>○ | Rc 5,5 – 7,0<br>○<br>○<br>○ | Rc 7,0 – 12,0<br>●<br>●<br>● |
| | Measures airtightness | Present ● | Not present ○ | | | |
| | Glazing | Double ○ | Triple ● | | | |
| | PV panels (m2 PV / dwelling) | 10 - 15 ○ | 15 - 20 ○ | 20 - 30 ○ | 30 - 40 ○ | >40 ○ |
| | Heating | Gas-fired boiler (HR-107) ● | Heat pump (water) ○ | Heat pump (air) ○ | Hybrid ○ | External source ○ |
| | Domestic hot water | Gas-fired boiler (HR-107) ● | Heat pump ○ | External source ○ | Shower heat recovery ○ | Thermal solar boiler ○ |
| | Ventilation system | Natural (C) ○ | Natural-controlled (C+) ○ | Mechanical (D) ● | Mechanical-controlled (D+) ○ | |
| | Energy supply | Gas + Electric ● | Electric ○ | External source (district heating) ○ | None (all-electric) ○ | |

According to the renovation guidelines of the PassiefBouwen Foundation (NL), the two apartment blocks have been designed and technically developed into full-bodied Passive houses. In order to make the apartments future-proof, the entrees and loggias / balconies are incorporated into the indoor floor plan. The façade openings have been replaced by a combination of insulated wood on the inside with an aluminum outer shell and are fitted with 3-fold glazing. The complete building façade have been insulated with a high insulation package and the cold bridges are minimized in the design. For the climate system has been chosen for a conventional (HR107) gas condensing boiler with only one centrally positioned radiator combined with a balanced ventilation system with heat recovery.

Demolition of parts of the façade and extension of the apartment block by incorporating the former entrees and loggias / balconies.




Conceptual design of the renovation of both apartment buildings

DESIGN DATA (after renovation)
Number of housing units [#]: 16
Heated floor area [m2]: 57-67
Energy consumption (heating + DHW) per housing unit per year [kWh]: 3900 (63kWh/m2)
Air tightness qv;10 [dm3/s] per m2 floor space: 0,25
Installed heating capacity per housing unit [kW]: - (-W/m2)
Electricity consumption per housing unit per year (excl. heating) [kWh/y]: - (-kWh/m2)
Rent [€]: 500
Rent increase per month [€]: 150
Reduction energy costs per year [€]: 50 (gas)

### Energy related Indicators

The energy consumption of the houses is expected to change significantly. Space heating demand will reduce to a calculated figure of below 25 kWh/(m²·y).

Key technologies:

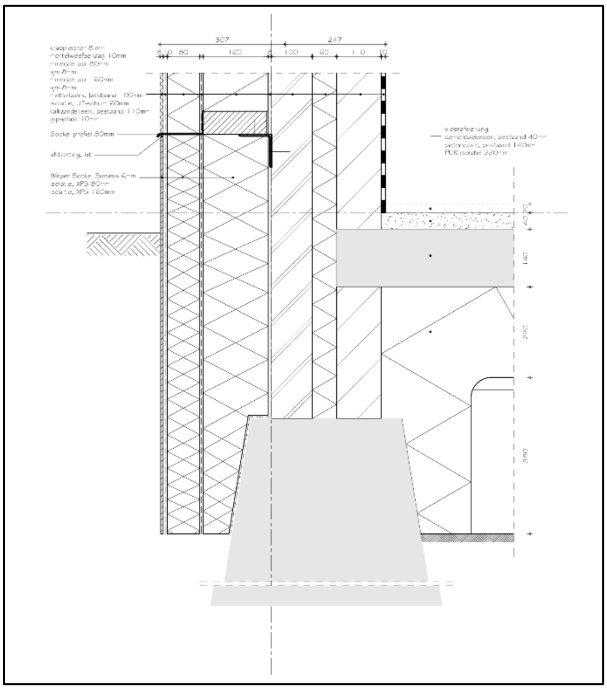
- Passive house insulation (EPS)
- Triple glazed windows
- Heat recovery ventilation
- Condensing gas boiler

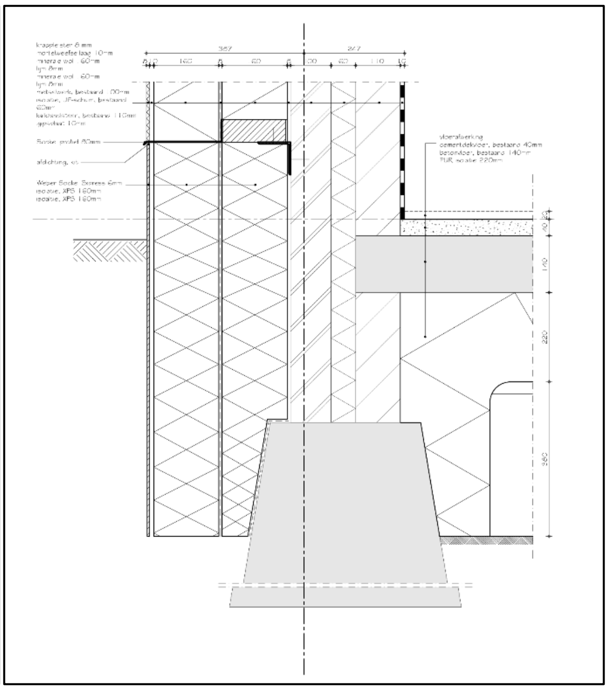
At completion of the renovation works blower door tests have been made resulting in an airtightness figure of below 1.0 air changes per hour at 50 Pa. Infrared imaging of the units did not show any anomalies.

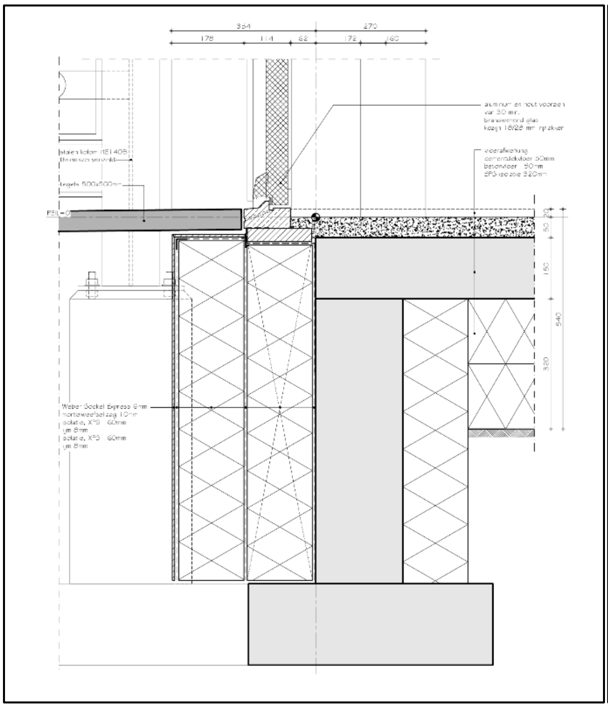
### Technological design - retrofit design details

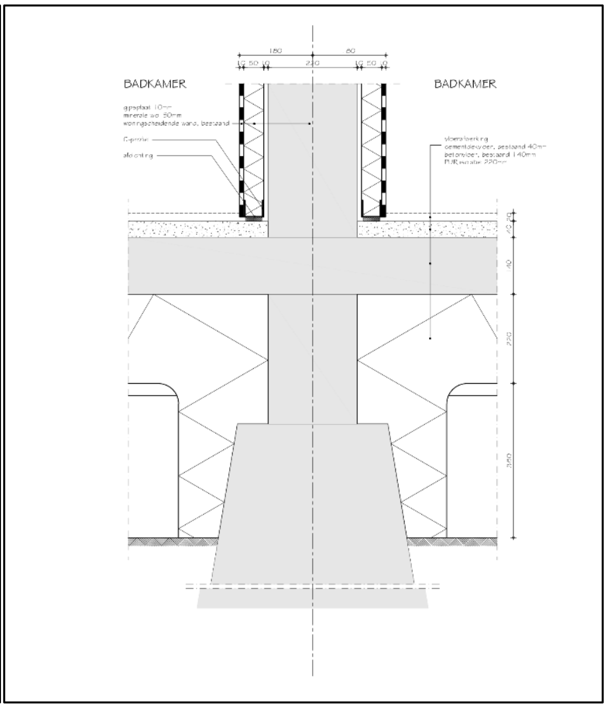
### Building envelope

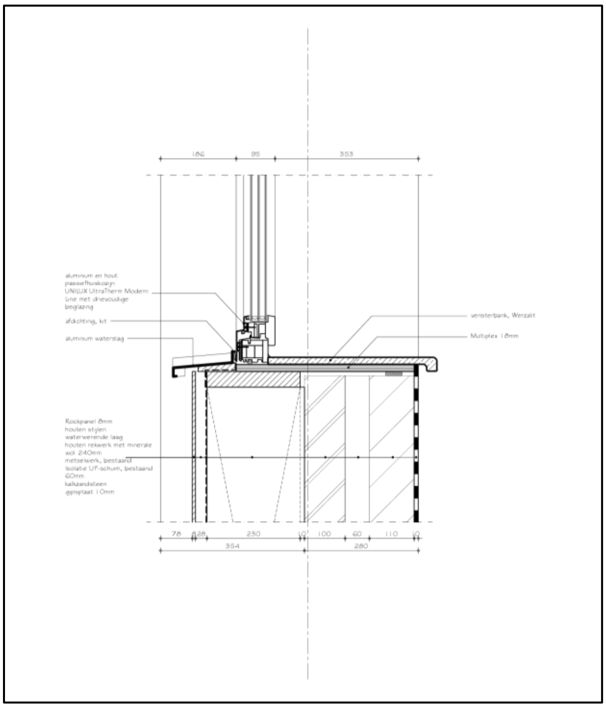
Only the window frames were removed at the beginning of the project and structural alterations have been made to include the balconies in the floor plan . The next step was to install new window frames. Finally, the apartment blocks were completely insulated and plastered. The design details are included below.

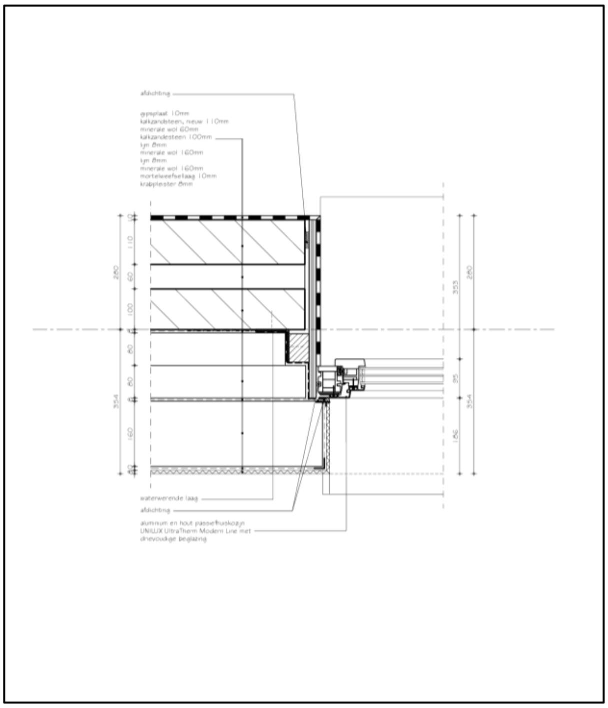


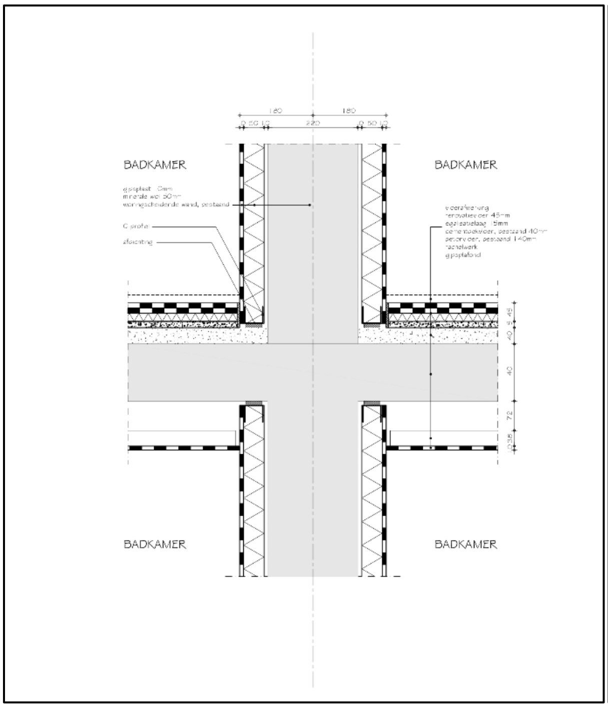



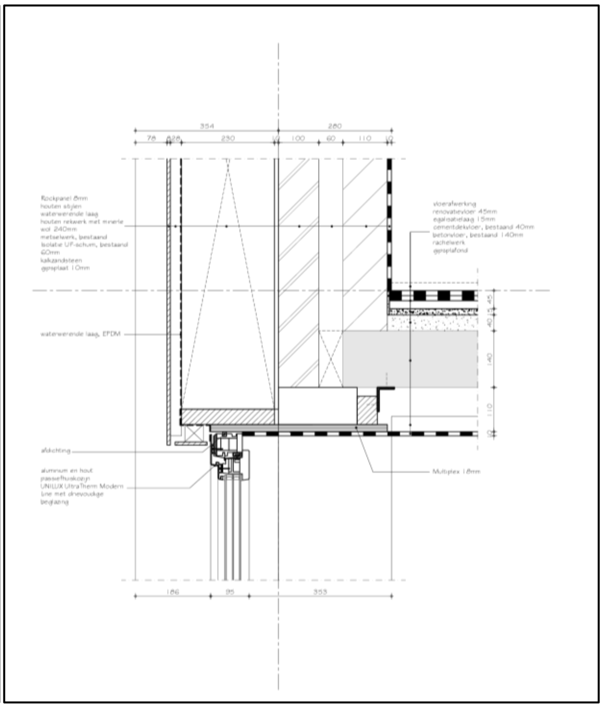


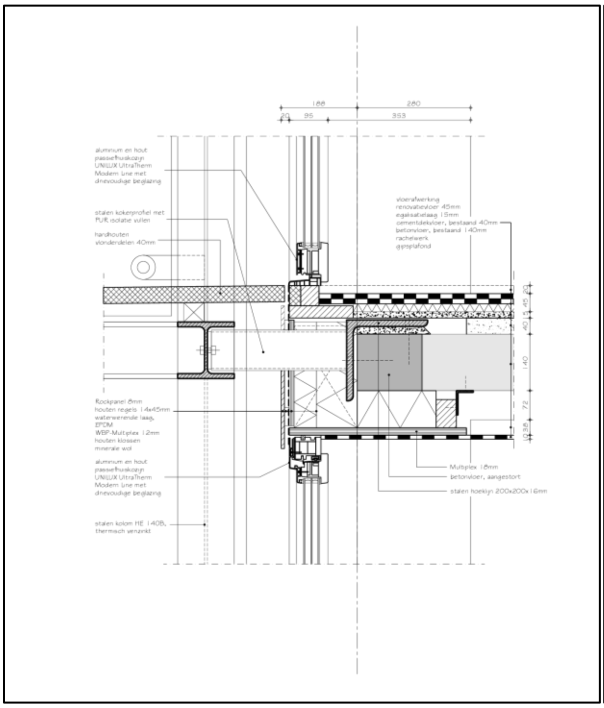

BADKAMER
BADKAMER

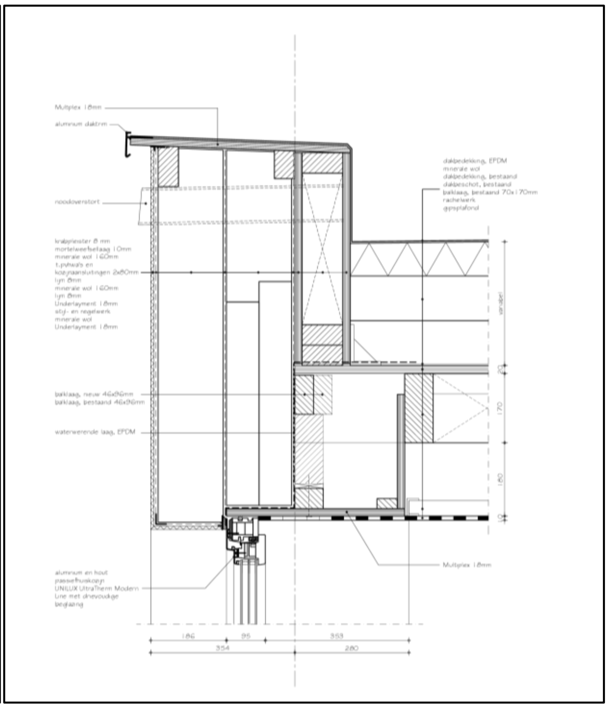


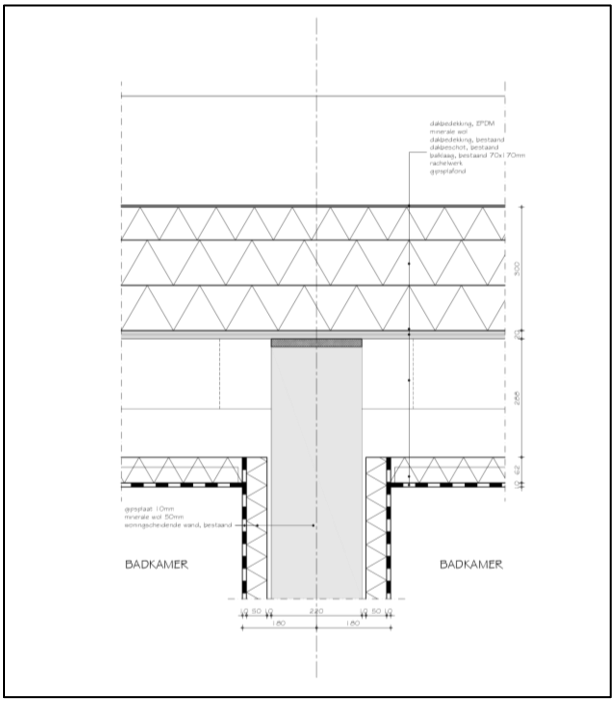



BADKAMER
BADKAMER
C-profiel
vloerafwerking
renovatievloer 45mm
egalisatielaag 15mm
rachelwerk
gipsplafond
BADKAMER
BADKAMER


Rockpanel 8mm
houten stijlen
waterwerende laag
houten rekwerk met minerle wol 240mm
metselwerk, bestaand
Isolatie UF-schuim, bestaand 60mm
kalkzandsteen
gipsplaat 10mm
vloerafwerking
renovatievloer 45mm
egalisatielaag 15mm
cementdekvloer, bestaand 40mm
betonvloer, bestaand 140mm
rachelwerk
gipsplafond
waterwerende laag, EPDM
afdichting
aluminium en hout passiefhuiskozijn UNILUX UltraTherm Modern Line met drievoudige beglazing
Multiplex 18mm


aluminium en hout passiefhuiskozijn UNILUX UltraTherm Modern Line met drievoudige beglazing
stalen kokerprofiel met PUR isolatie vullen
hardhouten vlonderdelen 40mm
vloerafwerking
renovatievloer 45mm
egalisatielaag 15mm
cementdekvloer, bestaand 40mm
betonvloer, bestaand 140mm
rachelwerk
gipsplafond
Rockpanel 8mm
houten regels 14x45mm
waterwerende laag, EPDM
WBP-Multiplex 12mm
houten klossen
minerale wol
aluminium en hout passiefhuiskozijn UNILUX UltraTherm Modern Line met drievoudige beglazing
Multiplex 18mm
betonvloer, aangestort
stalen hoeklijn 200x200x16mm
stalen kolom HE 140B, thermisch verzinkt


Multiplex 18mm
aluminium daktrim
dakbedekking, EPDM
minerale wol
dakbedekking, bestaand
dakbeschot, bestaand
balklaag, bestaand 70x170mm
rachelwerk
gipsplafond
noodoverstort
Underlayment 18mm
minerale wol
Underlayment 18mm
balklaag, nieuw 46x96mm
balklaag, bestaand 46x96mm
waterwerende laag, EPDM
Multiplex 18mm
aluminium en hout passiefhuiskozijn UNILUX UltraTherm Modern Line met drievoudige beglazing




### Construction process

After the former residents moved out, in October 2010 the deep renovation of the apartments started with the demolition of the interior and parts of the façade. Next, structural changes were made to include the entrees and loggias / balconies in the floor plan. After installing the window frames it have been assured that the connections were airtight. Subsequently, the interior construction took place and the blocks were completely insulated and plastered. Finally, the steel constructions of the entrances and balconies are placed on the facade and thus outside the thermal shell and are fitted with structural glazing attached with stainless steel rosettes.

### Business case – renovation costs

### Renovation costs

Compared to normal renovation costs for these fairly typical house types, the renovation to passive house level requires an additional investment of around € 25,000 per house. In Roosendaal, both an on-site external insulation concept and the prefab concept have been done at 112 and 134 houses. The prefab approach in this case turned out to be slightly cheaper. Also the renovation process is faster, and thus less intrusive to tenants. The tenants benefit by a lower heating bill, which in future is less sensitive to energy price increases.

The building owner has accepted a rent increase of € 65 per month, which equals the calculated energy saving at current energy prices. The owners has guaranteed that the cost of living for tenants will not increase. Added values are the long life time of the prefab renovation concept and in future the building owner may also expect a higher property value on the market.

**Deep renovation cost:**

| | |
|---|---|
| **Inducement renovation** | - |
| **Housing typology** | Apartment building |
| **Year of construction** | 1970 |
| **Number of housing units before/after** | 16/16 |
| **Rent before/ after [monthly]** | €350,- / €500,- |
| **Energy label (NL) before/after** | D/A++ |
| **Under construction** | 2010-2011 |
| **Investment installation per dwelling (total)** | €- |
| **Housing unit internally per dwelling** | €- |
| **Envelope housing unit per dwelling** | €- |
| **Cost outdoor per dwelling** | €- |
| **Additional (organizational) cost per dwelling** | €- |
| **Total investment per dwelling** | €100.000,- |

## APPENDIX B: OVERVIEW STATE-OF-THE-ART DEEP-RETROFITTING PROJECT ACROSS EUROPE

***An extensive overviewed has been prepared for the Pro-GET-onE project (Proactive synergy of inteGrated Efficient Technologies on buildings' Envelopes) - https://www.progetone.eu/project/***

| **Funding Scheme** | **Project Name** | **Solutions** |
|---|---|---|
| FP7 | A2PBEER (2013-2017) www.a2pbeer.eu/ | Retrofitting methodology for public buildings including existing available and newly developed innovative solutions. |
| H2020 | ABRACADABRA (2016-2019) http://www.abracadabra-project.eu/ | Renovation strategy coupling AdoRe, Assistant Building unit(s) – like aside or façade addictions, rooftop extensions or new building construction, with a densification retrofit policy |
| FP7 | ADAPTIWALL (2013-2017) www.adaptiwall.eu/ | Nanotechnology-based, multi-functional and climate-adaptive panels consisting of 3 elements: lightweight concrete with nano-additives for efficient thermal storage and load bearing capacity; adaptable polymer materials for switchable thermal resistance; and total heat exchanger with nanostructured membrane for temperature, moisture, and anti-bacterial control. |
| H2020 | BERTIM (2015-2019) www.bertim.eu/ | High energy performance timber prefabricated modules, atool for mass manufacturing and holistic methodologies for the renovation process, from data collecting to installation. |
| H2020 | BRESAER (2015-2019) http://www.bresaer.eu/ | Coupled cost-effective, adaptable, low-intrusive and industrialized envelope (for façades and roofs) with an innovative Building Energy Management System |
| FP7 | CETIEB (2011-2014) http://www.cetieb.eu/SitePages/Home.aspx | Monitoring, control systems and modeling tools of retrofitted indoor environments. |
| H2020 | E2VENT (2015-2018) www.e2vent.eu/ | Systemic retrofit solution including theuse of ventilated façade system, heat recovery units, photovoltaic cells, natural lighting and envelope insulation strategies. |
| FP7 | EASEE (2011-2014) www.easee-project.eu/ | Toolkit for envelope retrofit in existing multi-storey and multi-owner buildings combined with novel design and assessment strategies, with scaffolding-free installation approaches. |
| H2020 | EENSULATE (2016-2020) http://www.eensulate.eu/ | Curtain wall system with lightweight (35% weight reduction) and highly insulating energy efficient glass modular components |
| H2020 | IMPRESS (2015-2018) www.project-impress.eu/ | Pre-fabricated retrofitting modules supported by a BIM based Iterative Design Methodology (IDM) |
| H2020 | INSITER (2014-2018) www.insiter-project.eu/ | Intuitive self-inspection techniques using augmented reality for construction, refurbishment and maintenance of energy-efficient buildings made of prefabricated components |
| FP7 | iNSPiRe (2012-2016) www.inspirefp7.eu/ | Systemic renovation packages for residential and tertiary buildings |
| FP7 | MeeFS (2012-2016) http://www.meefs-retrofitting.eu/ | Multifunctional energy efficient facade system for residential buildings' retrofits |
| H2020 | MORE-CONNECT (2014-2018) www.more-connect.eu/ | Prefabricated, multifunctional renovation elements for the total building envelope (façade and roof) and installation/building services. |

| | | |
|---|---|---|
| H2020 | NewTREND (2015- 2018) http://newtrend-project.eu/ | Integrated design methods |
| IEE | NeZeR (2014-2017) http://www.nezer-project.eu/ | Smart and integrated NZEB renovation measures for nZEB |
| H2020 | P2Endure (2016-2020) https://www.p2endure-project.eu/en | Prefabricated Plug-and-Play (PnP) systems enabled by 3D printing, laserand thermal scanning integrated with Building Information Model (BIM) for deep renovation of building envelopes and technical systems. |
| H2020 | REFURB (2015-2018) http://go-refurb.eu/ | One-stop-shop model for energy renovations |
| H2020 | REnnovates (2015-2018) www.rennovates.eu | Smart services, technical solutions, energy-based communities |
| FP7 | RetroKit (2012-2016) www.retrokitproject.eu | Multifunctional, modular, low cost and easy to install prefabricated modules |
| H2020 | TransitionZero (2016-2018) http://transition-zero.eu/ | Net zero refurbishment solutions integrating standardized design of pre-fabricated technological modules and mass-production with innovative business case for housing associations |
| IEE | ZEBRA 2020 (2014-2016) http://zebra2020.eu/ | Monitoring system of market uptake of refurbished nZEB including data collection and recommendations |
| H2020 | Pro-GET-onE (2017-2021) https://www.progetone.eu/project/ | ProGETonE develops and proves an integrated approach to tackle two important needs in existing buildings: safety upgrades to face future earthquakes in seismic zones and nearly zero energy consumption to be aligned with EU climate change reduction targets |