Eindhoven University of Technology

MASTER

Towards low energy renovation of a post-war multi-family housing
the Dudokhaken as case study

Sánchez de la Garza, S.K.

Award date:
2015

TOWARDS LOW ENERGY RENOVATION OF A POST-WAR MULTI-FAMILY HOUSING

THE DUDOKHAKEN AS CASE STUDY

S.K. Sánchez de la Garza
August 2015

TOWARDS LOW ENERGY RENOVATION OF A POST-WAR MULTI-FAMILY HOUSING

THE DUDOKHAKEN AS CASE STUDY

Author: S.K. Sánchez de la Garza
ID-number: 0870194
27th of August of 2015

Graduation Supervision Committee:
Dr. A.R. Pereira Roders
Ir. L.C. Havinga
Ir. R.C. Verbruggen
Prof. dr. B.J.F. Colenbrander
Dr. ir. H.L. Schellen

Master Degree: Architecture, Building & Planning
Graduation studio: ~~Un~~sustainable historical buildings?
Units: Architectural Urban Design and Eingineering (AUDE)
and Building Physics & Services (BPS)
Department of the Built Environment
Eindhoven University of Technology

SUMMARY

The Netherlands is aiming to reduce by 40% the CO2 emissions by 2025 (RVO, 2014) by implementing several initiatives to the new built environment. However, most of the initiatives disregard the existing building stock. There is a need for creative solutions in order to compile conservation with new functions to turn heritage into an advantage for the society thus promoting a sustainable development (Tomback, et at., 2013).

The awareness to preserve existing buildings has led to monitor them to provide energy improvements through renovation (Meijer, Itard, & Sunikka-Blank, 2009) or adopt the use of innovative systems (Hoppe, 2012). Decision-making tools strive for the best and most profitable solution when renovating (Troi & Bastian, 2015; Mjörnell, Boss, Lindahl, & Molnar, 2014), while the development of a pre-fabricated envelope (CCEM, 2011) and the use of passive strategies (Moran, Blight, Natarajan, & Shea, 2014) aim for an energetic upgrade.

As historical buildings demand the preservation of heritage values worth preserving some authors attempt for a balance between the energy performance and their heritage value drawing the attention towards the former (Grytli, Kvaerness, Rokseth, & Ygre, 2012; Enriquez Reinberg & Reinberg, 2010; Cecchini, Cimini, & Morleo, 2014). There are a few methodologies which consider the heritage values and the energy performance upgrade, by using a LCA assessment (Grytli, Kværness, Sve Rokseth, & Fines Ygr, 2014), identifying their compatibility on different scenarios (Troi & Bastian, 2015; Polo López & Frontini, 2014) and presenting a heritage balancing process for their retrofit (Eriksson, Hermann, Hrabovszky-Horváth, & Rodwell, 2014). There should be a balance between: heritage preservation, cost-effective energy technologies, and human comfort (Fouseki & Cassar, 2014)

The main aim of this research is to understand the impact of an intervention on the historical values and the energy performance of the case study. It seeks the balance between them by trying to achieve a low-energy renovation without affecting its historical values.

The methodology answers a main question, which is determined by the following sub-questions:

- SQ1. What are the historical values of a building?

Identify the heritage value of the case study and why it is important (Icomos, 2014), by a documental research followed by a survey to identify the attributes of the building (Silva & Pereira Roders, 2012). Furthermore, the attributes are identified within the case study, to finalize with a heritage significance assessment rating given to the each attributes in order to classify them (Eriksson, Hermann, Hrabovszky-Horváth, & Rodwell, 2014; Icomos, 2014).

- SQ2. What is the impact on the heritage value of a building when an intervention occurs?

Determine the heritage impact assess of the current situation and future interventions, defined during this step. A scale of impact is given to each intervention by comparing it against the attributes that may be affected (Eriksson, Hermann, Hrabovszky-Horváth, & Rodwell, 2014; Icomos, 2014; Silva & Pereira Roders, 2012).

- SQ3. What is the energy performance and saving potential of possible interventions?

Identify the energy performance of the current situation, as well as the saving potential of possible interventions by comparing them against the original and current situation.

- MQ. Until what extent interventions can be implemented achieving energy saving without affecting the historical value of a building?

Comparative analysis of each intervention regarding its historical value and energy saving potential to implement design strategies of three cases, the energy efficient case, a conservation case and a balance between both aspects, to compare them against the pre-case and base-case.

The results during this research are divided by sub-question:

- SQ1 - The significance assessment showed that the urban scale has the highest ranking, while the typology and elements seem to be more valuable in comparison with all the primary values against its own scale. The attributes along with their primary values were identified, being the urban structure; strip, hooks and courts; the translations of the urban the structure into the architecture and the facade the most valuable attributes related to the case study.
- SQ2 - The interventions that are exposed towards the exterior received higher HI. The typology is usually affected the most and the overall impact per intervention is less than 2.
- SQ3 – The ENH reduction compare to the Pre-case shows that a reduction of around 50% is possible when using internal/external insulation, followed by the solar collector. The Base-case shows that almost 100% reduction is possible when placing solar collector.
- Comparative Analysis – Within the case study it is shown that the implementation of internal interventions reduces significantly the space heating demands without having a heritage impact. The comparative analysis led to three solutions for a balanced renovation. The criteria for choosing the interventions were based on the maximum energy reduction and minimum impact in the historical values.
- MQ - The optimization of the envelope of the case study has been proven to reduce more ENH while introduction higher HI. However, the balance 1 shows a reduction of almost 100% presenting more HI than the Base-case.

The main findings:

- The ENH reduction by single interventions achieved from 10% to more than 40% compare to the Pre-case and between 5% to more than 20% compare to the Base-case.
- Energy reduction does not imply heritage impact. However, the interventions with the highest reductions are shown to have more heritage impact. Nevertheless, solutions can be found in order to mitigate the impact.
- The renovation of a historical building is shown to demand for tailored and individual solution since the integrity of the historical value of the building should be preserve.

It is concluded that a renovation should not be considered a single intervention, in order for a building to reduce at its maximum the energy consumption. A holistic planning should be considered where different interventions are incorporated. Historical buildings are valuable for their uniqueness, thus demanding for tailored and individual solutions. The extent of interventions to be implemented depends on its historical value, since some of the interventions proposed during this research could be restricted in other cases. However, the methodology can be applied to different case studies as a decision-making tool that takes into account energy savings and the heritage impact on the buildings. Moreover, the economic implications should also be integrated into the proposed interventions and be compared to the heritage impact and energy saving potential. The social aspect should also be taken into count in order to provide a holistic approach that balances all the aspects of sustainability.

Keywords: low-energy, energy performance, post-war building, heritage impact, heritage assessment, balance renovation.

ACKNOWLEDGEMENT

This research project was possible by the funding received from *Rijksdienst voor het Cultureel Erfgoed* [Dutch Cultural Heritage Agency], RCE.

First of all, I would like to express my sincere gratitude for their guidance and supervision during this project to dr. ir. A.R. Pereira Roders, ir. L.C. Havinga, ir. R.C. Verbruggen, Prof. dr. B.J.F. Colenbrander and dr. ir. H.L. Schellen. They all contributed greatly into this research for their motivation, continuous support and immense knowledge within the different fields.

I thank my fellow students of the Graduation studio ~~Un~~sustainable Historical Buildings?, for the discussions, reflections, feedback and moral support through this studio.

Moreover, I would like express my gratitude to the Mexican National Council for Science and Technology (CONACYT) for financing my master studies.

And last but not the least; I would like to thank my parents, Rafael and Sandra, for their unconditional love and support in every step I have taken; to my siblings, Karla and Braulio for their motivation and moral support throughout these years. To all the people that have been supportive in Eindhoven and from Mexico, to my friends and family that accompanied me during this whole process. In particular, I am grateful to Stefanos.

TABLE OF CONTENT

1 RESEARCH DESCRIPTION

1.1 INTRODUCTION

The built environment is responsible for one third of the global energy consumption and one third of the CO2 emissions (IEA, 2013). Policies have changed through the years in order to diminish these emissions and reduce the energy consumption of the buildings. The Netherlands, as part of the European Union, is aiming to reduce by 40% the CO2 emissions by 2025 (RVO, 2014). Towards its accomplishment, several initiatives have started in order to achieve a more efficient new built environment. However, most of the initiatives do not consider the renovation of the existing building stock.

Creative solutions should be deployed in order to combine conservation of heritage with new functions. These solutions should be driven by both heritage historical value and need for more energy efficient buildings, while promoting sustainable developments. The historical value of a building creates a sense of place within the community and it is what people value the most because of its historical character and uniqueness (Tomback, et al., 2013).

This study contributes to the second phase of the graduation studio ~~Un~~sustainable Historical Buildings? As a consequence of the macro research developed during the first phase of the studio, with Amsterdam as case study. Within this research, the Dudokhaken is studied. It is located in the district of New-west, in Amsterdam. The research's main goal is the understanding of the impact of an intervention in the historical value and the energy performance. The optimum is the minimization of the impact in the historical value and maximization of the energy efficiency.

1.2 PROBLEM DESCRIPTION

The Netherlands aim to reduce the CO2 emission by 40% by 2025. In order to reach the goal from 2020, all new buildings must be nearly energy zero (RVO, 2014). Currently, the renovation projects are not considered within these measures because the energy efficiency legislation was applied after 1975 (Hoppe, 2012). In Europe, the 75% of the existing building stock will be standing in 2050 (IEA, 2013). Within the city of Amsterdam, 62% of the current dwelling stock was built before 1970 and 53% in the New West district (O+S, 2014). For this reason, there is an urgent need of upgrading the current stock in order to meet with the national and municipal energetic goals.

New West district as part of the AUP and Post-AUP area was part of the extension urban plan of the West of Amsterdam after the Second World War. The expansion plan was mainly due to a shortage of dwellings which needed to be addressed briefly. The district of New West is part of the 'Western Garden Cities' (*Westelijke Tuinsteden)*. Since 2013, it is regarded as a post-war area of national importance selected by the *Rijksdienst voor het Cultureel Erfgoed (RCE)*. This is due to the fact that this period is considered an innovative period regarding the materials and construction methods used *(Blom, Jansen, & Heide, 2004).* The principles of design behind the Western Garden Cities were mainly "Air, Light and Space", which led to the construction of low and high-rise building surrounded by green areas (CWM, 2013).

In spite of the importance of the post-war areas, the buildings do not meet current standards, especially the housing units, due to their inadequate size in comparison with today's demand (Sabaté Bel, J., & Galindo, J., 2000) and because they are highly energy inefficient. For this reason during the 90's part of the post-war area buildings were undergone renovations and large-scale demolitions. Later on, from 2002 to 2008, an urban regeneration of the area lead to large-scale demolitions and highly dense new building constructions, in order to increase the quality and quantity of the dwellings within the area. Lastly, due to the economic crisis and to agreements between the City council and corporations the search for new means or regeneration of the area has tackled the problem by small-scale renovations, rather than large-scale, which would lead to a more suitable approach (Van Agtmaal, Bosch, Dubbeldarn, De Heus, & Somé, 2013).

Most of the renovations undergone in these areas seek energy efficiency or merely design spaces that meet the requirements of the current users without considering the heritage value of these buildings. The main issue is the lack of knowledge regarding the heritage value of the buildings. Moreover, there is the need of a more active role of the heritage professionals in the renovations of valuable buildings (Fouseki & Cassar, 2014).

1.3 STATE OF THE ART

The awareness to preserve existing buildings rather than demolish them has increased during the latest years, leading to the renovation of existing buildings around the world. During this century researchers try to convince and emphasize the importance of our heritage building, by questioning the demolitions against renovations. The latter has been proven to be more environmental friendly since it reduces demolition waste, which has a negative impact in the environmental (Thomsen & Van der Flier, 2009). The renovation of an existing building is always more challenging than the construction of a new building. Nevertheless, it presents more opportunities in the long term (Ma, Cooper, Daly, & Ledo, 2012). It has been proven that a careful renovation of an existing buildings can have more environmental beneficial and can improve their performance as the current performance of new buildings (Power, 2008).

Some of the disregarded opinions concerning the renovations of existing buildings are due to the lack of knowledge on how to find the best and more profitable solution. Hence, decision-making tools have been developed. In Sweden a methodology based on an LCA tool was developed which aim to compare up to ten different alternatives from an environmental perspective (Mjörnell, Boss, Lindahl, & Molnar, 2014).

Studies have also focused on determine the quality of the existing buildings stock in order to provide possible energy improvements through renovation. Some of the obstacles identified are the lack of knowledge regarding the cost-benefit of a renovation and the lack of monitoring the physical state of the existing building stock (Meijer, Itard, & Sunikka-Blank, 2009). Moreover, there is mistrust in the adoption of innovative systems when renovating and conventional measures were preferred. Within the Netherlands this practice is not common and it is mainly adopted in new constructions (Hoppe, 2012).

There is an increased concerned in the retrofit of existing buildings, however, the rate of renovation of existing buildings is still low (Ma, Cooper, Daly, & Ledo, 2012). A state-of-the-art regarding the retrofits done to different buildings shows that different measures are use in order to save energy consumption, such as improvements on the envelope, the systems or by implementing solar systems. The energy reduction achieved was between the 10% and 64.9% from different case studies (Ma, Cooper, Daly, & Ledo, 2012). Moreover, a pre-fabricated enveloped was developed, that allowed reductions of 80 to 90% of energy consumption. Being its main advantage the fast installation and renovation process (CCEM, 2011). Others have applied retrofit packages with passive strategies with between 54% until 85% reduction of the primary energy use (Moran, Blight, Natarajan, & Shea, 2014).

The energy performance assessment of historical buildings is as well an important topic in today's research. The assessment of the materials used in historical buildings and the reaction to current climate changes are important issues to assess before providing a renovation solution. It has been acknowledged the durability of materials in old buildings which has led to its preservation (Ipekoglu, Boke, & Cizer, 2007). Due to the uniqueness of highly valuable building certain components are require to be preserved, such as exterior walls. The CCEM-SuRHIB focuses on non-protected historical buildings and developed a highly insulating plaster for inside insulation, a highly moisture tolerant and provided guidelines for low energy systems as well as solar systems integration within these buildings (CCEM & SuRHiB, 2012).

"There is a demand for a model/guidance on how energy efficiency can be managed without negative impact on the cultural and historical values in our heritage" (Norrström & Edén, 2009). Following the statement of the previous author, other studies claimed to provide a solution to a balance between the energy performance of historical buildings and the preservation of its heritage value. However, they

tend to some extent to focus on the energy performance without a final heritage impact assessment (Grytli, Kvaerness, Rokseth, & Ygre, 2012). At the same time, they opt for a passive renovation in which the façade is preserved (Enriquez Reinberg & Reinberg, 2010). However the lack of a heritage assessment may lead to the loss of some important features not considered during the renovation proposal. Moreover, some authors defined the interventions by providing *"progressive steps of interventions"* following three approaches: recovery, refurbishment and energy retrofit. The outcome is a design tool and methodology which proved a reduction of 40% energy consumption with passive strategies, consequently the implementation of active strategies, such as solar systems would allow a higher energy reduction (Cecchini, Cimini, & Morleo, 2014)

The lack of a heritage assessment is due to the fact that the current valuations do not deal with usability or sustainability. At the same time, they are merely documentary regarding the historical which could lead to the misinterpretation during the design phase (Franken & Meijer, 2013). Therefore there is a lack of comprehensive analysis regarding its history, heritage as well as the monitoring of the historical buildings (Troi & Bastian, 2015)

There are a few methodologies or tools which certainly take into account the heritage values of historical buildings and try to upgrade its energy performance, mostly developed during the past year. One of them aims for a holistic environmental assessment in which the heritage impact and environmental impact is compared against a LCA assessment. It was found a contradictory relationship between heritage and energy from which only passive strategies do not affect the heritage values of the building (Grytli, Kværness, Sve Rokseth, & Fines Ygr, 2014). The 3ENCULT, studied a process in which both the cultural and energy matters of the building are taken into account. It aims to identify different scenarios which should be evaluated by a multidisciplinary team with the purpose to aid as a decision-making tool. The different solutions are parallel qualified against its saving potential and cultural heritage compatibility (Troi & Bastian, 2015). Additionally, the EnBAU provides a methodology in which each building element is given a value regarding its historical value, preservation state and energy efficiency. The sum of the different elements provides an overview of the benefits of each solution (Polo López & Frontini, 2014). Lastly, the EFFESUS methodology is an undergoing project which will lead to a software tool to support decision-making on the retrofit of historical urban districts. It is divided by modules, being the heritage significance one of them. It is divided into three parts: the heritage significance evaluation, the heritage impact definitions and the heritage balancing process in which the different solutions are evaluate and consider being from acceptable to non-acceptable depending on their heritage significance (Eriksson, Hermann, Hrabovszky-Horváth, & Rodwell, 2014).

The state-of-the-art regarding the topic studied has appointed a focus on energy retrofit solutions, which focus on energy reduction. The majorities do not consider a heritage assessment and hence some historical value may be lost during renovations. There is the need for a comprehensive understanding of a building as a whole but also a simplified method to assess both aspects when considering the renovation of a historical building. Moreover, a comprehensive analysis of the building which considers the heritage values while monitoring the energy consumption of possible interventions is needed (Troi & Bastian, 2015*)*. The heritage value of a building should be consider and prioritize as much as the energy aspects. Therefore a heritage assessment should be made prior a renovation in order to achieve a balance between: heritage preservation, cost-effective energy technologies, and human comfort (Fouseki & Cassar, 2014).

1.4 STATE OF PRACTICE (IN PROGRESS)

Several projects have focused in renovation of the built environment, to overcome the issues of demolition, and poor energy performance. The Intelligent Energy Europe Programme (IEE) developed the project TABULA. It is a WebTool[1] which classifies by country, the different residential typologies according to size, age and systems. It displays as a brochure exemplary building of each typology and

---

[1] http://webtool.building-typology.eu/

their energy performance effects of the existing state, a usual and an advanced renovation. Data is available regarding a comparison between different variables, building and systems, as well as calculation details (Institut Wohnen und Umwelt GmbH, 2014). The Netherlands is part the countries analyzed during this project.

The RVO presents several projects, which act as exemplary efficient buildings, categorized in new, renovations and by typology (RVO, 2015b). The projects show several strategies in order to achieve high energy efficiency buildings. The measures implemented are shown, as well as the energy label achieved. One of those projects renovated 32 dwellings with monument status, achieving a Passive-House concept.

In Amsterdam, an ambitious project was developed, the restoration of “de Koningsvrouwen van Landlust” . The apartments were reduced by 30%, achieving an energy label A and A+ and a CO2 reduction of 49%. The accomplishment of this project was with the aim of a local subsidy called: *Naar Energieneutraal wonen* [Towards Energy neutral dwellings]. It promotes projects with energy savings targets and a reduction of at least 45% of CO2 emissions.

1.5 AIMS OF THE RESEARCH AND DESIGN PROJECT

This research aims to provide better understanding on how the renovation of a building can achieve sufficient energy reduction and preserve its historical value, while being a low-energy building (See Theoretical Framework for definition of Low-energy).

Accordingly the objectives of this research are:

- Analyze and identify the historical value of an existing building
- Identify the heritage significance impact of possible interventions (Individual components)
- Assess the energy reduction of the individual components
- Balance the energy reduction against the heritage impact of each intervention
- Provide design strategies and design guidelines

1.6 SOCIETAL AND SCIENTIFIC RELEVANCE

This research provides an insight into possible solution that tackles the preservation of historical value of a building and the upgrade of its energy performance. Its methodology contributes to a better understanding on how to deal with contradictory concepts. Each of the different steps can be implemented using a different case study. Moreover, the interventions can be broadening in order to help decision-makers to determine the most optimal solution for a renovation in regards of energy efficiency and historical values.

The outcome of this research is beneficial to disciplines such as: architecture, sustainable consultants, conservation experts and related disciplines. It can also aid local and national authorities to play an active role into the decisions regarding historical buildings.

Finally, the implementation of this methodology increases the quality of buildings and hence the living quality of its inhabitants.

2 THEORETICAL FRAMEWORK

The preconditions for an intervention to occur are mainly due to its cultural historical value, building's quality and the ownership status of the building (Bijlsma, Bergenhenegouwen, Schluchter, & Zaaijer, 2008, p. 50). The first two preconditions are investigated during this research.

2.1 HISTORICAL VALUE

Cultural heritage is a compilation of values, such as: aesthetics, historic, scientific, social or spiritual which are embodied in a place (Australia ICOMOS, 2013). This research aims to understand how to recognize, integrate and identify the importance of a building's values. Because the understanding of cultural heritage is crucial as it is often related to a sense of permanence (Troi & Bastian, 2015, Page 38). The historical value of a building creates a sense of place within the community due to its historical character and uniqueness (Tomback, et al., 2013).

Within this research, the historical value of a building is measure by identifying its heritage significance. Which it is the combination of eight primary values defined by Tarrafa & Pereira Roders, 2012. Such values are social, economic, political, historic, aesthetics, scientific, age and ecological. These values can be tangible (physical aspects) and intangible (non-physical aspects), and they are distinguished between real and assumed. The former are the ones implicit in the text examined. Moreover, attributes can as well be distinguished.

2.2 INTERVENTION

Several authors define transformation or interventions as the as the upgrade of an existing building regarding its energy efficiency, rehabilitation or conservation (Hal et al., 2010; Ipekoglu, Boke & Cizer, 2007; Ma, Cooper, Daly,c& Ledoc, 2012; Troi & Bastian, 2015).

CONSERVATION

According to ICOMOS, *Conservation* is defined as the protection of all aspects of a site, keeping its cultural significance intact. This concept is subdivided into: *Preservation*, limited to the protection and maintenance of the existing fabric; R*estoration*, when returning to the existing fabric; *Adaptation*, when a space is modified into a compatible one and *Maintenance,* when there is need to repair the fabric (ICOMOS, Burra Charter).

CAREFUL RENOVATION

A Careful renovation is defined by Botta, 2005, p.34 as the "…*awareness and knowledge of the building or area, its history, its users/inhabitants and its public image."* It tries to preserve the character of the building by proposing interventions respecting its qualities and keeping the values which are more valuable.

ENVIRONMENTALLY-FRIENDLY RENOVATION

The perspective regarding the mentioned concepts is shifting towards environmental issues. Since 1970, the building sector demanded building codes to consider such aspect (Botta, pp. 34). Consequently, ICOMOS, International Scientific Committee for Energy and Sustainability (ISCES) has acknowledged the importance of energy conservation and sustainable development as part the conservation of heritage buildings (ISCES, 2013).

An environmental renovation approaches interventions which regard the water conservation, energy efficiency and the use of renewable sources. It aims to avoid waste and to protect natural resources (Botta, 2005, p. 14)

POSSIBLE INTERVENTIONS

The interventions proposed during this study are based on the first phase of the graduation studio. These interventions are the parameters and sub-categories of the DEL defined by the RVO (RVO, 2014).

More specifically, they are parameters regarding the glazing, envelope and solar systems, which will be discussed later in Chapter 7.

2.3 ENERGY PERFORMANCE

The energy performance of this research is evaluated by determine the performance indicator: Space Heating (SH) demand (energy needed for heating). This factor is related to the heat transmission losses, the quality of the building and the efficiency of the heating system (Meijer, Itard & Sunikka-Blank, 2009). The final space heating demand is translated into energy savings. Several concepts are outline which are a consequence of the energy savings achieved.

DEEP RENOVATION

Most of the time a standard renovation is performed, that offers minimum energy savings of approximately 20% and 30% energy reduction (GBPN,2013, p. 6). However, a major renovation could aim to reduce more than 75% of the original building. It is defined a D*eep renovation* with an overall consumption of 60kWh/m2/year (GBPN, 2013).

LOW-ENERGY BUILDING

The concept of a low-energy varies depending on author and national standards. It aims to minimize the building's operating energy, which is the energy needed for heating, cooling, hot water and electricity (ventilation, lighting and appliances) (Sartori & Hestnes, 2006). In addition, it improves the envelope in to reduce heating and cooling demand, as well as the implementation of high efficient systems and renewable sources (Chlela, Husaunndee, Inard, & Riederer, 2009). Lastly, it is generally consider as half of the energy that national standards demand (Our-energy, 2009).

This research addresses the concepts developed as low-energy by measuring the space heating demand aiming for a reduction of half of the national standards. Since January 2015, the building code in the Netherlands demands for an Energy Performance Coefficient (EPC) of less than 0.4 for residential building (RVO, 2015). In accordance to the goal of this research, the space heating demand should aim for 30kWh/m2y, which is half of demanded standards (60kWh/m2y) (Atanasiu, Kunkel, & Kouloumpi, 2013).

2.4 BALANCE RENOVATION

In this study, we try to develop a holistic methodology that integrates the concepts of historical value conservation and energy efficiency as equally important variables in order to meet the current energy standards. The final outcome is defined as a Balances Renovation, which is a sustainable renovation approach based on the previously mentioned criteria.

3 METHODOLOGY

The methodology is divided into six main steps, which lead to recommendations, conclusions (7) and the final product (8) (Figure 3-1). It is important to introduce the different scenarios analyzed within each step, as they will be discussed during the whole research.

- Pre-case. It is defined as the pre-existence of the case study (Pereira, 2006), which is the initial state of the building before renovation.
- Base-case. It is the current state of the building, the existence (Pereira, 2006).
- Possible interventions. They are briefly introduced during the previous chapter and they are identified as the interventions that could lead to a higher energy performance of the building.
- Three solutions. They are the new cases determined by the fifth step and they will be described in Chapter 9.

The implemented methods are divided into the Sub-research questions (SQ) and the Main Question (SQ).

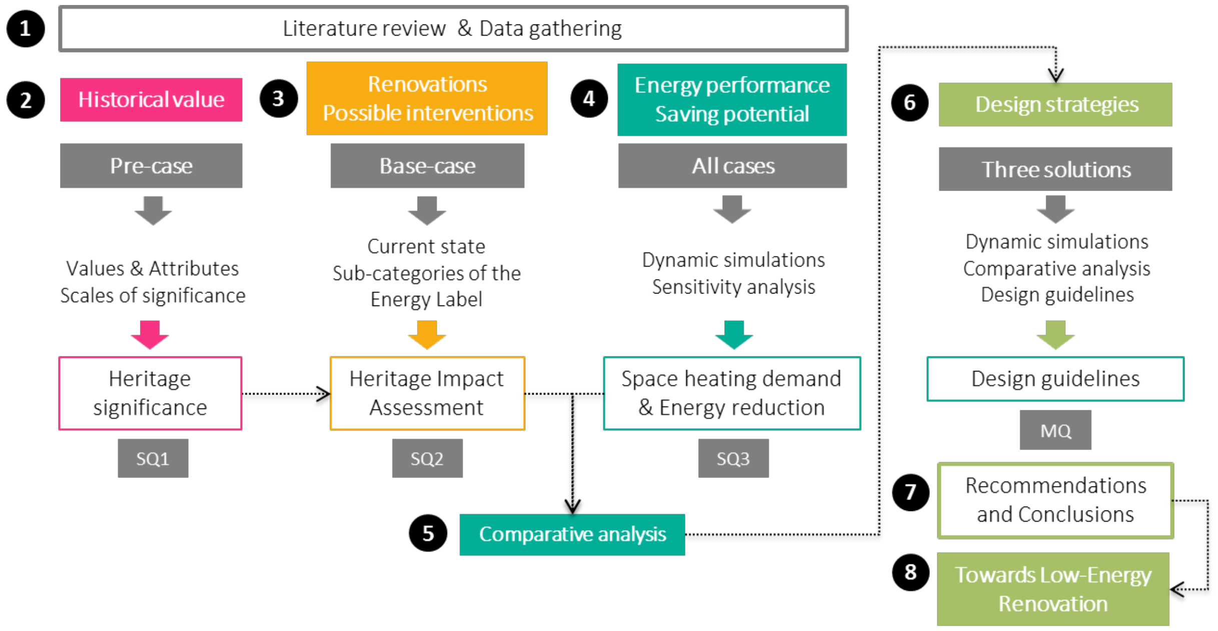


Figure 3-1. Methodology

3.1 SUB-RESEARCH QUESTIONS

3.1.1 WHAT ARE THE **HISTORICAL VALUES** OF A BUILDING? (SQ1)

The first analysis of the building is done in the pre-case. It analyzes the historical values of the case study. The first sub-question is based on what is the heritage of the building is and why it is important (Icomos, 2014). The integrity of the most important aspects of the building regarding its heritage value is of great importance. Therefore, the derivation of quantitative data out of the extracted qualitative data, is required, in order to understand each aspect

3.1.1.1 METHODS

DOCUMENTAL RESEARCH

A series of reports and literature regarding the area and the building were studied in order to acquire an overview of the building's value. The main sources were: "*The Qualities of the Western Garden Cities*" by Sabaté Bel & Galindo (2000), "*The General Expansion Plan of Amsterdam*" by Hellinga (1983), *W.M. Dudok* by van Bergeijk (2001), one chapter of the "*Atlas AUP Gebieden Amsterdam*" by Schilt (2013, pp. 82-101 and "*De Schoonheid van Amsterdam*" [The Beauty of Amsterdam] by Bureau van de Commissie voor Welstand en Monumenten and Gemeente Amsterdam (2013).

Unfortunately, no literature was found regarding the specific case study. Therefore, the Beauty of Amsterdam was chosen for the heritage significance assessment. It is an aesthetics report regarding the different valued areas within Amsterdam that contribute to the building heritage of the city (Gemeente Amsterdam & CWM 2013). The case study is part of the AUP, which is one of the areas described within the report. The case study is evaluated according to its area (AUP) and the order (Assigned cultural value). The valuation will be discussed in Section 6.2.

PRIMARY VALUES AND ATTRIBUTES

After the literature review, a survey was performed based on the methodology proposed by Silva & Pereira Roders, 2012. The methodology follows different stages. The report is divided in different sections. The scales of significance were identified and at the same time correlated with the current valuation (See Section 6.3). The analyzed text is divided into quotations. From each quotation an attribute is identified (What) as well as the qualifier or value, which it is the reason to be an attribute (Why). Consequently, they are categorized between tangible and intangible. Then, the primary values are identified on each attribute, and divided into real and assumed. The former is when the value is explicit on the text, while the latter is an assumed value. Furthermore, each attribute gets a value that is related to one or more primary values. They are summed to generate a total of primary values from which it can be regarded the most important attributes and when the primary values are summed, it is possible to obtained the amount of primary values of the analyzed text. Lastly, the series of quotations related to the case study were identified, by means of drawings analysis, observation and comparing it against the literature mentioned.

HERITAGE RANKING (SCALES)

Subsequently, a heritage ranking between 0 and 5 is given to each Scale of significance. There are two rankings assigned. The first one compares the total primary values of each scale to a ranking table. This is derived by the previous step where a ranking 5 is given to the scale which has the highest amount of primary values. The second ranking is compared to its own Scale of significance, by means of comparing the primary values obtained in the Dudokhaken (scale A) to the ones obtained in the AUP (scale A). The second ranking serves as discussion with the assigned valuation of the building given by the CWM.

HERITAGE RANKING (ATTRIBUTES)

Finally, a ranking is given to each attribute, with 5 being the most valuable because it has obtained the highest amount of primary values. The outcome is a heritage significance assessment which shows which attributes are more valuable and should be considered during the intervention.

3.1.2 WHAT IS THE IMPACT ON THE HERITAGE VALUE OF A BUILDING WHEN AN INTERVENTION OCCURS? (SQ2)

The second analysis of the building is done to the base-case. The purpose is mainly to assess the impact of possible interventions. However, since the case study has been renovated it is important to identify the remaining, additions and demolitions of each intervention (Pereira, 2006). Based on this, the Pre-case and Base-case are compared.

3.1.2.1 METHODS

DOCUMENTAL RESEARCH

A documental research is performed as well as drawing analysis aiming to extract the architectural aspects of the building. The drawings were retrieved from the *Bouwarchief* [Building archive] of New West and the documentation regarding the renovation of the Dudohaken was provided by Van Schagen architekten. The technical conditions are gathered following a quantitative approach from which the technical specifications of the building such as: window types, insulation values from roof, walls and floor, specific HVAC systems, area and volume of the apartments are obtained.

HERITAGE IMPACT ASSESSMENT

In order to determine their impact, firstly the attributes affected by each intervention are identified. Afterwards, an in-depth analysis is made from which the exact quotations that are affected are studied. The primary values are then summed, thus obtaining a total of primary values lost. Lastly, a scale from 0 to 5 is given with 5 showing the largest impact. Thanks to the Scale of HI applied, the affected primary values are turned into quantitative data.

3.1.3 WHAT IS THE SAVING POTENTIAL OF POSSIBLE INTERVENTIONS? (SQ3)

The last sub-question aims to determine the energy performance of both cases, pre-case and base-case, as well as the saving potential of possible interventions. The chosen energy performance indicator is space heating, as it accounts of 60% of the energy used in dwellings within the European Union (Meijer, Itard, & Sunikka-Blank, 2009). This SQ aims to determine the optimal energy retrofit for the case study.

3.1.3.1 METHODS

SIMULATIONS AND SENSITIVITY ANALYSIS

The first step is to perform a dynamic simulation with IES VE software. The first simulation executed is the pre-case, followed by the base-case and a sensitivity analysis of the possible interventions. The latter is done by changing one parameter at a time based on the geometry and thermal characteristics of the Pre-case and the Base-case. The sensitivity analysis is done for both cases. A theoretical schedule is determined by the current users, based on documentation regarding the recent renovation (Van Schagen Architekten). An occupancy profile by area is determined based on that.

ENERGY REDUCTION

The results obtained by previous method are compared. The possible interventions are compared to the pre-case and base-case in order to determine the saving potentials in terms of percentage of energy reduction of space heating.

3.1.4 MAIN RESEARCH QUESTION (MQ)

The answer of the Main Question is determined by the sub-questions previously presented. It aims to answer:
Until what extent interventions can be implemented achieving energy saving without affecting the historical value of a building?

3.1.4.1 METHODS

The first step is the comparative analysis of SQ2 and SQ3. The results outline the heritage impact and saving potential of each intervention as a multidimensional approach. Consequently, three solutions are determined which consider several of the interventions analyzed. The criteria for choosing the interventions were based on the maximum energy reduction and minimum impact in the historical values. The three solutions are considered to be the design strategies. The first one is an optimized case of the Base-case. Subsequently, two more solutions are identified which aim for the interventions with the highest energy reduction and the lowest heritage impact to the Pre-case (Balance renovation).
The three solutions used dynamic simulation to determine the energy reduction. Lastly, all three cases are compared to the pre-case and base-case on the heritage impact and the energy reduction. Finally, design guidelines provide solution to mitigate the heritage impact of the proposed interventions.

3.2 WORK PACKAGES

Each of the methods is divided into work packages in order to finalize the individual approach of the graduation studio.
WP1. Literature review and data gathering. An in-depth literature review was performed to to investigate the state of the art of heritage assessment and energy conservation. Scientific articles, books

and projects in which best practices were developed are reviewed. Secondly, the data gathering is closely related with the following work packages and it will be explain in more detail during each method, since the sources will vary.

WP2. Historical value (SQ1). It is carried out as part of the analysis and evaluation of the existing building in order to determine what it is valuable and the main aspects that should be kept when searching for possible interventions. This gives an understanding of the historical value of the case study regarding the most important criteria described within the AUP area of Amsterdam.

WP3. Identify transformation, impact and significance of interventions (SQ2). The possible interventions are defined and the results from SQ1 are considered to delimit the scale of impact of possible interventions, as well as the impact of the current renovations. The outcome is a summary of the changes made during time and how the optimization of the envelope may affect the historical value of the building.

WP4. Assessment of the energy performance of possible interventions (SQ3). The energy performance of both, pre-case and base-case is determined. Further step is to investigate the saving potential of each possible intervention in comparison with the base-case and pre-case.

WP6. Comparative analysis (Pre-step MQ). The comparative analysis quantitative compares the impact of each intervention on the historical value and energy saving potential.

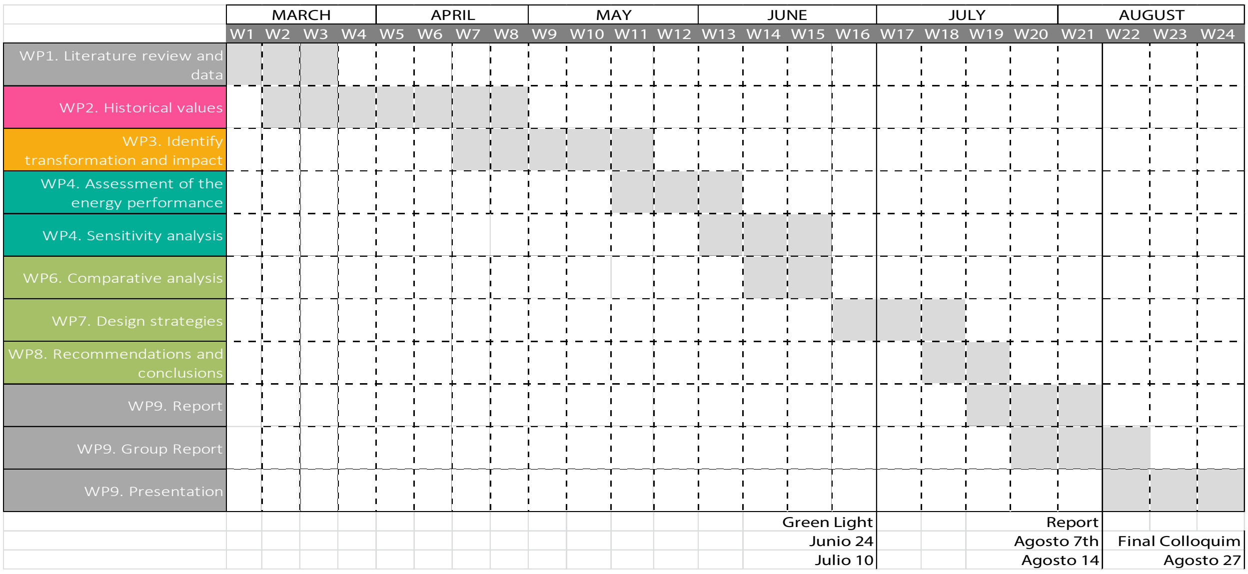
WP7. Design strategies (MQ). The main question is answered by providing design strategies and guidelines to prevent heritage impact.

WP8. Conclusions and recommendations. Furthermore, conclusions of the different strategies will be presented and discuss, as well as future research guidelines will be given.

WP9. Preparation of paper and final presentation. The expected results will lead to a final colloquium in which the analysis, results and conclusions will be presented. Finally, a comparison between the macro-research will be carried out after the final presentation.

3.3 EXPECTED RESULTS AND DELIVERABLES

A summary of the different sections of the thesis lead to a quantitative approach in which different values are calculated, such as heritage value, scale of impact, energy savings and significance of the change to be able to have a comparative analysis that concludes the optimal solution for the design.



	MARCH				APRIL				MAY				JUNE				JULY				AUGUST			
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24
WP1. Literature review and data	▨	▨	▨																					
WP2. Historical values		▨	▨	▨	▨	▨	▨	▨																
WP3. Identify transformation and impact							▨	▨	▨	▨	▨													
WP4. Assessment of the energy performance											▨	▨	▨											
WP4. Sensitivity analysis													▨	▨	▨									
WP6. Comparative analysis														▨	▨									
WP7. Design strategies																▨	▨	▨						
WP8. Recommendations and conclusions																		▨	▨					
WP9. Report																			▨	▨	▨			
WP9. Group Report																				▨	▨	▨		
WP9. Presentation																						▨	▨	▨
																Green Light					Report			
																Junio 24					Agosto 7th			Final Colloquim
																Julio 10					Agosto 14			Agosto 27

Table 3-1. Timetable

4 LIMITATIONS

The research has certain limitations which will be outline by topic specifically.

4.1 HISTORICAL VALUE

The current valuation of the case study rated by CWM is only used as a reference and discussion for the findings of the heritage significance assessment. It will be explain during section 6.2.1, however it is important to outline that it is only a ranking given to certain buildings within an area without extensive explanation on why this ranking occurs. Therefore, the use of the ranking as heritage significance was not sufficient for this research.

As mentioned during previous Chapter. The main text analyzed is The Beauty of Amsterdam (Further explanation regarding the text in Chapter 6.2) It refers to the valuable areas within Amsterdam. However, its main limitations are that it does not highlight or specify the value of a certain building. The text groups the buildings by urban unit type which are similar in the way they are organize within the urban fabric of the city. However, several buildings differ aesthetically from each other. Therefore, the valuation is generic and lacks of specific values for an individual building (Swart, Veldpaus, & Pereira Roders, 2013). For this reason the heritage assessment encounters some limitations as the text evaluated is not specifically related to the case study. In the search for possible validation the results are compared against literature related to the AUP, observation and drawings analysis. Since there is no specific literature about the case study, other than reports and news regarding its renovation.

4.2 RENOVATIONS AND POSSIBLE INTERVENTIONS

The possible interventions to be studied will focus on the envelope and renewable energies as they can have a greater impact into the heritage significance of the case study. Furthermore, from research it is shown that a great amount of energy can be saved through the upgrading of the systems (Ma, Cooper, Daly, & Ledo, 2012; Dulski, Vliet & Unen 2012). However this research due to time limitations regarding time simulations, these options were not explored.

4.3 ENERGY PERFORMANCE AND SAVING POTENTIAL

The modelling of the case study encounter limitations regarding the pre-case building, although original drawings were found information regarding the systems is lacking. Therefore, assumptions regarding typology and year of constructions were taken from RVO (RVO, 2014) to specify the systems of the pre-case. Moreover, the model was simplified and only four apartments were modelled with its specifications taking into account the current situation of the building. As the occupants behavior plays a major role on the energy use of the building (Moran, Blight, Natarajan, & Shea, 2014) an specific and more accurate occupancy profile was considered only for the four apartments mentioned while the rest of the apartments were applied an occupancy profile of a working couple, even though around 50% of the tenants are elderly (Van Schagen Architekten, 2008a, p.11). Finally, since no systems are taken into consideration for the possible interventions the minimum ventilation rate was considered, specifications of the simulation will be further explained in Chapter 8 and Appendix C.

5 CASE STUDY, 'DUDOKHAKEN'

The research is based on a case study located in the district of New-West in Amsterdam. The case study fulfilled certain characteristics, such as have been recently transformed considering the historical value of the building. It is within this area where the fieldwork of the first phase of the studio was developed. New west is characterized for being part in the AUP and as a post-war area where social housing were developed. The building to analyze, assess and optimized is the 'Dudokhaken' in the neighborhood of Geuzenveld.

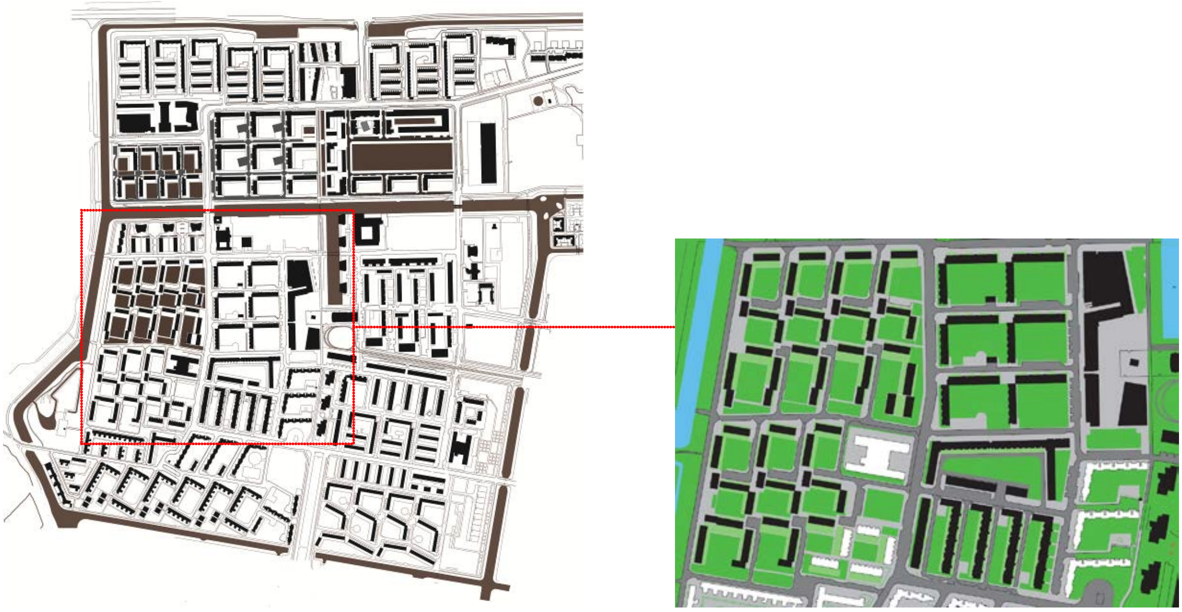


Figure 5-1. Geuzenveld and the Dudokbuurt [Dudok Neighbourhood]

The Dudokhaken poses particular aspects which makes it highly valuable that will be explore during the following chapter. However, a brief explanations if first given. The architectural unit is composed of six identical buildings. They are built in a L-shape around a semi-public courtyard. The building facing north/south follows a Portico typology with the main entrance towards the street (north) made by three Porticos. A series of balconies are accomodated towards the courtyard. After renovation, the typical apartment within this typology is of around 74m^2. The building facing west/east has a Gallery typology and the entrance and balconies are reversed in comparison with the Portico. The entrance to the apartments is made from a series of corridors oriented towards the courtyard, while the balconies aare situated towards the outside (streets). They apartment within this wing is of around 100 m^2.

Figure 5-2. View from the Courtyard, Gallery (left) and Portico (right)

6 HISTORICAL VALUE

6.1 HISTORY

6.1.1 AUP, THE EXPANSION OF AMSTERDAM IN 1938.

The *Algemeen Uitbreidingsplan* [General Urban Expansion] (AUP) was part of the urban extension plan designed by Cornelis Van Eestern and adopted in 1935 by the City Council of Amsterdam. The development of the extension plan was mainly due to a shortage of dwellings which was a consequence of the suburbanization and a period of economic growth (van den Berg, et al., 2003, p. 39). It aimed to increase the current dwellings stock by 55.3% in 1930 (Schilt, 2013, p. 82). The vision of Van Eesteren took into account "town planning elements", which had expressive qualities and were part of the aesthetics of the urban space (van den Berg, et al., 2003, p. 51). The importance of these extensions was due to the fact that it marked a break point in the urban planning of the city. According to van den Berg, et al., 2003, p. 69: "*It was an integral plan drafted by a team of researchers and town planners, emphatically functionalist in character and supported by a series of empirical studies".*

The AUP projected 53 655 houses especially for the lower income categories aiming for a new garden city environment (Schilt, 2013 p. 86). The plan was based on *"the separation of living, working, traffic and recreation. Principle in the design of the neighborhoods and the homes was the entry of air, light and space. An open planning was in strips before the solution: a combination of low-, medium- and high-rise buildings where the greenery around the buildings 'flows'*" (Gemeente Amsterdam, 2013). The green areas are a physical element which aims to structure the expansion by making the transition between the built-up area and the rural area as well as the different parts of the planned expansions (van den Berg, et al., 2003, p. 72).

The areas previously planned were assigned to specific architects, sometimes by building units and others as a whole neighbourhood. The architects involved in the AUP expansion focused on a main problem, the design of simple but efficient dwellings for the working class. The architect's vision was mainly reflected on the façade, by emphasizing the rhythm applied in some of the building components, such as balconies, loggias, doors, frames and windows (Schilt, 2013, p. 92-94).

6.1.2 GEUZENVELD

The districts of the western part of the AUP are identified as the 'Western Suburbs of Amsterdam'. They are mainly located in the neighbourhoods of Slotermeer, Geuzenveld, Slotervaart, Osdorp Overtoomseveld and Westlandgracht. Its implementation began in 1951 with Slotermeer (Blom, 2013). According to Sabaté Bel & Galindo, 2000: "*…the garden cities of the West are not identical to those of the AUP, neither in the way they were built in the post-war, nor in their apparent form today. For this reason, not only the AUP, meaning the planned city, but also the current situation, the city that was built must be analyzed."*

According to literature the quality of Slotervaart, Osdorp and Buitenveldert are considered only above average, without being special. On the contrary, Slotermeer and Geuzenveld are an exception from which one can still detect some of the original aspects of the AUP (van den Berg, et al., 2003).

The special features of Geuzenveld are stated by van den Berg et al, 2003, p. 57:

> "*Geuzenveld could be regarded as the AUP's epilogue. It marked the conclusion of the modernist experiment in town planning. Geuzenveld is a fascinating neighbourhood, especially compared with Slotermeer, because it is still a town planning design pur sang, the work of a creative designer who is a superior master of his craft rather than an everyday product churned out by functionaries. In Geuzenveld all the stacked construction is rigorously situated at the centre of the neighbourhood, with a ring of low-rise construction surrounding it. In order to emphasize its grand scale it was designed by a limited number of architects, each of whom designed a large number of housing units. The architecture in Geuzenveld is therefore much more distinctive than in Slotermeer".*

In 1957, 50,000 dwellings were built in Geuzenveld as part of the AUP. The urban plan of the area was developed by six housing corporations, collaborating with six well-known architects such as: W.M. Dudok, W. M. Dudok, B. mugwort, B. Merkelbach, J. H. van den Broek, Van Tijen and C. Wegener Schleswig. The characteristics of the building within the area were mostly formed by L-shaped buildings to create shared courtyard gardens (Van Eesteren Museum, 2014). W. M. Dudok was one of the architects that participated in the design of the urban plan of the area as well as the dwellings to be developed (Figure 6-1). The urban plan of Geuzenveld was envisioned as a concentration of high-rise buildings surrounding by low buildings (Hellinga, 1983).

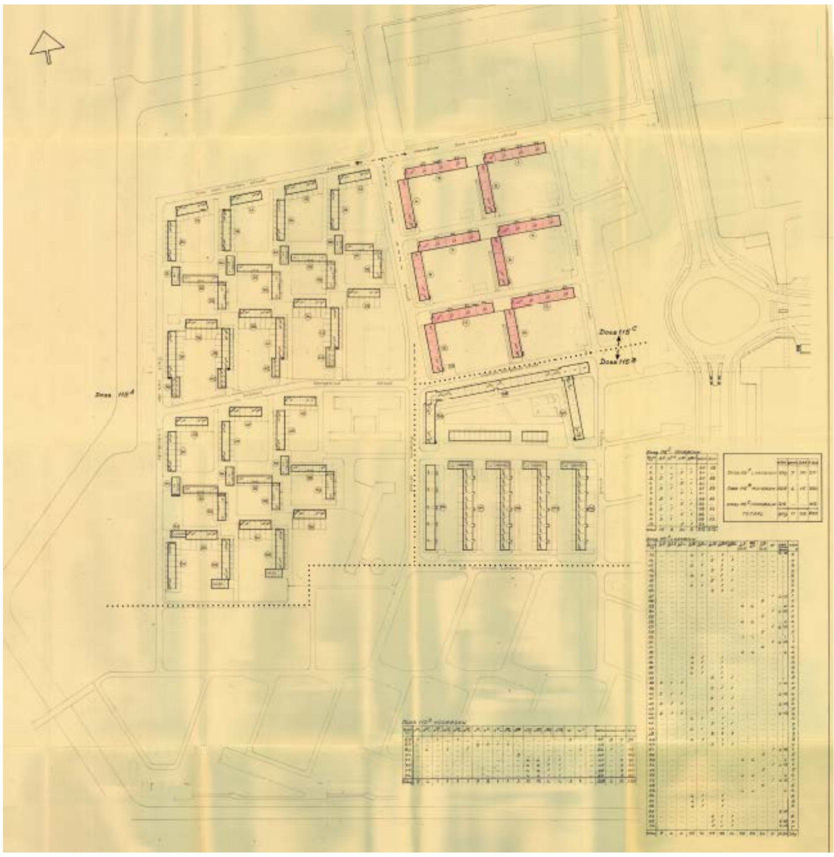


Figure 6-1.Geuzenveld, garden city. Section designed by W. M. Dudok

6.1.3 WILLEM MARINUS DUDOK

Willem Marinus Dudok was the architect who designed the building of the case study. The 'Dudokhaken' is not the most important building that Dudok designed. He is well-known for his masterpiece, the *Raadhuis* [Townhall] in Hilversum (Figure 6-2), designed in 1923 but finally finished in 1931. This work is regarded as an explicit piece of modern architecture. The architect achieved movement and contrast by alternating the heights and the horizontal and vertical volumes. And according to Van Bergeijk, 2001; "*…one of the remarkable features is that one is able to admire the distinctions between the administrative sections without affecting the design unit".* Moreover, Dudok was in charged with the development plans of The Hague from 1934 until 1942, in which he proposed a rhythm between the neighborhoods creating repetitions of the buildings, also the green areas were of great significance aiming to create a continuous system and linking the different areas by these green areas (Van Bergeijk, 2001)

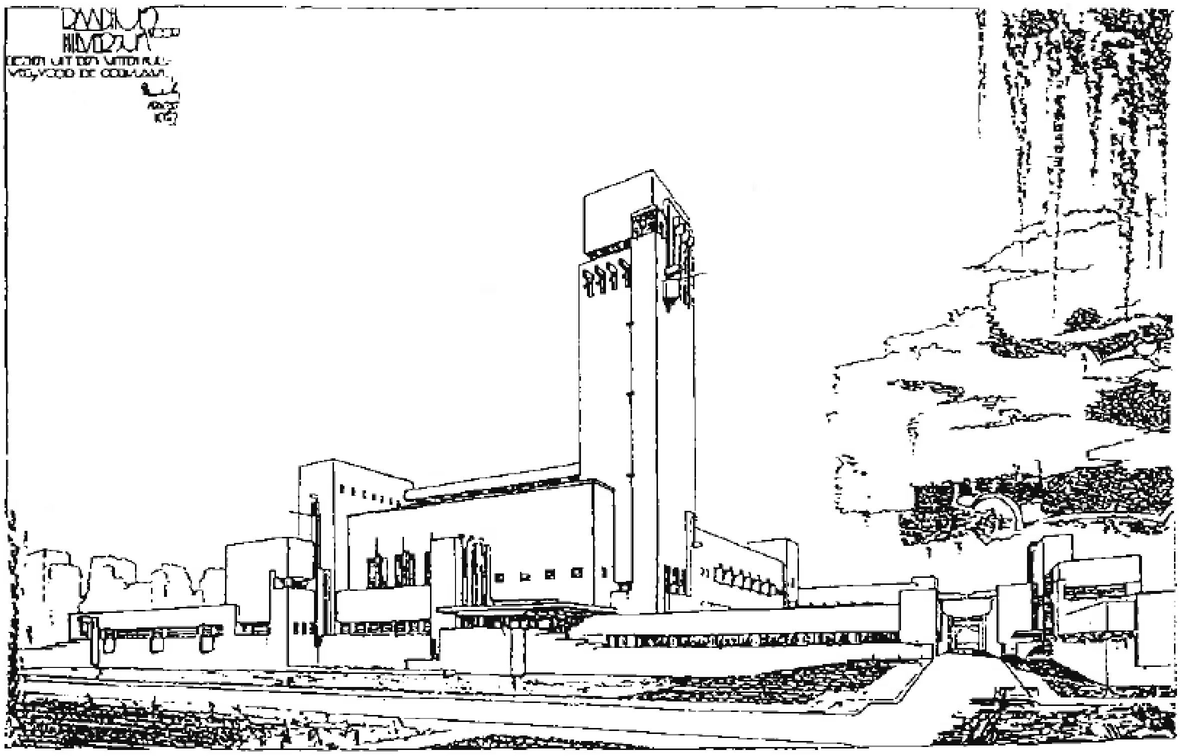


Figure 6-2. Sketch of the Raadhuis in Hilversum

Dudok was in charge of the design of one of the areas within Geuzenveld. Dudokhaken was part of this area, his design was divided into two block. One of them accommodated six L-shape building, that are repeatedly into a four-storeys with a slopped roof connecting the three storeys high building, which is accessed by a gallery (Figure 6-3) (Van Bergeijk, 2001).

According to Sabaté Bel & Galindo, 2000, p. 27:

"As we have seen, for many people, the value is in the physical characteristics, in their spatiality, in the visual openness. In these districts, space, infinity, growth and expansion were concepts which attained the quality of symbols. The new social phenomena of the post-war, from liberty to welfare, were translated in spatial terms and metaphors"

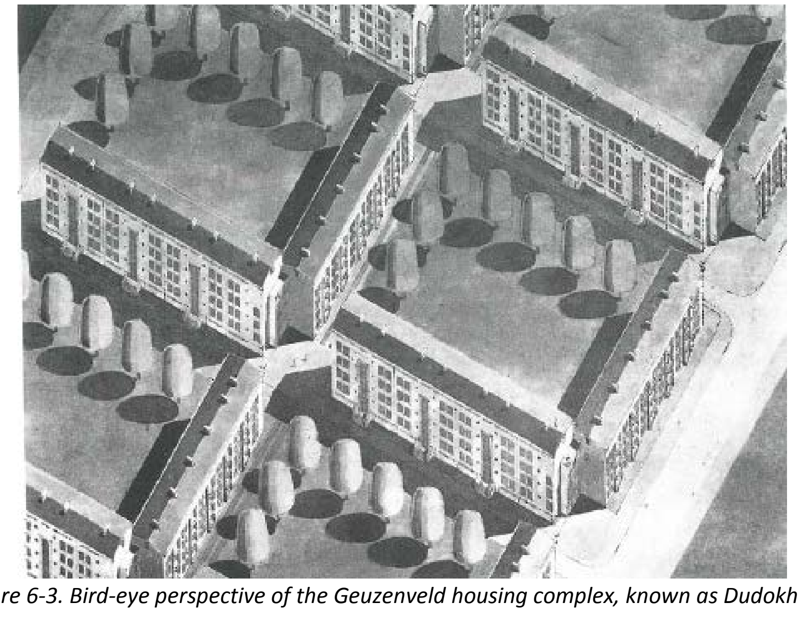


Figure 6-3. Bird-eye perspective of the Geuzenveld housing complex, known as Dudokhaken

6.2 HERITAGE SIGNIFICANCE, UNDER AUP CRITERIA DEFINED BY THE 'CWM'

6.2.1 WHAT ARE THE AESTHETIC CRITERIA OF THE AUP?

The Aesthetics and Monuments committee, '*Commission Welstand and Monuments Amsterdam'* (CWM), is the department that provides advices and recommendations to the Amsterdam city council. Its main task is the endurance of the quality of the existing built environment (CWM, 2014). At the same time, advices are giving when certain areas of the city are intended to be transformed based on the *Waarderingskaart* [Valuation map]. It aims to support future transformations and give several possibilities that are allowed or not to certain building in relation with its architectural and urban value. Therefore, in a building rated low a radical transformation can take place rather than in a high valued building (Gemeente Amsterdam & CWM, 2014).

There are 10 areas identified, established as *Ruimtelijke systemen* [Spatial systems]. When considering the criteria's established by CWM, the case study falls under the spatial system **AUP and Post AUP**, which consists of a planned residential area with a strong emphasis on the urban structure. Under this system four *Gebiedstypen* [Types of Area] are defined, determined by the urban unit type. Moreover, assumptions, appreciation and policy are defined in accordance to this urban unit type. Each building within the spatial systems has a valuation based on a value given between 1 to 5, 5 being the most valuable, to the following categories:

Architectural elements:

- A Typology, which is the internal organization of the object
- B. Architecture, the spatial design of the object, internal organization

Urban planning:

- C. Subdivision, the grouping of the objects.
- D. Relationship with the surroundings, which is their contribution to the quality of the garden cities

After this grading, the sum of the four categories leads to an *Order* rating: basic order, order 3, order 2 and order 1, the latter being the monuments. Finally, a different valuation is assume based on the *Welstandskaart Architectuur* [Architecture Aesthetics Map], that determines the minor changes that can take places in accordance to four architectural orders: WA-basis, WA3, WA2 and WA1, being the latter for monuments (Gemeente Amsterdam & CWM, 2014).

6.2.2 AESTHETIC CRITERIA OF THE 'DUDOKHAKEN'

The '*Dudokhaken*' falls under the criteria of the AUP for its location and construction period. It is stated to be of Order 2, which is considered as *Hoge waarde* [High Value]. The buildings which are part of this category are important because they are an architectural unit which is distinctive for its architectural design and or/ typology, at the same time it contributes to the composition of the subdivision unit and the field (Gemeente Amsterdam & CWM, 2014, p.47). Moreover it is also considered as WA2, which its valuation aim to maintain and restore the original elements in shape, size, material, detail, proportion and color in respect to its design and with similar quality. The use of non-original materials is possible if this is done with respect to the authenticity of the façade. (Gemeente Amsterdam & CWM, 2014, p.48).

Regarding the urban unit, the 'Dudokhaken' belongs to the *Vernieuwde stroken haken hoven* [Renewed strips courts and hooks]. They are similar to the *Oorspronkelijke stroken, haken en hoven* [Original strips courts and hooks], however, they have been renewed at different scales, therefore making the subtleties barely noticeable. And they are based on an open planning with repeated simple volumes of different sizes along green streets. Moreover, it is advice to preserve the image repetition of buildings lines as well as the façade layout, keeping a consistency on the design and material use (Gemeente Amsterdam & CWM, 2014, p.153).

"*For Dudok the city's aesthetic was always a fundament approach. The city was a unit that could be visually expressed... Capturing the borders was of great importance. Transition from city to countryside must remain clearly recognizable*" (Aukes, B., 2007 P.41)

6.3 HERITAGE SIGNIFICANCE ASSESSMENT

After a brief introduction of the history as well as the current aesthetics valuation of the case study, the following section aims to answer SQ1: What are the **historical values** of a building? According to the criteria’s followed by the current valuation of the case study (See Section 6.2.1) a division was made into four different scales. It aims to emphasize and interconnect the different attributes within the area (Table 6-1). As previous during the Chapter 3, the text analyzed is divided into different chapters, which made it easy to identify the Scales of significance. The first scale (A) is based on the *Inleiding* [Introduction], the second (B), based on the *Geuzenveld – Welstandnota* [External appearance of building] (Gemeente Amsterdam & DMB, 2009), the third (C), which is the architectural unit *Vernieuwde stroken, haken en hoven* (D) based on the *Veel voorkomende kleine bouwplannen* [Possible minor changes].

	Scales of Significance identified	**Valuation by CWM**
A	Urban structure. *AUP and Post-AUP*	Contribution to the quality of the Garden City (D)
B	Neighbourhood. *Geuzenveld (Welstandnota)*	Grouping of the objects (C)
C	Typology. *Renewed strips, courts and hooks*	Spatial design (A)
D	Building elements*. Possible minor changes.*	Internal organization (B)

Table 6-1. Comparison of the Scales of the Significance

6.3.1 RESULTS AND DISCUSSION

TANGIBLE VS INTANGIBLE

The aim of this distinction between tangible and intangible is merely to highlight and to prove that not only intangible attributes are consider, making it possible to assess a heritage impact of both. The values within the AUP present more intangible values within the Urban scale (Figure 6-4). On the other hand, the typology and elements show more tangible values. The Dudokhaken (DH) have lost more tangible values for the first two scales, while for the last one the values are proportional (Figure 6-5). Morevoer, the first three scales presents similar share of intangible values while for the AUP the neighbourhood represents more than double.

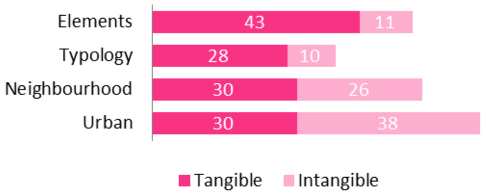


Figure 6-4. Tangible and intangible values of AUP

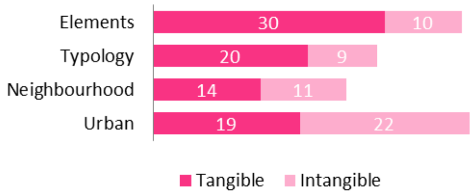


Figure 6-5. Tangible and intangible values of DH

PRIMARY VALUES BY SCALE OF SIGNIFICANCE

The primary values are divided by Scale of significance and distinguished between AUP and DH (Figure 6-6 to Figure 6-13). The aesthetical value is the most relevant value in every scale. However, at the urban scale (Figure 6-6) the historic, political and ecological values are weighted almost as similar as the aesthetical. This is due to the fact that the AUP plan is considered according to Sabaté Bel & Galindo, 2000 as: *“… a milestone in the history of urban planning…”* and it is internationally recognized. The neighbourhood (Figure 6-8) is weighted with more aesthetical values, followed by historical, political and social values. As some authors different from the sources stated that the social context is involved within these neighbourhoods: *“The structure of the neighborhoods and districts they wanted to contribute to the development of the individual, the family and different communities,* (Blom, 2013)*”*.

A discussion regarding the assumed values aims to highlight the values that may be lost but are important to outline. The first scale (Figure 6-6), presents additional scientific values since the AUP implied a conceptual contribution in most of its aspects, such as the strong relationship between the building and its surroundings as well as the strategic positioning of the greenery (Blom, 2013). On the other hand, the neighbourhood (Figure 6-8) shows added historic values due to its historic-conceptual (Tarrafa Silva & Pereira Roders, 2012). The situation of the typology (Figure 6-10) is the same as the former scale. Lastly, the building elements (Figure 6-12) scale shows additional political values since most of the text refered to admisible policy regarding possible interventions.

Regarding the case study, the results give an overview of the primary values identify within Dudokhaken. The first scale, urban, (Figure 6-7) shows variations within the values but being the aesthetical and the historic the most valuable. In comparison with the AUP at the same scale (Figure 6-6), the social aspects seem to be less important, while the ecological is the one which is less reduced. The neighbourhood scale (Figure 6-9) seems to be less valuable, since the reduction is considerable, being the aesthetical value the most valuable. The typology (Figure 6-11) was reduced in the aesthetical values, however, it is still the most important value, followed by the historic and political. Lastly, the building elements (Figure 6-13) show less influence by the political values, while the rest decreased constantly.

A. Urban

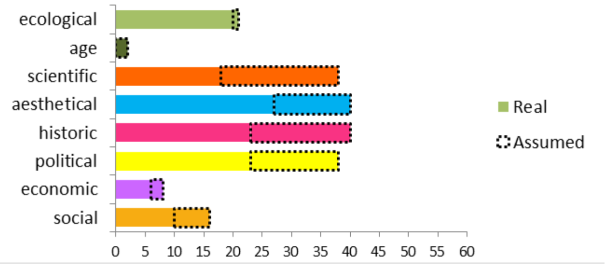


Figure 6-6. Primary values, Urban scale of AUP

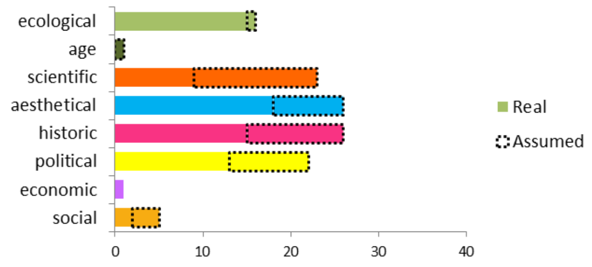


Figure 6-7. Primary values, Urban scale of DH

B. Neighbourhood

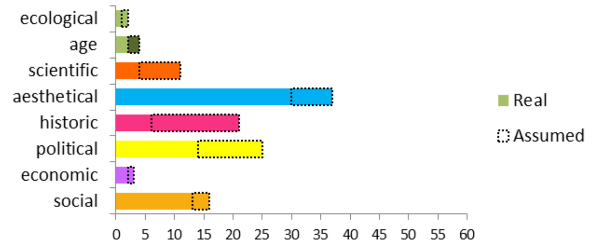


Figure 6-8. Primary values, Neighbourhood scale of AUP

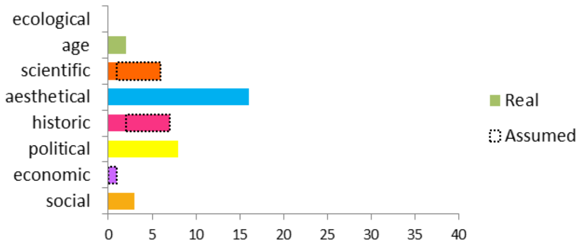


Figure 6-9. Primary values, Neighbourhood scale of DH

C. Typology

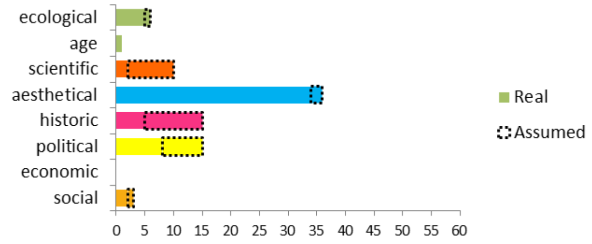


Figure 6-10. Primary values, Typology scale of AUP

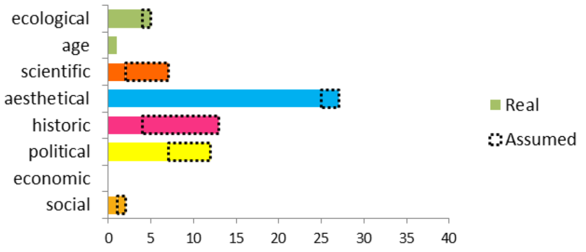


Figure 6-11. Primary values, Typology scale of DH

D. Building Elements

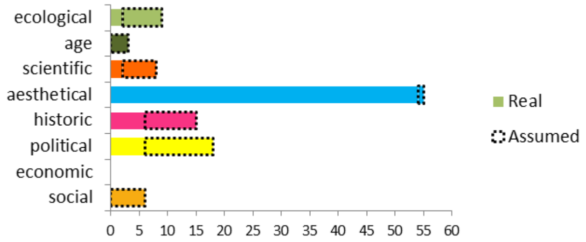


Figure 6-12. Primary values, Building Elements scale of AUP

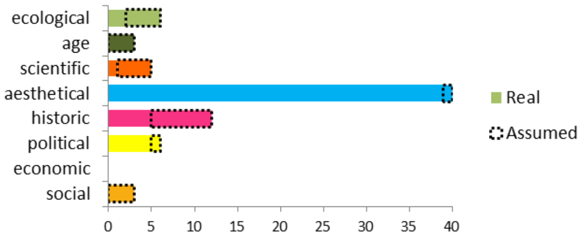


Figure 6-13. Primary values, Building Elements scale of DH

ATTRIBUTES BY SCALE OF SIGNIFICANCE

After analyzing the primary values of the AUP, they were categorized into attributes, in order to zoom in into more specific aspect concerning the building. The results are shown only for the case study (Figure 6-14). For results of the AUP please see Appendix A.

Within the urban scale (A) 15 attributes were identified. The urban structure, followed by the green areas and streetscape seem to be the most important attributes. The urban structure seems to have higher weighted on the political and scientific values, while the green areas and streetscape present similar situation with most of them being historical and ecological. The second scale, the Neighbourhood (B) shows most of the values falling into the strip and hooks, which is the typology of the case study. The majority of the values are aesthetical, and political. For the Typology (C), the attributes which received most of the values are the urban structure, followed by the building and streetscape. Finally, the Building elements (D) show to be the façade the most remarkably attribute, with more aesthetical values, as well as the roof, and lastly the architectural unit which seems to have an almost equal distribution of the different primary values.

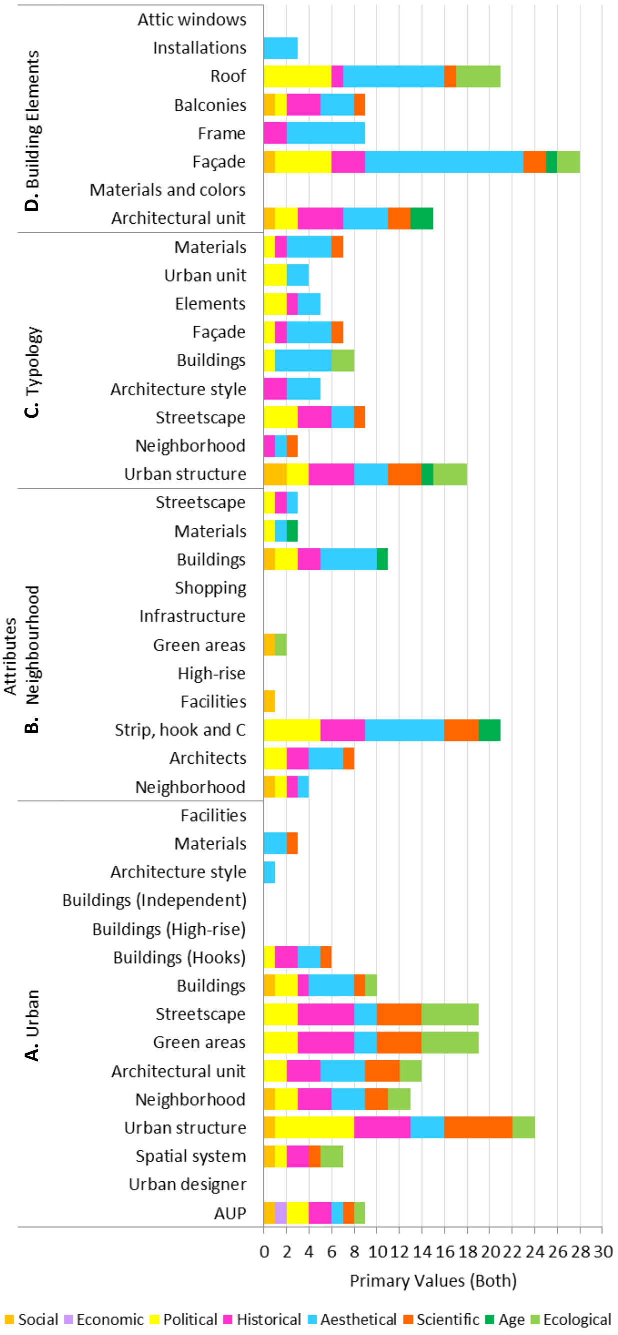


Figure 6-14. Primary values of Attributes by Significance Scale

HERITAGE SIGNIFICANCE RANKING (HSR) BY SCALE

Finally, the last step within SQ1 is the heritage significance assessment, in which a ranking is given to each scale and attribute. There are two rankings given. The first one compared the total of primary values obtained in each scale and compared with Table 6.2. The ranking 5 is extracted from the scale which has the highest amount of primary values, being the urban scale of the AUP. The findings show that the neighbourhood, followed by the elements achieved a ranking 3. Lastly, the typology seems to be less valuable with a ranking 2. The AUP areas are mostly valuable because of the contribution to the urban planning of the area. On the other hand, the DH presents different results, while the urban scale has still a high ranking 3, with 62% values in comparison with AUP. The rest of the scales present less valuable ranking. The neighbourhood is the scale which has lost more than half of the primary values identified in the AUP (Figure 6-15).

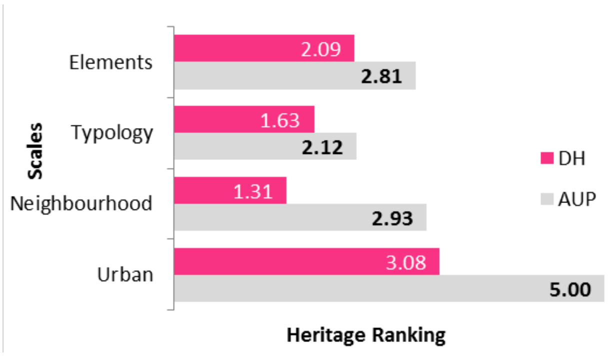


Figure 6-15. Heritage ranking by Scale of significance

Ranking	5	4	3	2	1	0
Primary Values	203	162	122	81	41	0
%	100%	80%	60%	40%	20%	0%

Table 6.2. Rankign and Primary values

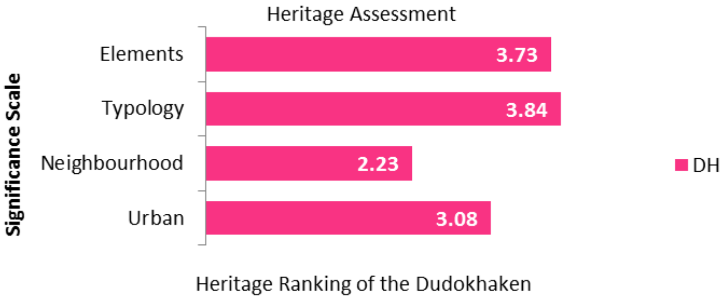


Figure 6-16. Heritage ranking compared between each Scale

	BA	DH	DH / BA	
Urban	203	125	62%	3.08
Neighbourhood	119	53	45%	2.23
Typology	86	66	77%	3.84
Elements	114	85	75%	3.73

Table 6.3. Ranking between each scale (AUP-DH)

As mentioned in Section 6.3 the Scales of significance identified are related to the valuation used by CWM showed in Table 1. In order to compare the results to the current valuation the amount of primary values of each scale was compared to the primary values given in the AUP (Table 3). As an example, the elements in AUP have 114 values, while 85 were identified on DH, therefore the ranking given is 3.7. The current valuation of the DH is ranking 4 on each scale. A summary of a ranking 4 is as follows (BMA, 2010, p. 13):

- Internal organization (Elements). High quality in terms of a particular type of dwelling or particular building type. The access, solar orientation and relationship with public space are important.
- Architecture design (Typology). High quality in terms of design. There is consistency between form, construction and application of modern materials. It shows an expressive expression of various functions within the design as a whole.
- Unit allotment (Neighbourhood). High quality of placement (or non-repeating) architecture units in an integrally designed grouping, in which a varied streetscape is created with a combination of a degree of seclusion and open sight lines to the outside (or a strong interaction with the public space)
- Contribution to the garden cities (Urban). High quality in the relationship between architecture unit, the parceling, the composition of the construction area and the garden city character as a whole.

Since the methodology used on this research is not the same as the current valuation the comparison only aims for an insight on how valuable the information review is. At the same time, it aims to highlight some limitations that the information encounter in the text reviewed may have. The ranking of the scales which are similar to the current valuation are the Elements and Typology. However, the urban scale presents a ranking of 3 which according to CWM it is still representative of the AUP areas but would not have a high quality. On the other hand, the Neighbourhood shows slightly more than half of the current points, when comparing to the ranking it would be considered as lacking of interaction with surroundings.

Heritage Significance Ranking by Attribute

Each attributes is given a ranking to identify the most important attributes. The attributes' ranking differs from the scales. The total of primary values is obtained from the attribute which has the maximum values, being the Façade with 40 values and a ranking 5. The attributes with the highest ranking should be carefully considered in the process of a renovation, whereas the lowest ranking could accept major changes (Figure 6-17).

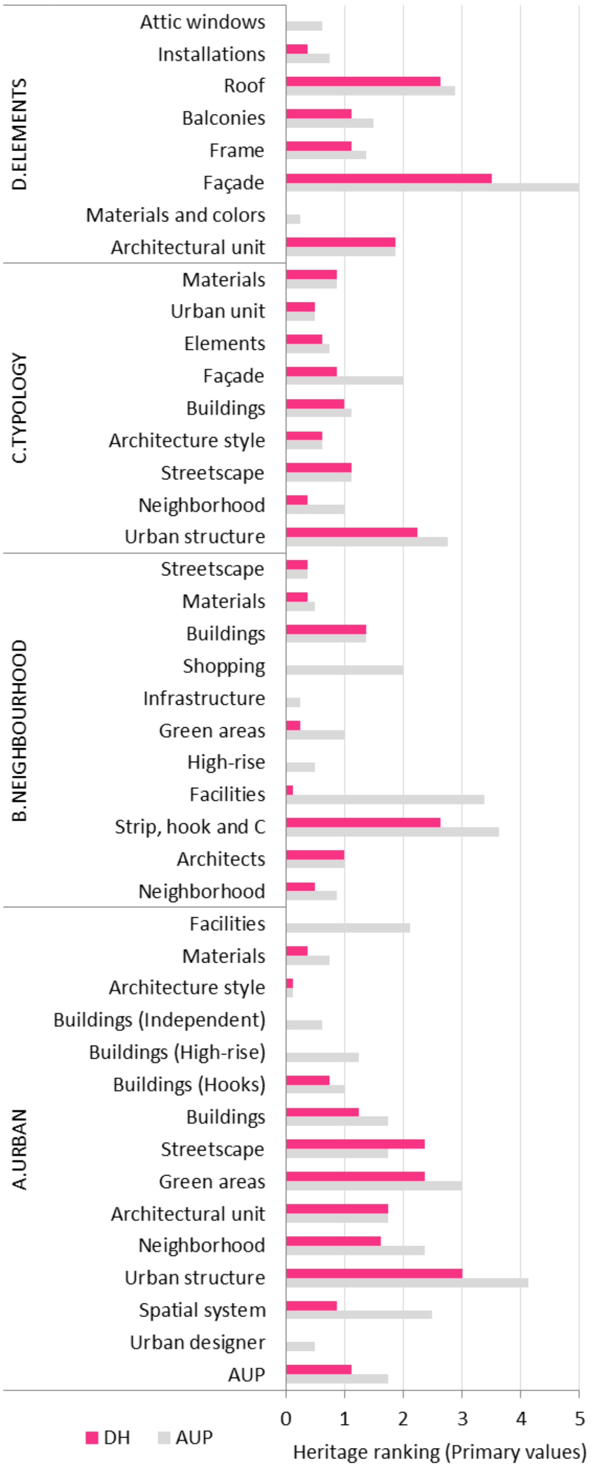


Figure 6-17. Heritage ranking of Attributes by Significance Scale

A summary of the attributes with the highest rating is as follow:

A. Urban

The **urban structure** presents correlation between public space, green areas and the building. The parceling system creates a rhythmic composition of size and scale, following a sequence: residential area, field, allotment, architectural unit and building. Moreover, it is mostly open with strip building surrounded by courtyards or greenery.

B. Neighbourhood

The **strips, hooks and courts** buildings present architectural entity with its own characteristics by composing carefully the architectural unit with a clear building mass. The use of traditional materials is mostly used (masonry and sloped roofs). The design changes in the public space, therefore the façade towards the outside is of a great importance.

C. Typology

The **urban structure** value lies on its peaceful image and the functionalist urbanism structure. It is worth preserving the way the urban structure is translated into the architecture.

D. Building elements

The **façade** towards the public have accessible windows. The consistency and rhythm on the façade gives value to the streetscape. The materials and color should be equal or similar to the main building and surroundings. It should be maintained and restored the original elements in shape, size, material, detail, proportion and color or design.

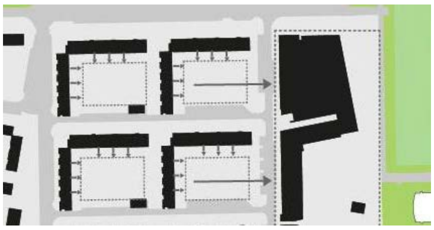


Figure 6-18. Urban structure

The following drawings and diagrams are intended to identify the most valuable attributes within the case study. They mean to solve the lack of information regarding the values of the Dudokhaken. It is an attempt to present some of the attributes. However, it is important to identify all of them in order to confirm the text studied.

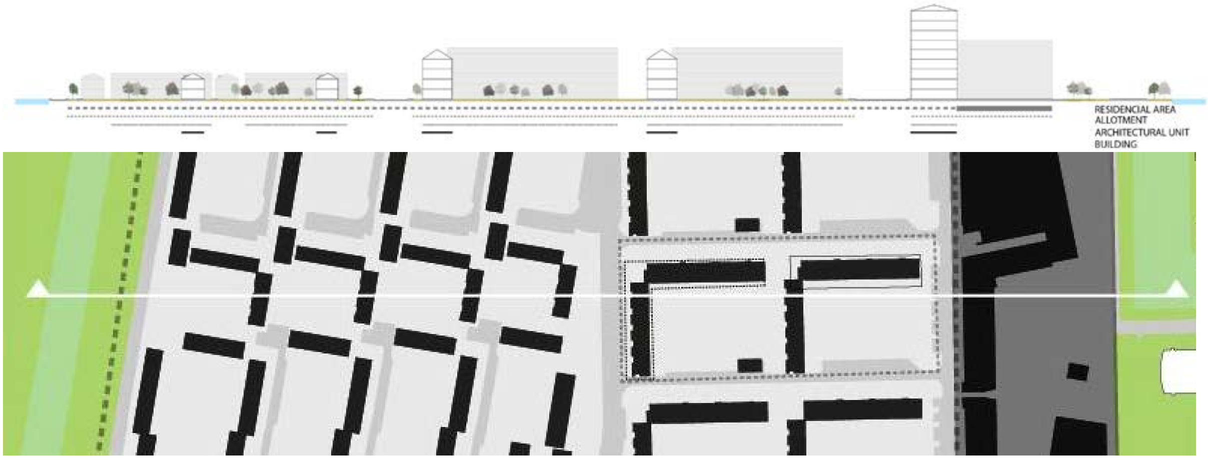


Figure 6-19. Urban structure. Rhythmic composition of size and scale

Figure 6-20. Neighbourhood. Building mass

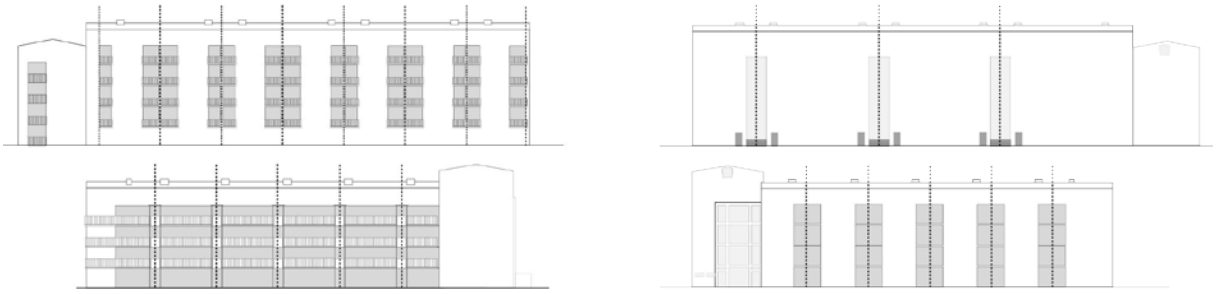


Figure 6-21. Typology. Public vs Semi-public (Courtyard)

Figure 6-22. Building Elements. Balconies and windows.

7 RENOVATIONS AND POSSIBLE INTERVENTIONS

7.1 RENOVATIONS OF THE CASE STUDY

The Dudokhaken has been renovated thought the years. As stated previously the main reason of the development of the AUP areas was due to dwelling shortage, therefore a mass production of dwellings was held (Bijlsma, Bergenhenegouwen, Schluchter, & Zaaijer, 2008, p. 75). The consequence nowadays is a poor performance of buildings that do not meet with today's standards (Schilt, 2013). Therefore, during the seventies and eighties an urban renewal took place to enhance the performance of current Dutch building stock (Bijlsma, Bergenhenegouwen, Schluchter, & Zaaijer, 2008, p. 52). Within the district of Geuzenveld and Slotermeer an urban renewal took place in 2003. The *Parkstad 2015* was based on an analysis that highlighted some issues, such as lack of insulation, noise and poor moisture resistance (Aukes, B., 2007 P.41). It was envisioned as an urban renewal with the 2015 as a main target. It included demolitions, constructions and renovation of the Dudok, Bakema, Van Tijen and Wegener Schleswig areas.

1957:

Construction details (U-value):		Systems:
External Wall	1.78 W/m2K	Natural ventilation
Internal Wall	2.28 W/m2K	Collective CV
Ceiling/Floor	2.15 W/m2K	
Windows	4.13 W/m2K	
Ground Floor	3.10 W/m2K	
Roof	2.32 W/m2K	

2008:

Construction details (U-value):		Systems:
External Wall	0.53 W/m2K	Natural inlet
Internal Wall	0.22 W/m2K	Mechanical outlet
Ceiling/Floor	0.60 W/m2K	District heating
Windows	2.51 W/m2K	Radiators
Ground Floor	3.10 W/m2K	
Roof	0.22 W/m2K	

Figure 7-1. Evolution of the Dudokhaken

In 2008,the Dudokhaken was renovated as part of the Parkstad 2015 urban strategy. The architectural firm in charged was Van Schagen architekten. The project was thought to be built in different phases but due to crisis two out of the six buildings were renovated. The rest of the buildings were later renovated without following the current design[2]. The main visible intervention is the on-top dwellings (Figure 7-4), where the dry-attics were originally located. The addition accommodates extra apartments. The general changes are the followings:

- On-top dwellings (See Appendix B, Figure 0-1)
- HR++ glazing and window ventilation grilles
- Bigger apartments, changes on the internal organization of the building
- Expansion of the lobby, as well as lift addition (See Appendix B, Figure 0-2)
- Expansion of the balconies
- Floor After insulation on the Gallery building
- Internal insulation (See Appendix B, Figure 0-3)
- Ceiling/Roof insulation
- Mechanical ventilation
- District heating

---

[2] These renovations were not studied during this research.

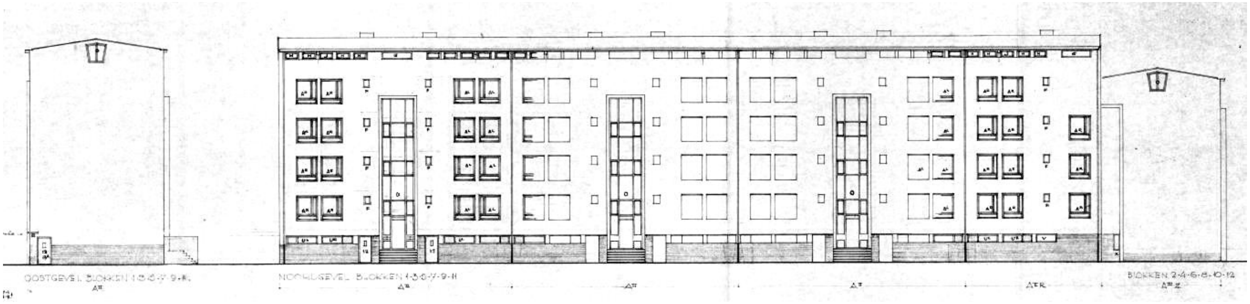


Figure 7-2. North Façade, Pre-case (Original)

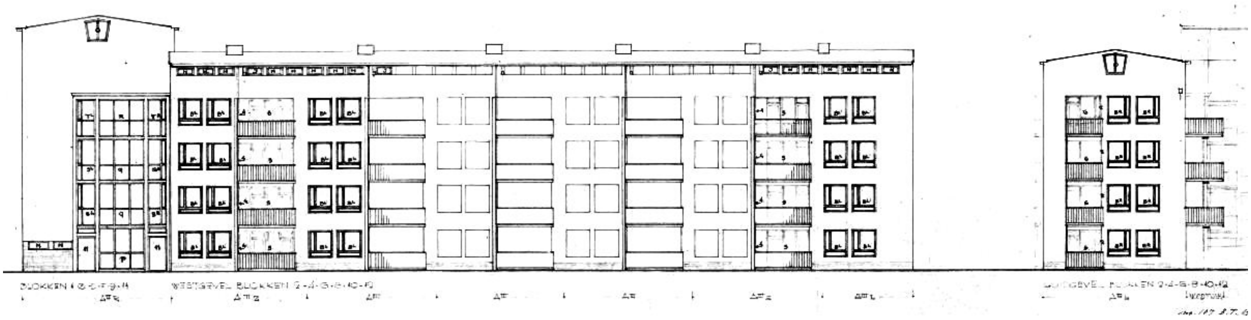


Figure 7-3. West Façade, Pre-Case (Original)

Figure 7-4. North Façade, Base-Case (Current)

The renovation plan developed by Van Schagen Architekten aimed for higher-quality dwellings thought for starters, the elderly, families and small households. The buildings are divided into rental for social housing (three eastern blocks) and for sale (three western blocks). The apartments were increased from 312 to 339, resulting 27 additional dwellings with the additional on-top dwellings (Van Schagen Architekten, 2008, p.11).

7.2 POSSIBLE INTERVENTIONS

The possible interventions proposed are related to the macro research followed prior to this research. It was previously studied the interventions that are applied in a building in order to upgrade its energy performance, by analyzing the energy label (Original and Current). The current Energy Label calculation is defined by RVO as *Definitief Energilabel,* based on the NEN 7120 NV (RVO, 2014c). The calculation method is determined by 10 parameters, which are subdivided into 34 sub-categories. Assumptions are made, based on year and typology of the dwelling. The parameters are divided into glazing, insulation of the envelope, systems and solar systems. For the purpose of this research the systems were not taken into account as possible interventions. The interventions proposed are the following:

Windows:
- HR++
- Triple glazing

Walls:
- External insulation, type A. Insulation on the side walls (Base-case)
- External insulation, type B. Different render to the original
- Internal insulation, type A. After insulation (Base-case)
- Internal insulation, type B. Extremely good insulation
- Cavity insulation.

Ceiling/Floor:
- Insulation ceiling. After insulation
- Insulation Ceiling/Floor. Extremely good insulation

Roof:
- External insulation. Extremely good insulation
- Internal insulation. Extremely good insulation

Renewable sources (Solar systems):
- PV panels Roof, type A. Same inclination as the roof
- PV panels Roof, type B. Optimum inclination
- PV panel Façade, type A. To be placed on the balconies
- PV panel Façade, type B. To be placed on the non-openable windows
- Solar collector

Additions:
- External blinds, type A. All windows.
- External blinds, type B. Sliding glazed doors only, located on the balconies.
- External blinds, type A. All windows.
- External blinds, type B. Sliding glazed doors only, located on the balconies.
- New roof*

The additions were chosen for several reasons. The use of shading allows the optimization of natural light. At the same time, it is possible to control the solar gains allowing them during winter while acting as protection during summer (Troi , A., & Bastian, Z., 2015, p, 150). Additionally, internal blinds are mostly use in dwellings therefore the impact on the heritage values as well as the energy performance of the building is important for this research. Lastly, the on-top apartments were studied since they are considered in the last renovation of the case study.

7.3 HERITAGE IMPACT

The analysis of possible interventions has the purpose on identifying the impact that they may have on the heritage significance of the building by answering SQ2: What is the impact on the heritage value of a building when an intervention occurs? The Heritage Impact (HI) is deduced by identifying the attributes that may be affected of each intervention. At the same time, the specific quotations are studied, since an intervention may affect only some primary values. Therefore and following the methodology, another question was formulated: How are the identified attributes affected by the possible interventions? The specific attributes affected by each intervention are presented in Appendix B, Table 4A and 4B.

7.3.1 RESULTS AND DISCUSSION

IMPACT OF POSSIBLE INTERVENTIONS

The interventions that are exposed towards the outside have higher HI. Especially the ones implemented in the façade, since, it is the attribute with the highest HSR. The scale which is impact the most is the typology (C). The urban scale (A) seems to have the least impact (Figure 7-6). When comparing the HI with the HSR (Figure 6-15) the urban scale, which has the highest ranking, will be less affected. While the typology, being less important, will have a higher impact. Moreover, the intervention with the highest HI is the new roof presenting impact on the typology (C) and building elements (D).

Finally, the overall impact per intervention (Figure 7-5) is less than 2, being the new roof and external insulation A the interventions with higher impact. Even though the HI seems to be adequate for a renovation of a highly valuable building, it is important to take into account that most of the renovations will consider several interventions that consequently will increase the HI.

Impact of the Base-case

The base-case (Dudokhaken) has already a HI. The Figure 7-7 shows that the urban scale has a HI of 1, while the neighbourhood 1.5 which is less than 2.5 on the building elements. While, the highest HI is in the typology, being 2.6. The intervention which impacted the most is the on-top apartments which have changed the streetscape of the area. This intervention is irreversible as the old roof is lost, however other aspects are assumed to be gained.

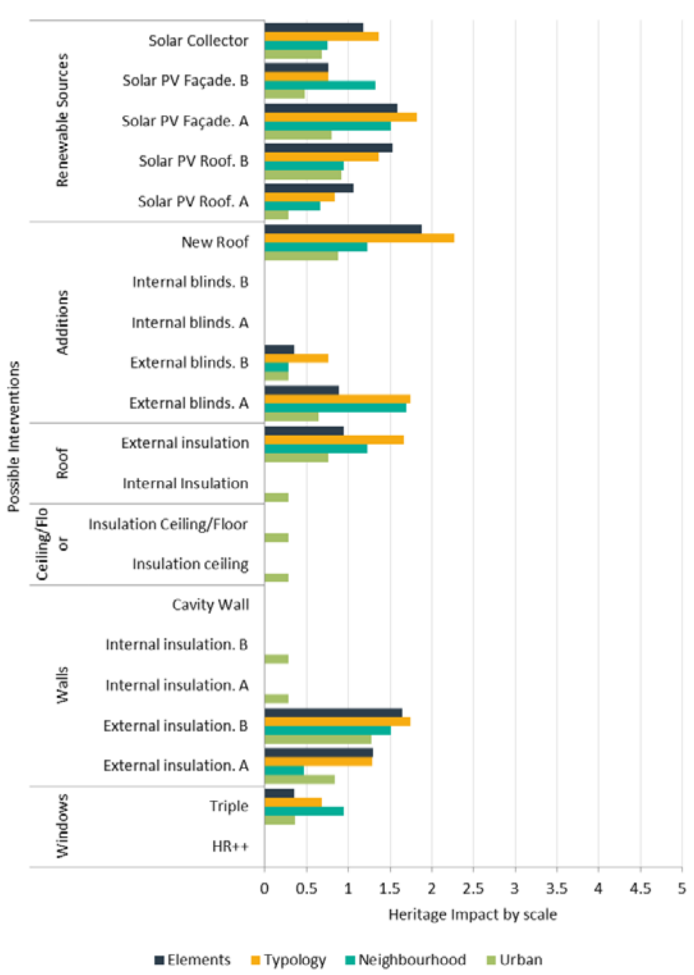


Figure 7-6. Heritage Impact of interventions by Scale

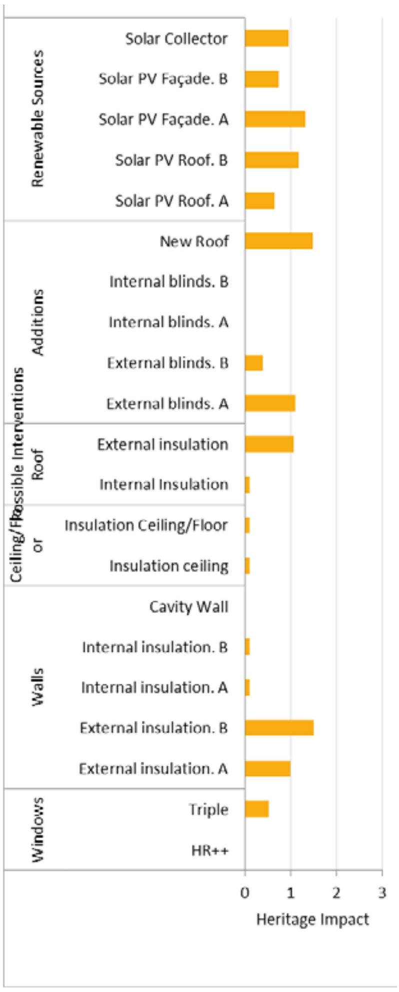


Figure 7-5. Heritage Impact of interventions

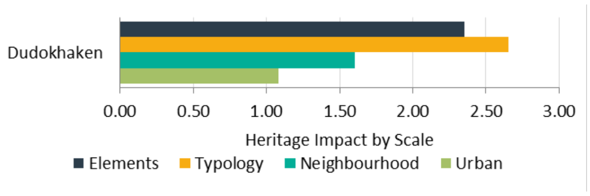


Figure 7-7. Heritage impact of Base-case

8 ENERGY PERFORMANCE AND SAVING POTENTIAL

The prediction of the energy performance of future interventions is crucial during the planning of a renovation (Troi & Bastian, 2015, p, 99). This chapter aims to answer the last SQ3: What is the saving potential of possible interventions? Dynamic simulations were performed in IES VE of the different cases. Firstly, simulations of the Pre-case and Base-case were performed. Secondly, a sensitivity analysis was performed, by simulating each intervention on both, Pre-case and Base-case. However, for the simulations done to the Base-case some of the interventions were already implemented, thus those interventions were not considered in the sensitivity analysis of the Base-case.

8.1 MODEL DESCRIPTION

The model used for the simulations were based on the cluster of the apartments on the edge. For the Portico, module A was modelled (Figure 8-1) and for the Gallery, module B (Figure 8-2). This made possible the comparison between both typologies. The on-top apartments were not considered within these modules in order to compare later on, the results of the Pre-case and Base-case.

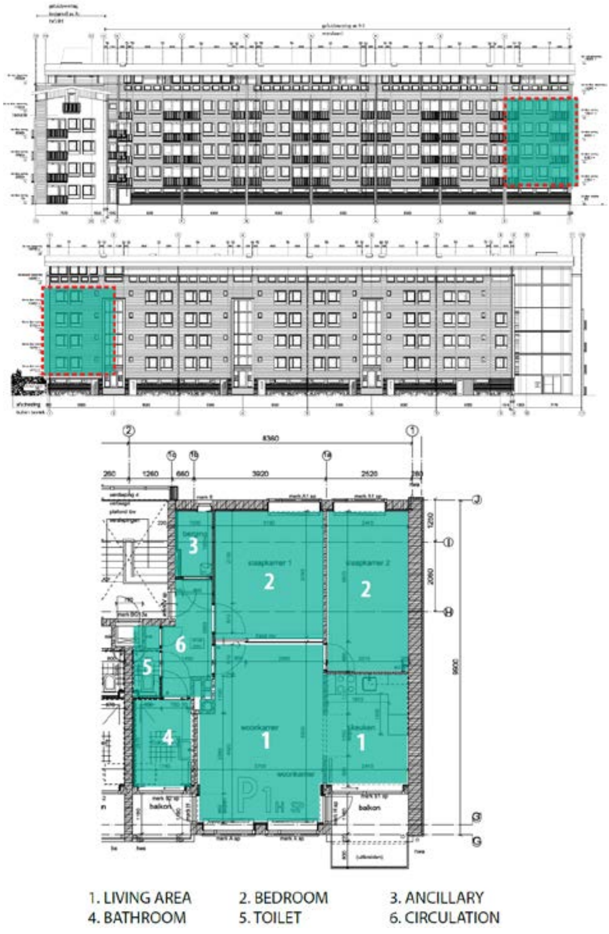


Figure 8-1. Module A (Portico)

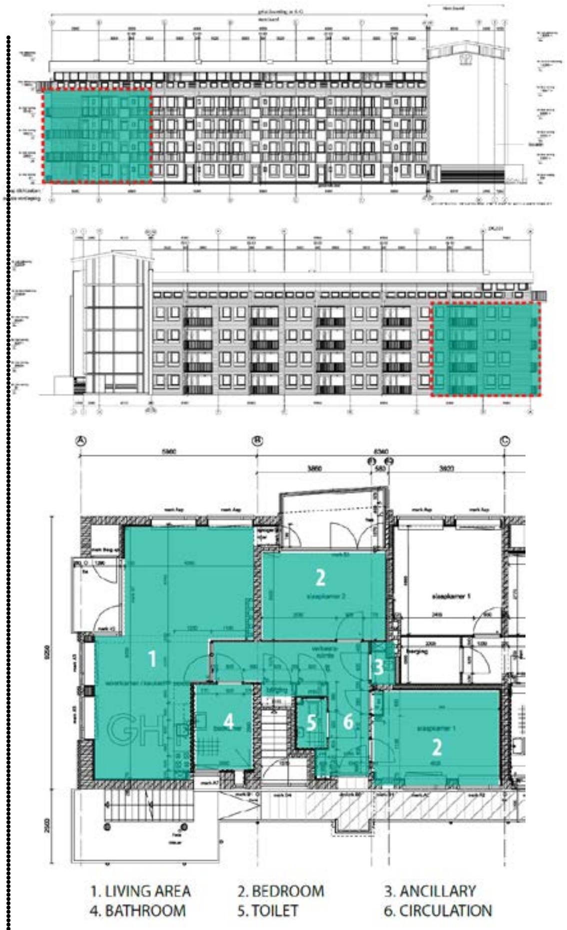


Figure 8-2. Module B (Gallery)

8.2 ASSUMPTIONS

The simulations of the apartments were created by using six different thermal zones (Figure 8-1 and Figure 8-2).The occupancy profile and set point temperature are related to each of the thermal zones. For specifications regarding occupancy profile, set point, construction details and systems of the Pre-case and Base-case see Appendix C.

The chosen energy performance indicator is space heating or Energy Needed for Heating (ENH). Therefore, the values for ventilation, lighting as well as DWH are considered the minimum average of a household. Moreover, the energy produce by the solar energy is calculated by means of the general building and then subtracted to Space heating.

8.3 RESULTS AND DISCUSSION

8.3.1 ENERGY PERFORMANCE

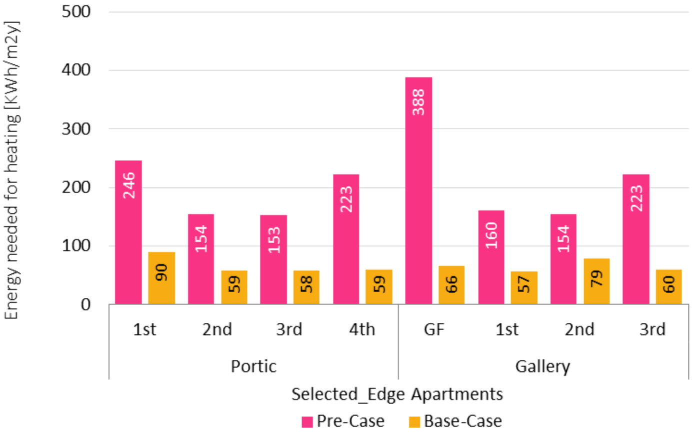


Figure 8-3. ENH per Apartment and Module

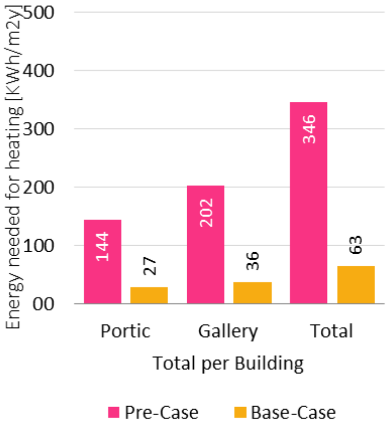


Figure 8-4. ENH per Typology

Firstly, the energy performance is compared between the Pre-case and Base-case, by module (Figure 8-3), and typology (Figure 8-4). For the Pre-case, the apartments of the Portico consume less ENH, being the highest consumption of 246 KWh/m2year in the 1st floor. On the other hand, the Gallery presents the highest consumption on the ground floor since it is in direct contact with the ground, being 66% more than the 1st floor of the Portico. The Base-case presents an average reduction of 66%. The highest reduction is achieved in the ground floor apartment of the Gallery, with 83% reduction. The least reduction was found in the second floor of the Gallery, with 49% reduction. Finally, the highest consumption is presented in the apartment which consumed less ENH of the Pre-case, the first floor of the Portico (90 KWh/m2year).

The reduction of the typologies is proportional within each building, being 82%. The pre-case consumed an average of 346 KWh/m2year, while the base-case 63 KWh/m2year of space heating. It can be regarded how the Gallery shares 58% of the consumption of the whole building. This is mainly due to its orientation, as the facades are mostly exposed towards East and West.

8.3.2 SAVING POTENTIAL

COMPARISON TO THE PRE-CASE

The saving potential is first compare to the Pre-case. The Portico (Figure 8-5) shows a significant reduction of around 50% in the middle apartments (2nd and 3rd floor), when using internal insulation and external insulation, the latter being slightly better. The glazing upgrading shows as well more reduction in the middle apartments, being 30% reduction. While the ceiling and floor insulation have more influence in the 4th and 1st floor apartments (more than 30%). Moreover, the roof shows a reduction in the top apartment (4th).

The Gallery's apartments (Figure 8-6) are slightly similar to the Portico, however, the reduction with wall insulation is more, being around 57% (1st and 2nd). The glazing upgrading, cavity wall and ceiling/floor insulation reduces less space heating than in the Portico, while the roof insulation reduces slightly more. This is due to its orientation; more efficient measures are needed within this typology, as is the case for the solar energy which is more efficient when orientated towards East/west for this case study.

The major reduction of the typologies is presented installing solar collector and wall insulation, which influences more the Portico. The new roof and the glazing upgrading have the major reduction (Figure 8-7). An important remark is that the HR++ is slightly better than the triple glazing, because of the envelope efficiency. Triple glazing will not be efficient when the envelope has poor performance, since there will be heat losses through the envelope, that influences the performance of the building.

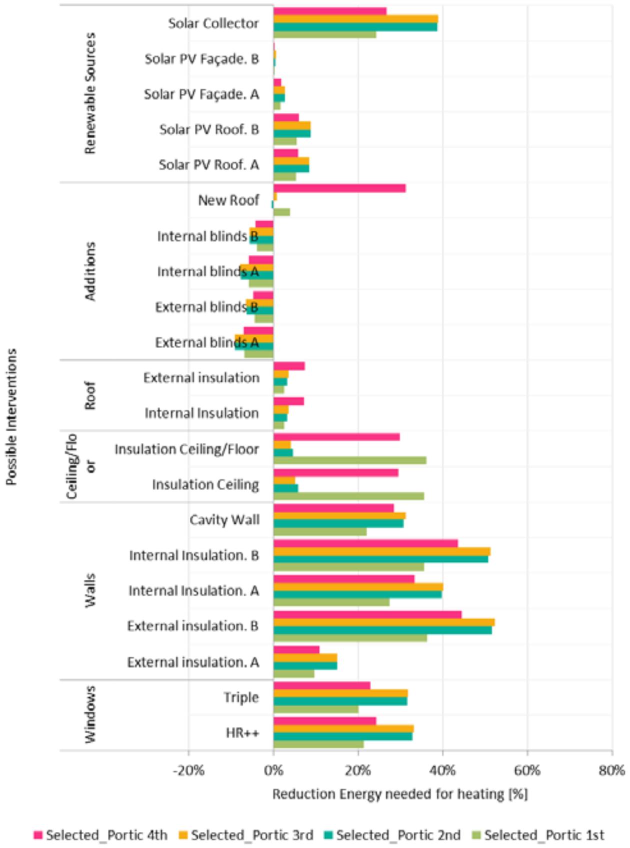


Figure 8-5. ENH reduction by Module A (Portico) compare to Pre-Case

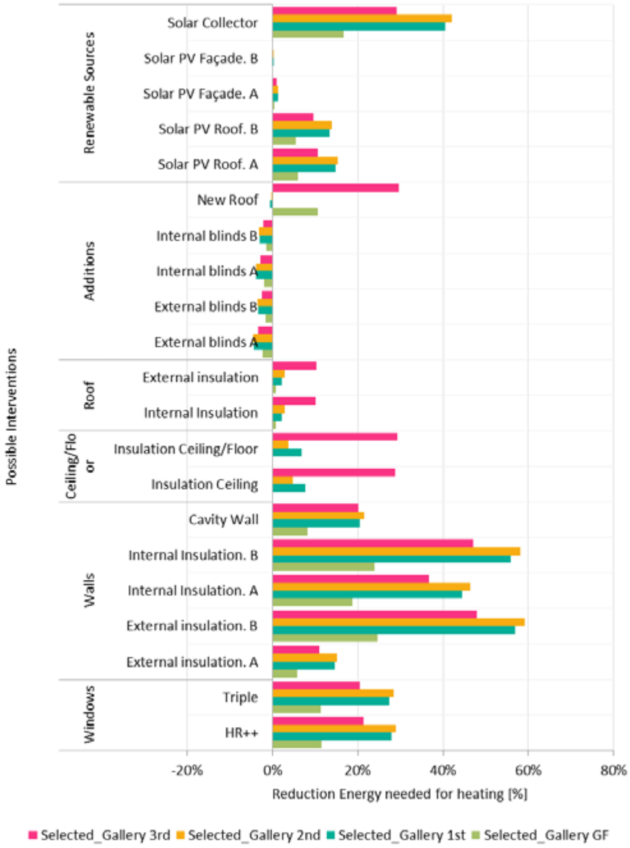


Figure 8-6. ENH reduction by Module B (Gallery) compare to Pre-Case

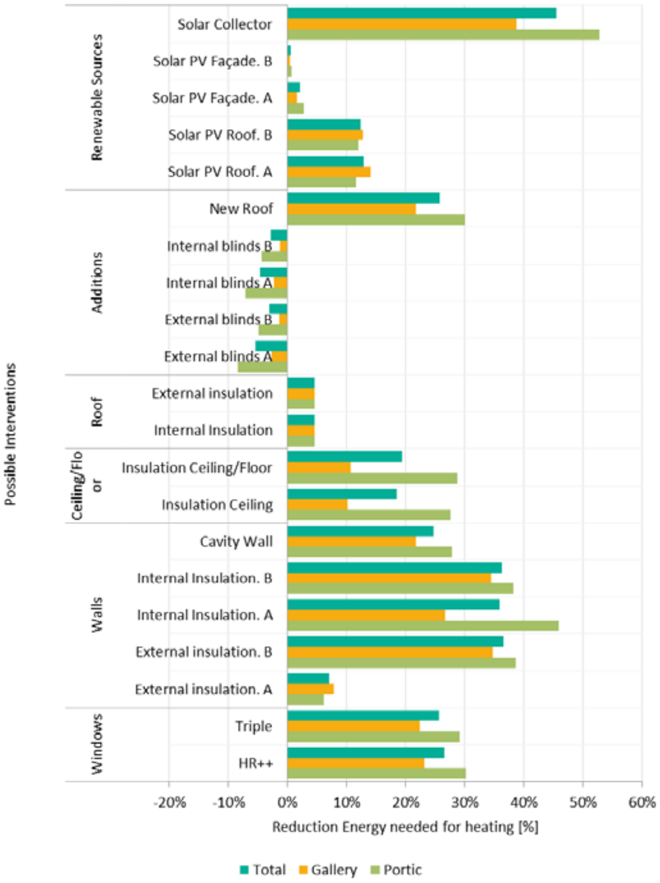


Figure 8-7. ENH reduction by Typology compare to Pre-case

COMPARISON TO THE BASE-CASE

The possible interventions are also compared to the Base-case. The apartments in the Portico show more reduction when placing solar collector, slightly more than 100% (Figure 8-8). This means that the energy obtained is sufficient for all the apartments of this module. The walls insulation shows around 30% reduction, being higher the influence in the middle apartments. Moreover, the triple glazing appears to have a better performance than the HR++, being less than 20% difference. This confirms the previous statement regarding the efficiency of the envelope. Lastly, the blinds shows additional ENH since it is only considered space heating as the energy reduction.

The apartments in the Gallery have slightly different results (Figure 8-9). The triple glazing, external insulation and solar energies, especially the PV panels on the roof, have more reduction than in the Portico. As in previous discussion the solar energy provides more energy due to its orientation. The typologies and total ENH of the building (Figure 8-10), shows that there are still some improvements to be done to the building which will allow the building to have need less space heating. It is evident that the solar energies play a major role in the reduction of space heating.

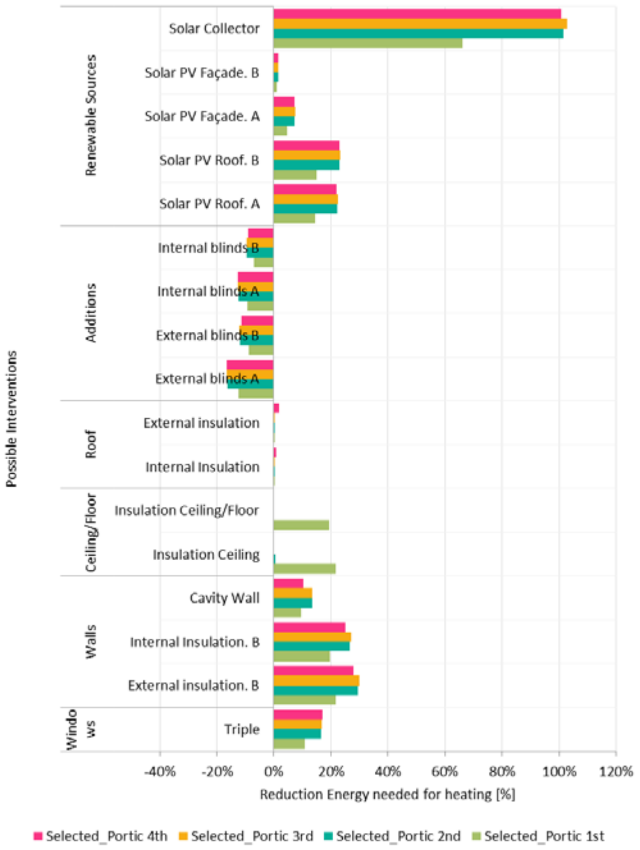


Figure 8-8. ENH reduction by Module A (Portico) compare to Base-Case

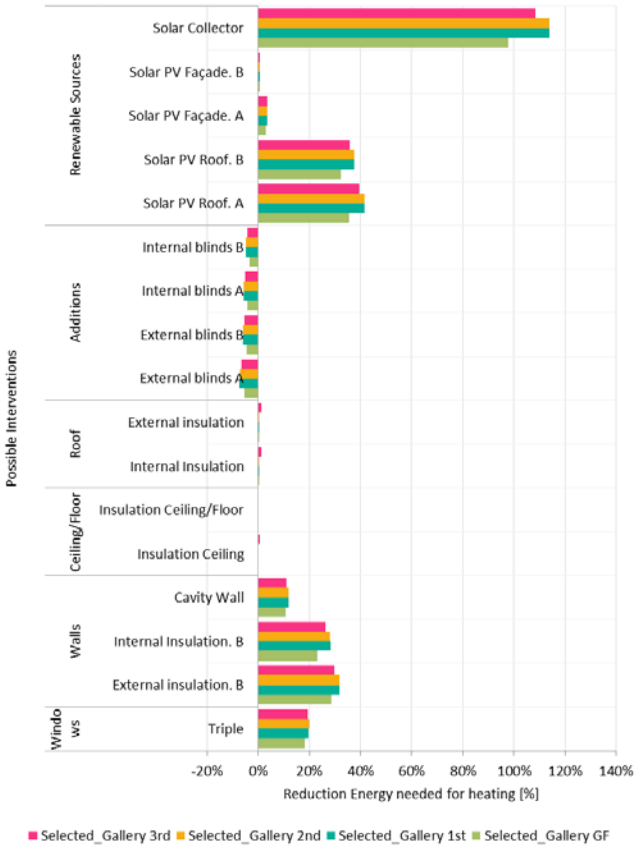


Figure 8-9. ENH reduction by Module B (Gallery) compare to Base-Case

Figure 8-10. ENH reduction by Typology compare to Base-Case

9 DESIGN STRATEGIES

Prior to explore new solutions, which will balance HI and energy reduction; a comparison between these concepts is needed to determine the most suitable solution for the case study. The analysis compares the interventions to the Pre-case and the Base-case.

9.1 COMPARATIVE ANALYSIS

9.1.1 COMPARISON PRE-CASE

As the results regarding HI and energy reduction were already discussed in previous chapters the discussion will focus in the comparison only. The apartments of both typologies show a correlation between energy reduction and HI, since when the energy reduction is higher, so is the HI (Figure 9-1 and Figure 9-2). Nevertheless, there interventions places towards the inside of the apartments have negative correlation, as the energy reduction is significant while the historical value is barely affected.

The upgrading of the windows show that HR++ achieved the same reduction as the triple glazing, however, the former does not have HI. For the solar energies, they all present HI, being the PV panels on the roof, type A the ones with less HI and a reduction of less than 20%.

The comparison of the typologies and the total architectural unit confirms previous results, since the external insulations and new roof have more energy reduction and higher HI (Figure 39). However, it is visible that significant reduction can be achieved without affecting the heritage of the building.

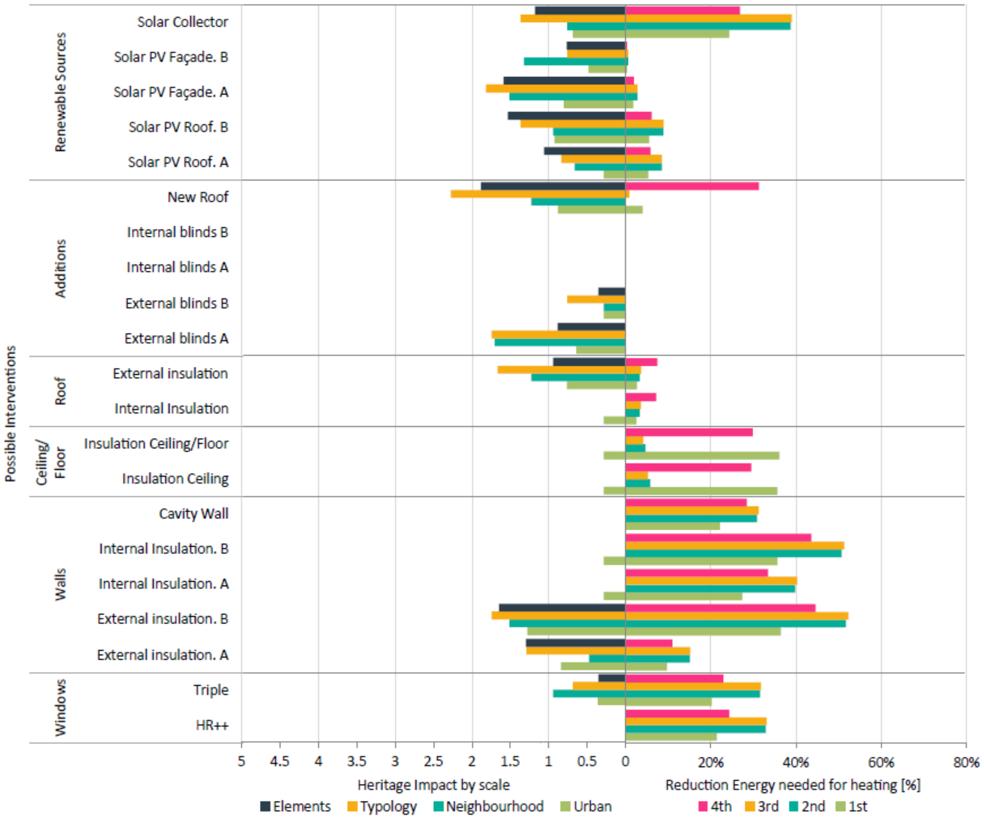


Figure 9-1. Comparative analysis by Scale of significance and Module A (Portico)

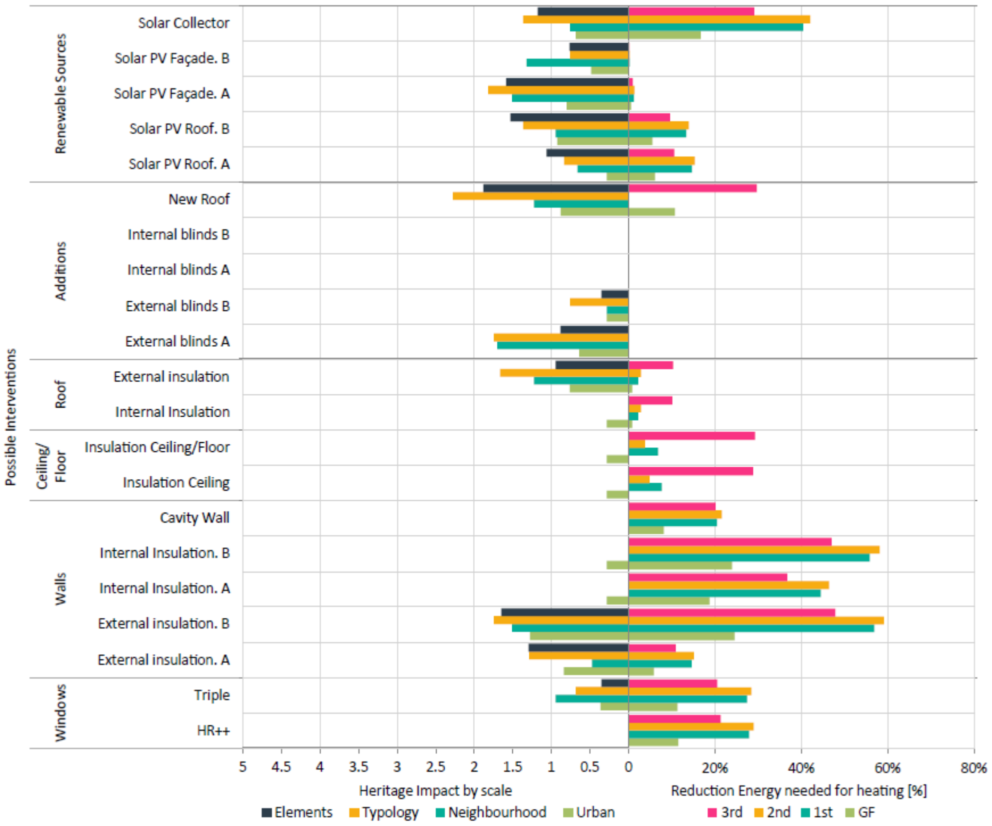


Figure 9-2. Comparative analysis by Scale of significance and Module B (Gallery)

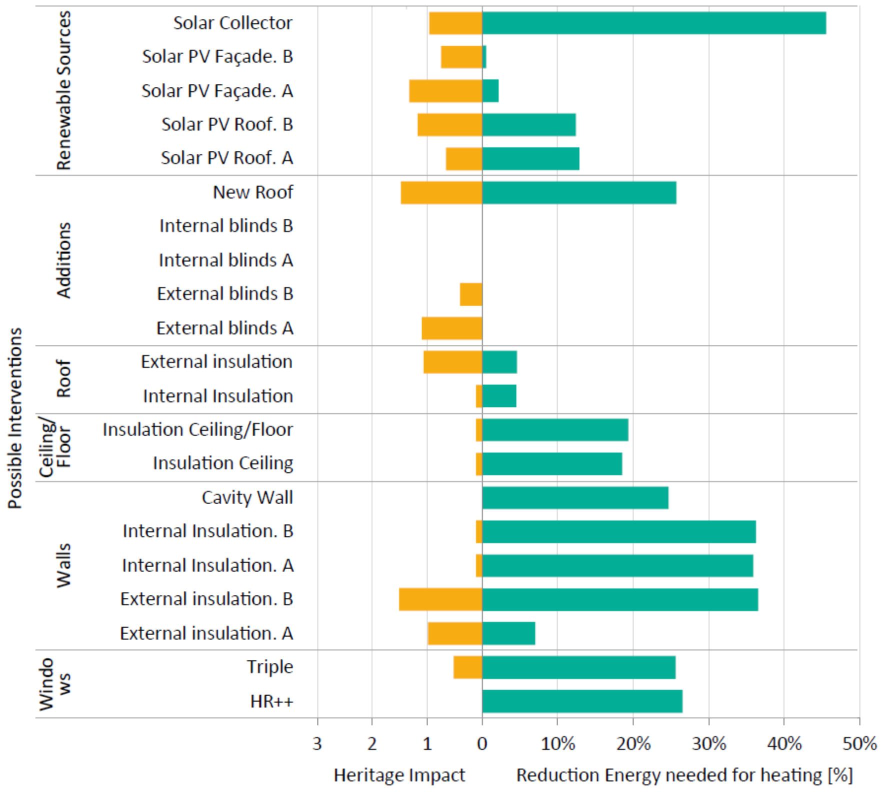


Figure 9-3. Comparative analysis heritage impact and energy reduction

9.1.2 COMPARISON BASE-CASE

The analysis of the apartments according to their typologies is presented in Figure 9-4 and Figure 9-5. From previous analysis regarding the energy performance the interventions which reduced more space heating are the solar collector, external insulation, internal insulation and triple glazing. The last two interventions show less HI, therefore they should be preferred when optimizing the building. The glazing upgrade seems to have significant energy reduction. Even though, it would be expected that the building elements will be affected the most, the neighborhood scale shows higher HI. The solar energies show a higher HI and significant energy reduction. However, since the typology of the case study is of a multifamily the use of them could be restricted and not completely be beneficial by a single unit (apartment)

The comparison between of the architectural unit (both typologies) shows some differences between the previous comparisons (Figure 9-6). The correlation between HI and energy reduction is negative, since higher energy reduction does not mean higher HI. The solar collector shows a great reduction with an HI less than 1.

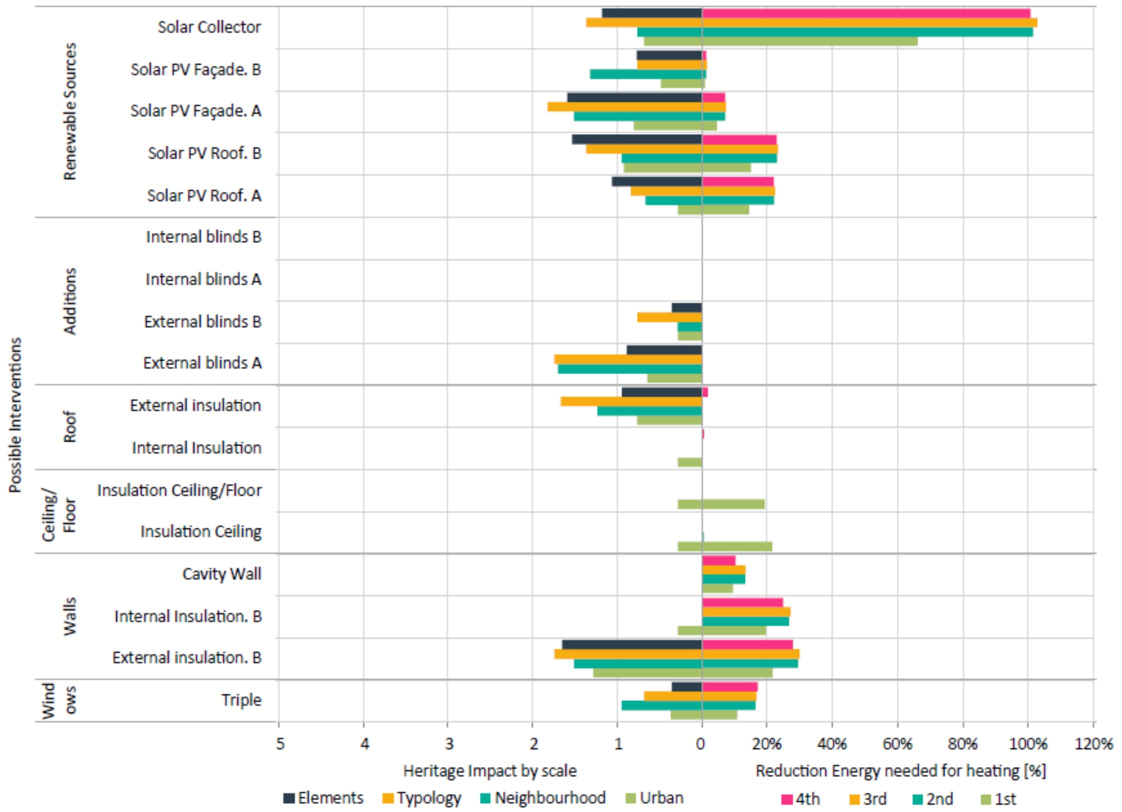


Figure 9-4. Comparative analysis by Scale of significance and Module A (Portico)

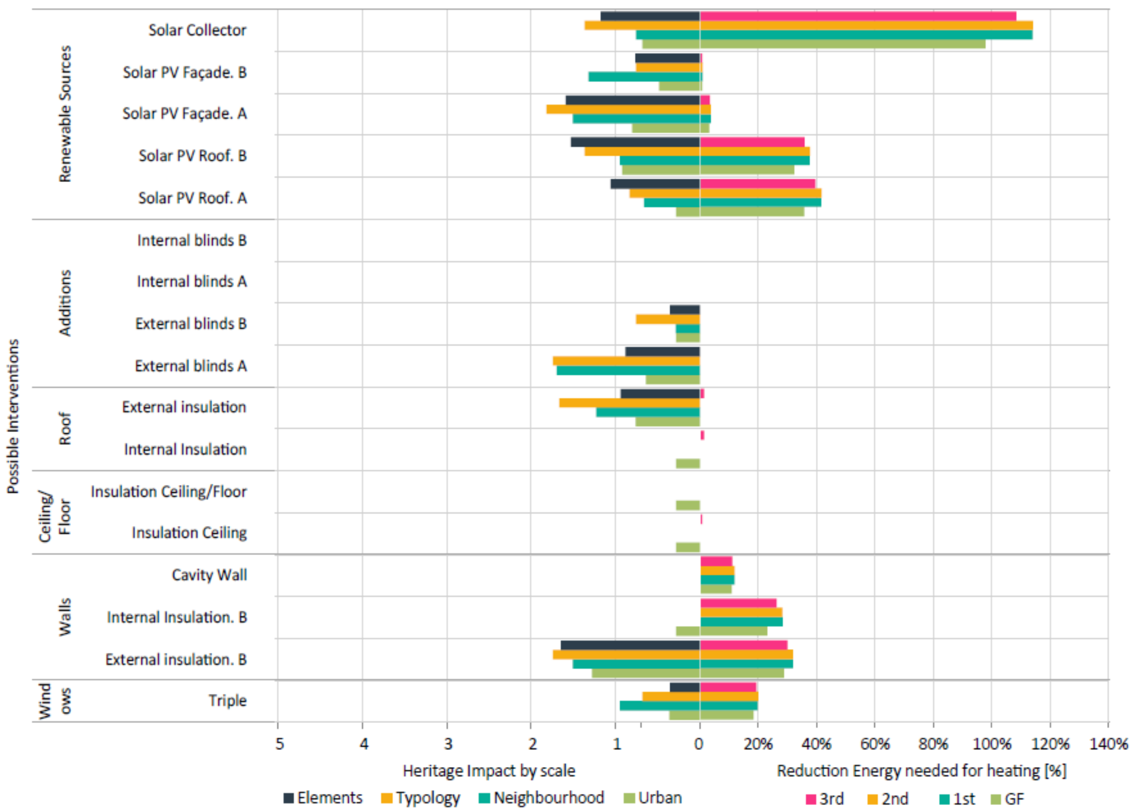


Figure 9-5. Comparative analysis by Scale of significance and Module B (Gallery)

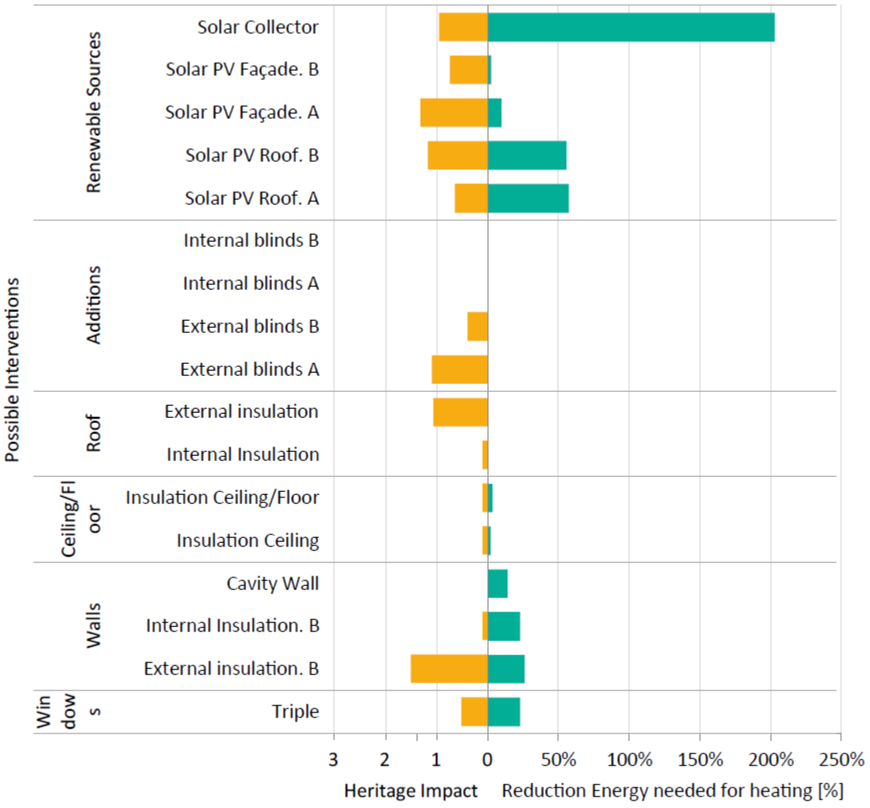


Figure 9-6. Comparative analysis heritage impact and energy reduction

9.2 BALANCE RENOVATION

After the comparative analysis several interventions were combined in order to analyze their energy performance and HI. The interventions were chosen when the reduction of the energy is significant but they do not have considerable impact on the historical values of the building. Three solutions were analyzed. The first aims for an optimization of the base-case, while the other two serve as a discussion for the base-case. Their target is to achieve a balance between both aspects (heritage value and energy reduction). The three solutions are the following:

- Optimized: Base-case + extra interventions, such as: cavity wall insulation, extra internal insulation, extra ceiling/floor insulation, roof insulation, triple glazing and PV panels Roof, type A.
- Balance 1: Pre-case + Base-case systems (Without on-top apartments) + Extra interventions, such as: cavity wall insulation, extra internal insulation, extra ceiling/floor insulation, roof insulation, HR++ glazing and PV panels Roof, type A.
- Balance 2: Pre-case + Base-case systems (Without on-top apartments) + Extra interventions, such as: cavity wall insulation, extra internal insulation, extra ceiling/floor insulation, roof insulation, triple glazing and PV panels Roof, type A.

The U and Rc values are visible in Table 9-1, for further details regarding the construction details as well as the systems see Appendix D.

		Pre-case		Base-case		Optimal		Balance 1		Balance 2	
		U-value W/m2K	R-value m2K/W	U-value W/m2K	R-value m2K/W	U-value W/m2K	R-value m2K/W	U-value W/m2K	R-value m2K/W	U-value W/m2K	R-value m2K/W
External Wall	1	1.78	0.39	0.60	1.50	0.14	7.20	0.14	7.20	0.14	7.20
	2	1.90	0.35	0.57	1.57	0.14	7.03	0.14	7.03	0.14	7.03
	3			0.53	1.73	0.19	5.21	0.19	5.21	0.19	5.21
	4			0.19	5.20	0.19	5.20				
Internal Wall		2.29	0.18	0.59	1.43	0.59	1.43	0.59	1.43	0.59	1.43
Ceiling/Floor	1	2.43	0.21	0.00	0.00	0.22	4.41	0.22	4.41	0.22	4.41
	2	2.09	0.28			0.22	4.41	0.13	7.71	0.13	7.71
	3					0.13	7.71				
Roof		2.32	0.29	0.22	4.40	0.22	4.40	0.13	7.40	0.13	7.40
Ground Floor	1	3.10	0.11	3.10	0.11	3.10	0.11	3.10	0.11	3.10	0.11
	2			0.12	8.73	0.12	8.73	0.12	8.73	0.12	8.73
Window	1	4.14	0.18	2.16	0.62	1.85	1.00	1.85	1.00	1.54	0.80
	2	4.99	0.18	2.72	0.37	1.34	1.00	1.34	1.00	1.98	0.80
	3	5.42	0.18	2.53	0.61	2.09	1.00	2.09	1.00	2.26	0.80

Table 9-1.U and Rc-values of all cases

9.2.1 RESULTS AND DISCUSSION

ENERGY PERFORMANCE

The energy performance of all cases is shown in Figure 9-8. The Optimized and Balance 2 case seem to have similar space heating consumption, differing only in the apartments on the top (4th of the Portico and 3rd of the Gallery). This is due to the fact that the new floor made the Base-case more efficient.

The apartments in the Portico show a better performance for the middle apartments. The average space heating consumption achieved is between 28kWh/m^{2}y and 24kWh/m^{2}y. Similar are the results for the apartments in the Gallery, with less space heating consumption of between 21kWh/m^{2}y and 25kWh/m^{2}y. The Optimized case is the most energy efficient. The Balance cases, with a difference only in the glazing type, show a better performance in the Portico, due to its orientation towards south.

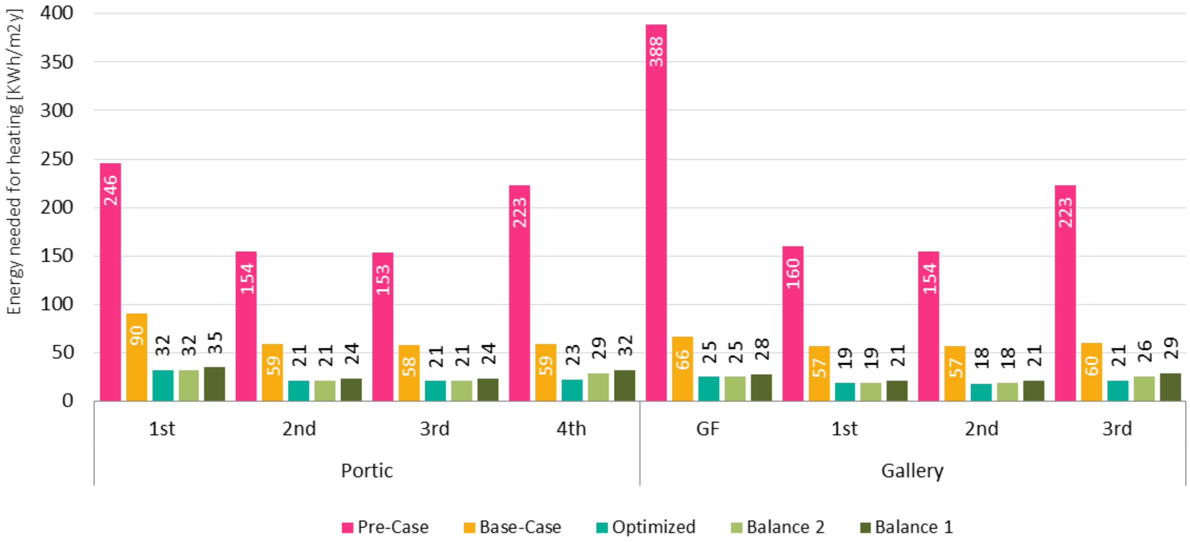


Figure 9-7. Energy needed for heating per Module by Case

SAVING POTENTIAL

The energy reduction is first compare to the Pre-case (Figure 9-10). The highest reduction is achieved in the ground floor apartment of the Gallery, while for the Portico differs in every case. The Base-case and Optimized shows higher reduction in the 4th floor apartment. While is the same case for the Balance cases, however, the same reduction is achieved in the 1st floor apartment.

The energy reduction is then compare to the Base-case (Figure 9-9) since the purpose of this research is to analyze also the latest renovation. The Optimized solution certainly achieves the highest reduction with around 65%, followed by the Balance 2, with 62%, while the least reduction is achieved in the Balance 1, being 58%.

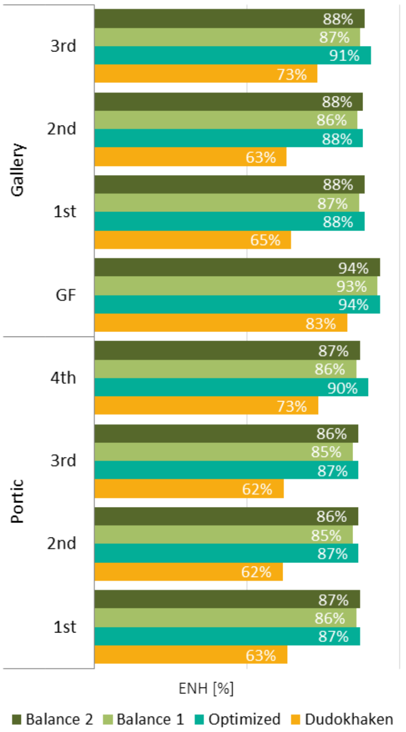


Figure 9-9. ENH reduction compare to the Pre-case

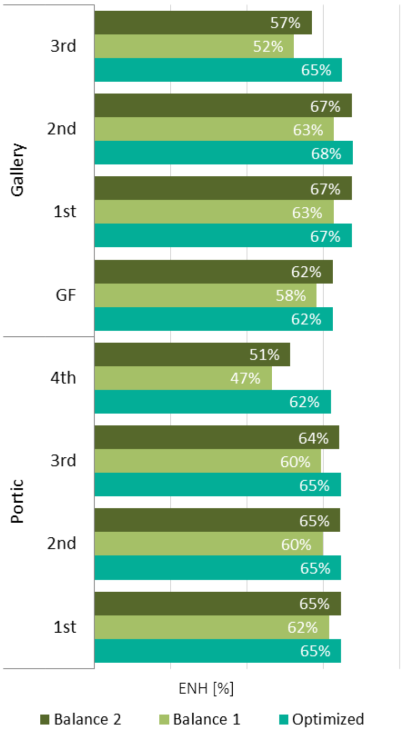


Figure 9-8. ENH reduction compare to the Base-case

COMPARATIVE ANALYSIS, HI & ENH REDUCTION

The optimization of the envelope of the case study has been proven to reduce around 80% from the pre-case and around 62% of the base-case. However, the HI should be aligning with the energy reduction strategy. The case with the highest space heating reduction is the Optimized, which presents as well higher HI. If it is only compared this case with the Base-case, the assumptions will be that with higher energy reduction, higher is the HI. Nevertheless, the balance cases show different results. The reduction achieved is higher than the Base-case, with more than 80% on both typologies, while the two scales of significance have less HI for the Balance 1, begin the Neighbourhood and Typology. The Balance 2 shows slightly more HI on the first three scales, while on the elements the increment is of around 0.5 (Figure 9-11 and Figure 9-12).

When comparing the total reduction of the architectural unit, the Balance 2 shows more energy reduction while it is not the option with higher HI. It is also visible how the Balance 1 has less HI, while achieving a significant space heating reduction in comparison with the Base-case (Figure 9-13)

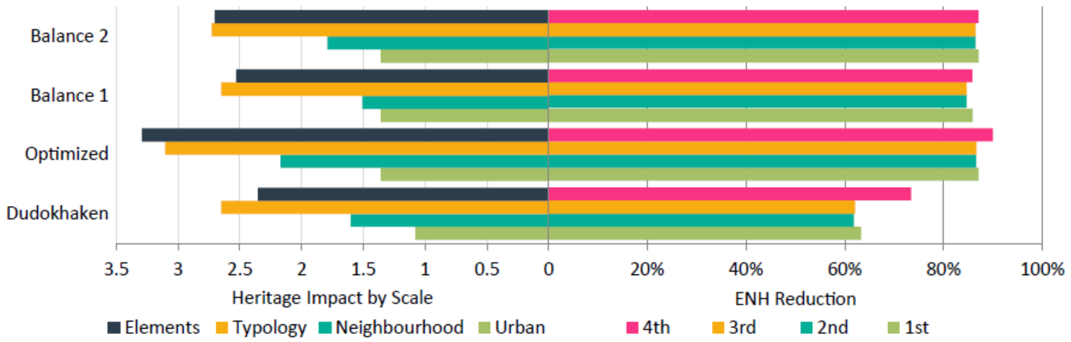


Figure 9-10. Comparative analysis per Scale of significance of Module A (Portico)

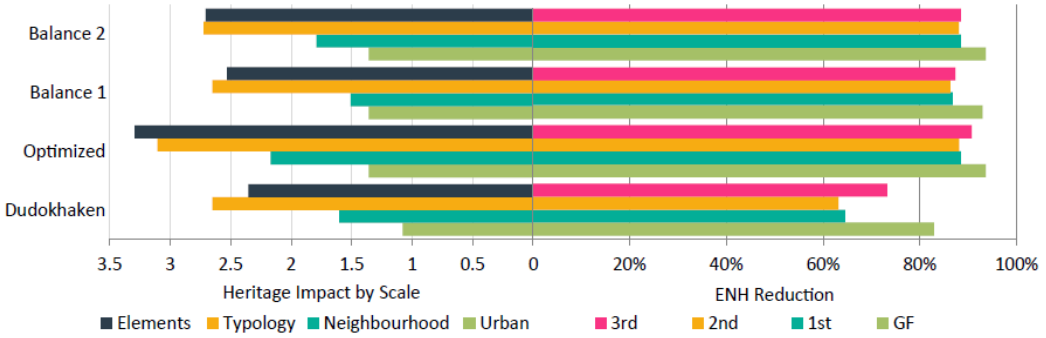


Figure 9-11. Comparative analysis per Scale of significance of Module B (Gallery)

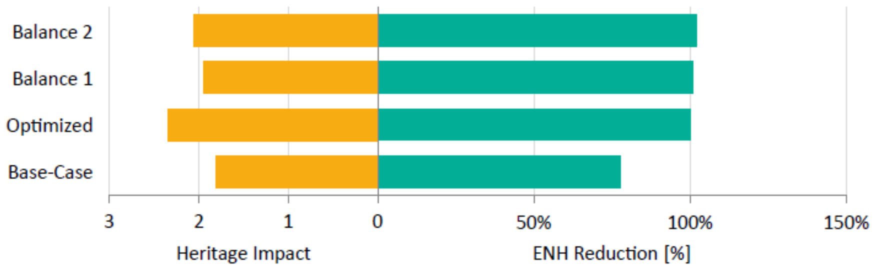


Figure 9-12. Comparative analysis heritage impact and energy reduction

9.3 DESIGN GUIDELINES

The following section approaches possible solutions to mitigate heritage impact. They intend to be use as guidelines for the interventions proposed during this research. At the same time it aim for the integration of future interventions.

INSULATION

External insulation has been proven to have a higher reduction of the ENH than internal insulation. However, the latter is preferable since it has no HI on the case study. Nevertheless, its implementation should be carefully design for avoiding thermal bridges, heat losses and condensation on the wall (Troi , A., & Bastian, Z., 2015, pp. 122) . The connections between the window and the adjacent walls should be study in detail and properly design. The use of a moister barrier is crucial to avoid condensation.

GLAZING

During renovation it is almost unavoidable to upgrade the glazing. Specially, since building before 1970 were constructed with single glazing (RVO, 2014). Triple glazing has indicated to have higher energy performance when the envelope is highly efficient (extremely good insulation). However, it represents a higher HI than HR++. Due to the size of the new frame that needs to accommodate three glass panes. A solution for a thinner frame is the use of a thin-layer glass, which reduces the width of the window and thus the frame, while achieving lower U-values (Troi , A., & Bastian, Z., 2015, pp. 144).

BLINDS

The optimal use of blinds is dependent to the season, function and orientation. During summer, external blinds avoid overheating. Whereas, for winter internal blinds are preferable in order to avoid glare while taking advantage of solar gains. Despite, the use of blinds in the case study increases the space heating needs, they can be implemented for the mentioned reasons (overheating, glare). For the external blinds, they could be restricted to be used in the secondary exterior wall, which is the exterior wall inside the balconies that has contact to the external environment but is less visible from the street. Another solution is the implementation of them on the interior facades. Lastly, the use of blinds is inevitable as it also provides privacy into the dwelling, the restriction of internal blinds cannot be implemented

ENERGY RENEWABLE SOURCES

However, the use of them represents a high HI as shown on the results of chapter 6. Therefore, tailored solutions should be applied in order to integrate them on the building. New studies have produces PV panels which match the shape and colour of a roof tile, as well as semi-transparent PV that can be implemented on the windows, providing shade as well as replacing the window glass (Troi , A., & Bastian, Z., 2015, pp. 180). Moreover, other existing PV panels can be implemented, such as: the use of PV on the rail of a balcony, the integration of them on an external blinds and integration on the roof tiles making them less visible (Polo López & Frontini, 2014, pp. 1501).

10 DISCUSSION

LACK OF INFORMATION

The city of Amsterdam offers a valuation to important buildings which are not monuments. It gives an insight into the most important aspects of a building. However, as most of the valuations, it does not provide additional details regarding the significance levels of specific parts of a building. The information analyzed made a distinction between tangible and intangible values. The former presents higher levels of understanding, since they can be interpreted more objectively. The urban scale, as part of the AUP, presents half intangible values due to the fact that it is considered an exemplary urban plan. When analyzing the attributes, the typology relates to the urban scale in one of its most valuable attributes. The translation of the urban structure into architecture should be preserved. Nevertheless, the background information of these attributes can be misleading. The interventions proposed are tangible aspects of the building that could lead to the disturbance of its intangible aspects of the buildings. For this reason, a clear understanding of the intangible values is crucial.

RETROSPECTION OF THE BASE-CASE

According to findings the current state of the building (base-case) can still be improved. It has been proven by the Optimized case that a reduction of space heating is possible. However, the larger the reduction, the higher is the heritage impact. The implementations of rigorous saving measures were not applied during the last renovation of the Dudokhaken. It seems that the materials used and systems implemented were chosen simply to meet current standards. This has resulted in an average energy label B, which will not be sufficient in the near future, as standards are stringent.

One of the main issues of the last renovation is the high heritage impact of the on-top apartments. According to conservation experts, the changes should be fully reversible, by returning to the original fabric. Even though, is not a monument, such considerations should be taken into account. Nevertheless, a critical view should be towards this reversibility. Post-war dwellings have been proven to have poor energy performance but high historical value. Therefore, one must consider which is the most important of the two variables (energy efficiency or historical value). An on-top apartment is a common measure adapted in historical buildings, due to the lack of space and in order to maintain the mass of the building. The reversibility is not possible in this case. However, when the new roof is adapted properly, the acquired space will have a positive social impact.

BIGGER SCALE INTERVENTIONS

The AUP AUP and W. Dudok agree upon the evolution of the design principles. The AUP itself says that the design principles are meant to be evolved. As for W. Dudok, he said: "…a town or a village is never complete: life means change; the living city is also in a continuous process of change." (as cited in Van Bergeijk, 2001, p.20). Therefore, if both believed in a continuous change, so should their architecture by embracing the most important features and enhance them for current needs. One of the main issues when renovating the buildings within the AUP areas is that only one or two buildings are taken into count. The object in stake should be broader.

The case study is surrounded by several buildings which were designed also by W. Dudok. By walking through this neighbourhood the streetscape is instantaneously perceived. The buildings were designed following the same pattern with repetitive façade lines and building mass that are almost identical. Thus the optimization of one building (Dudokhaken) can be applied to a bigger ensemble (Dudok area). Even though the rest of the buildings are not considered valuable, their improvement can benefit the neighbourhood and so the current valuation of the case study.

ADDITIONAL SAVING POTENTIALS

The findings regarding the energy savings have shown a reduction of space heating of around 85% in comparison with the Pre-case. Even though space heating accounts for 60% of the total amount of energy needed, additional savings are possible. The use of efficient systems along with renewable energy can decreased the energy consumption. For example, the use of heat pump together with underfloor heating can lead to higher energy reductions. Moreover, not only a renovation can achieve considerable energy reduction but these reductions can be implemented in a bigger scale, as mentioned previously. At least seven buildings have similar characteristics as the Dudokhaken. If the interventions proposed are applied, the area can become an exemplary area. The historical value can be preserved while reducing around 50% of the total energy needed, just by optimizing the envelope.

11 FURTHER RESEARCH AND CONSIDERATIONS

SYSTEMS

The systems were not considered in this study. However, it has been proven that the reduction of the energy can be significant when implementing high efficient systems, such as the use of heat recovery, balance ventilation (Ma, Cooper, Daly, & Ledo, 2012; Dulski, Vliet & Unen 2012). The HI of their implementation should be studied. Even when they are most likely to not have a direct impact on the attributes, the impact should not be neglected either. For example, the impact on the use of grids for balance ventilation or the space for new systems should also be considered and carefully adapted to the building~~.~~

COMFORT

The comfort should also be considered for meeting current standards. The implementation of future interventions could consider these aspects as well, by means of investigating the PMV or PDD values. They can be added to the comparison between HI and energy reduction.

COST-OPTIMAL SOLUTIONS

The proposed interventions do not consider the cost of their implementation. Therefore, it should be studied and compared to the HI and ENH reduction. It would give a broader overview to the actors involved in the decision-making process. For instance, the use of internal insulation is not always exploited to its maximum potential for economic reasons. Nevertheless, there are insulation materials which are cost-optimal in terms of energy-saving and thermal capabilities, such as PUR foam board, which achieves a better U-value with smaller thickness than other materials (Tomback, et al., 2013)

SOCIAL ASPECT

Finally, the social aspects should as well be considered. The study of the historical value of the case study, have shown that the social value is not the most important value. However, a renovation may improve it. By considering the social aspects of the building, the renovation can be sustainable and enhance the sense of place within the community (Tomback, et al., 2013). All the mentioned aspects should be considered in order to provide a place for future generations.

12 CONCLUSIONS AND RECOMMENDATIONS

HISTORICAL VALUE

Prior to the renovation of a historical building, it is important to outline its significance and to evaluate its current state. This research proposes a methodology that evaluates the historical value and energy performance of a building, before an intervention. The case study, the Dudokhaken, was part of the urban extension plan of Amsterdam after the Second World War, the AUP. Due to its importance, these areas, amongst others in the Netherlands, are considered of national importance. A valuation to these areas was made and the Dudokhaken was ranked as a highly valuable building without being a monument. According to literature the post-war tissue can adapt and at the same time preserve its identity (Bijlsma, Bergenhenegouwen, Schluchter, & Zaaijer, 2008). To investigate this, the current valuation was studied and it was analyzed a text regarding the AUP of The Beauty of Amsterdam (Gemeente Amsterdam & CWM, 2013). The primary values identified have shown more aesthetical values in each Scales of significance, with the exception of the urban scale, which have equal share between the historical and scientific values. The attributes along with their primary values were identified, being the urban structure; strip, hooks and courts; the translations of the urban the structure into the architecture and the facade the most valuable attributes related to the case study.

Certain limitations were encountered during the historical analysis of the building, since the text does not concern the specific case study. It refers to the AUP areas within the different Scale of significance identified within this research. A deeper analysis is needed to validate and prove the attributes identified. An attempt was made in order to demonstrate how the most valuable attributes are related to the case study. However, it was not possible to study every attribute. An in-depth analysis will identify or discard primary values. As a future research and in order to validate the text provided by CWM, the analysis of different buildings can be performed by comparing their identified ranking with the current valuation. Moreover, when renovating a historical building the valuation of the building is not sufficient. A detailed evaluation of the building elements is needed to determine to what extent a component can be alternated (Eriksson, Hermann, Hrabovszky-Horváth, & Rodwell, 2014). Thus architecture historians and conservations experts should play an active role into the renovation of valuable buildings (Fouseki & Cassar, 2014). Design strategies could be incorporated into the current cultural heritage assets as well as detailed information regarding the valuation. It will help current architects, urban planners and designers to reinterpret the valuation of a building into the current needs of society.

HERITAGE IMPACT

In this research, the heritage significance assessment did not lead to the valuation of the building elements, but to the understanding of the values attributed to the building, which made it easier to define the heritage impact of possible interventions. The heritage significance ranking (SQ1) is not directly linked to the impact of the interventions, since the heritage impact was determined by identifying the attributes that can be affected without making any distinction of their ranking. Even though the main limitations are related to the heritage significance, the validation of the text identified could affect the heritage impact analysis. An in-depth analysis could reveal new primary values and attributes. Consequently, the heritage impact could change when the interventions have an impact on the discovered values.

Findings showed that the interventions placed towards the outside have higher heritage impact. However, they can sometimes enhance other primary values, thus causing a positive impact to the renovation. The understanding of the values lost can be discussed together with conservation experts by incorporating the values acquired during a renovation. Experts in cultural heritage should consider the impact on the environment, space and matter without applying restrictions (Troi & Bastian, 2015) or being overprotective (Prins, Habets, & Timmer, 2014). They should as well be involved into the decision-making and shift the perspective towards environmental issues. There is need for a retrospective in which future needs and the endurance of the building in stake are considered.

SAVING POTENTIAL

The proposed interventions were focused on the optimization of the envelope and the implementation of solar energy systems. The former affects between 20 to 60% of the energy consumption of a building, thus its optimization should be prioritized in an energy reduction strategy (IEA, 2013). The results indicate that a reduction of 60% of space heating is possible compared to the pre-case and less than 40% to the base-case. An exception was found in the implementation of the solar collector, which exceeded the space heating needs. Nevertheless, the saving potentials of an individual intervention are not meant to be summed since the thermal behavior of the building depends on their implementation as a whole. Moreover, retrofit solutions should not be based on guidelines, such as an EPC because it ignores user's behavior (Troi & Bastian, 2015) and thus the energy performance of a building will be affected. Lastly, the saving potentials can also be determined for the Dudok area, enhancing the energy performance of the whole area and preserving its identity. This action demands a closed coordination between various stakeholders such as developers, corporations and most important municipalities (Bijlsma, Bergenhenegouwen, Schluchter, & Zaaijer, 2008)

BALANCE RENOVATION

It has been proven that a renovation of a highly valuable building can improve its energy performance without harming its heritage significance. Within the case study it is shown that the implementation of internal interventions reduces significantly the space heating demands without having a heritage impact. The comparative analysis led to three solutions for a balanced renovation.

TOWARDS LOW-ENERGY RENOVATION

An optimized base-case showed higher reduction of more than 80% of space heating. However, the heritage impact increased as well due to the fact that the base-case had already between 1 to 2.5 heritage impact rankings. One of the other two solutions explored (Balance 1) proven a reduction in space heating of more than 90% (26kWh/m^{2}y) while decreasing the heritage impact on three out of four scales of significance. The criteria for choosing the interventions were based on the maximum energy reduction and minimum impact in the historical values.

It is concluded that a renovation should not be considered a single intervention, in order for a building to reduce at its maximum the energy consumption. A holistic planning should be considered where different interventions are incorporated. The renovation of an existing building has environmental benefits (Power, 2008) and creates more opportunities in the long term (Ma, Cooper, Daly, & Ledo, 2012). Historical buildings are valuable for their uniqueness, thus demanding for tailored and individual solutions. The extent of interventions to be implemented depends on its historical value, since some of the interventions proposed during this research could be restricted in other cases. However, the methodology can be applied to different case studies as a decision-making tool that takes into account energy savings and the heritage impact on the buildings, converting the restrictions regarding historical building into guidelines on how to proceed with a project.

The international concern is increasing regarding the consequences of energy efficiency measures implemented on historical buildings (Grytli, Kværness, Sve Rokseth, & Fines Ygr, 2014). Their renovation demands equality between heritage and energetic goals from the beginning of the project (Fouseki & Cassar, 2014). The impact on the heritage due to renovation is inevitable because some changes are necessary in order to meet current standards. However, tailored solutions can provide sufficient energy reduction. Technical solutions which reduce CO2 emissions without harming the cultural and historical values of the historical buildings already exist (Hal, 2010). Some recommendations for mitigating the impact of such interventions are given in this study; namely the use of thin-layer triple glazing, integrated PV panels that match the color of the tiles or the use of external elements (blind) on the second external wall or avoiding its placement on the exterior and public facades. Some of these measures involve extra economical resources. Therefore, the economic implications should also be integrated into the proposed interventions and be compared to the heritage impact and energy saving potential. The social aspect should also be taken into count in order to provide a holistic approach that balances all the aspects of sustainability.

"*Only when understanding our place, we may be able to participate creatively and contribute to its history*." (Norberg ESchulz, 1980)

NOMENCLATURE

AUP - *Algemeen Uitbreidingsplan* [General Urban Expansion]
DH - Dudokhaken
HI – Heritage Impact
HSR – Heritage Significance Ranking
RVO - *Rijksdienst voor Ondernemend Nederland* [Netherlands Enterprise Agency]

REFERENCES

Books

- Bijlsma, L., Bergenhenegouwen, G., Schluchter, S., & Zaaijer, L. (2008). *Transformatie van woonwijken met behoud van stedenbouwkundige identiteit*. NAi Uitgevers.
- Blom, A. (2013). Atlas van de wederopbouw Nederland 1940-1965; ontwerpen aan stad en land. Rotterdam: Rijksdienst voor het Cultureel Erfgoed en nai010 uitgevers.
- Blom, A., Jansen, B., & Heide, M. v. (2004). *De typologie van de vroeg-naoorlogse woonwijken*. Rijksdienst voor de Monumentenzorg.
- Hellinga, E. (1983). *The General Expansion Plan of Amsterdam*. In Het Nieuwe Bouwen (pp. 52-111). Delft, the Netherlands: Delft University Press.
- Pereira Roders, A. (2007). *RE-ARCHITECTURE: Lifespan rehabilitation of built heritage, scapus* (Published doctoral dissertation). Technische Universiteit Eindhoven, Eindhoven, The Netherlands.
- Sabaté Bel, J., & Galindo, J. (2000). *The Qualities of the Western Garden Cities*. Amsterdam, The Netherlands: The Amsterdam Town Planning Advisory Council.
- Schilt, J. (2013). *Van 50m2 naar 100m2. Het AUP en de zoektocht naar een goede sociale woning.* In Atlas AUP Gebieden Amsterdam (pp. 82-101). Amsterdam, the Netherlands: BMA.
- Troi (EURAC), A., & Bastian (PHI), Z. (Eds.). (2015). *Energy efficiency solutions for Historic Buildings - A Handbook*. Basel: Birkhauser Verlag GmbH.
- Van Bergeijk, H. (2001). *W. M. Dudok*. Rotterdam, the Netherlands: 010 Publishers.
- Van den Berg, M., Van Ro, V., Klusman, E., & Teunissen, B. (2003). *Amsterdam's General Extension Plan.* In Planning Amsterdam: Scenarios for urban development, 1928-2003 (pp. 39-75). Rotterdam: NAi Publishers.

Articles

- Cecchini, C., Cimini, S., & Morleo, R. M. (2014). *Strategic scenarios in energy-environmental refurbishment of historic massive building stock*. In Historical and existing buildings: designing the retrofit. An overview from energy performance to indoor air quality. Rome: AiCARR.
- Chlela, F., Husaunndee, A., Inard, C., & Riederer, P. (2009). *A new methodology for the design of low energy buildings*. Energy and Buildings, 41(9).
- Dulski, B., & Vliet, C. (2012). *How progressive can cultural heritage management be?* European Energy Innovation , 58-61.
- Enriquez Reinberg, M., & Reinberg, G. (2010). *Preservation of the historical stock in passive house refurbishment*. In Central Europe towards Sustainable Building. Prague.
- Eriksson, P., Hermann, C., Hrabovszky-Horvп, S., & Rodwell, D. (2014). *EFFESUS Methodology for Assessing the Impact of Energy-Related Retrofit Measures on Heritage Significance*. The Historic Environment, 5(2), 132-149.
- Fouseki, K., & Cassar, M. (2014). *Editorial: Energy Efficiency in Heritage Buildings - Future Challenges and Research Needs*. The historic environment, 5(2), 95-100.
- Franken, V., & Meijer, S. A. (2013). *Sense of history capturing and utilizing immaterial values for sustainable heritage protection*. In Living Scientific.
- Grytli, E., Kværness, L., Sve Rokseth, L., & Fines Ygr, K. (2014). *The Impact of Energy Improvement Measures on Heritage Buildings*. Journal of Architectural Conservation, 18(3), 89-106. doi:10.1080/13556207.2012.10785120

- Hal, A. v., Dulski, B., & Postel, A. (2010). Reduction of CO2 Emissions in Houses of Historic and Visual Importance. Sustainability (2), 443-460.
- Hoppe, T. (2012). *Adoption of innovative energy systems in social housing: Lessons from eight large-scale renovation projects in The Netherlands*. Energy Policy, 51(2012), 791-801.
- Ipekoglu, B., Boke, H., & Cizer, O. (2007). *Assessment of material use in relation to climate in historical buildings.* Buildings and Environment, 42(2007), 970-978.
- Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). *Existing buildings retrofits: Methodology and state-of-the-art.* Energy and Buildings, 55(2012), 889-902.
- Meijer, F., Itard, L., & Sunikka-Blank, M. (2009). *Comparing European residential building stocks: performance, renovation and policy opportunities*. Building Research & Information, 37(5-6), 533-551.
- Mjörnell, K., Boss, A., Lindahl, M., & Molnar, S. (2014). *A Tool to Evaluate Different Renovation Alternatives with Regard to Sustainability*. Sustainability, 2014(6), 4227-4245.
- Mofidi, S. M., Moradi, A. M., & Akhtarkavan, M. (2008). *Assessing Sustainable Adaptation of Historical Buildings to Climate Changes of Iran*. In 3rd IASME/WSEAS Int Conf. on Energy & Environment. Stevens Point, WI: World Scientific and Engineering Academy and Society.
- Moran, F., Blight, T., Natarajan, S., & Shea, A. (2014). *The use of Passive House Planning Package to reduce energy use and CO2emissions in historic dwelling*. Energy and Buildings, 75(2014), 216-227.
- Norrström, H., & Edén M. (2009). *Energy Efficiency and Preservation in our Cultural Heritage in Halland, Sweden*. Chalmers University of Technology.
- Prins, L., Habets, A. C., & Timmer, P. J. (2014). *Bekende gezichten, gemengde gevoelens*. Retrieved from Rijksdienst voor het Cultureel Erfgoed website: http://cultureelerfgoed.nl/sites/default/files/publications/bekende-gezichten-gemengde-gevoelens-rce.pdf
- Polo López, C. S., & Frontini, F. (2014). *Energy efficiency and renewable solar energy integration in heritage historic buildings.* Energy Procedia, 48(2014), 1493-1502. doi:10.1016/j.egypro.2014.02.169
- Power, A. (2008). Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability? Energy Policy, 36(2008), 4487-4501.
- Sartori, I. & Hestnes A.G. (2006). *Energy use in the life cycle of conventional and low-energy buildings: A review article.* Energy and Buildings, 39 (2007), 249-257
- Taranto Rodriguez, L., & Kacel, S. (2013). *Energy efficient retrofit of a Protected Building of Historical Significance* Sustainable Architecture for a Renewable Future, Munich.
- Thomsen, A., & Van der Flier, K. (2009). *Replacement or renovation of dwellings: the relevance of a more sustainable approach*. Building Research and Information, 37(5-6), 649-659.
- Tomback, D., Brennan, T., Chambers, M., Rowlands, J., Colley, R., Joyce, R., & Ryder, K. (2013). Heritage Works. The use of historic buildings in regeneration. A toolkit of good practice.
- Yuceer, H., & Ipekoglu, B. (2012). *An architectural assessment method for new exterior additions to historic buildings*. Jornal of Cultural Heritage, 13(2012), 419-425.

Reports

- Atanasiu, B., Kunkel, S., & Kouloumpi, I. (2013). nZEB criteria for typical single-family home renovations in various countries. Retrieved from Intelligent Energy Europe Project COHERENO (Collaboration for housing nearly zero-energy renovation website: http://www.cohereno.eu/fileadmin/media/Dateien/D2_1_BPIE_WP2_12092013_3_5_-final.pdf
- Australia ICOMOS. (2013). *The Burra Charter. The Australia ICOMOS Charter for Places of Cultural Significance*. Burwood: Australia ICOMOS Incorporated.
- CCEM. (2011). *Advanced Energy Efficient Renovation of Buildings* (Final Report). Retrieved from http://www.empa-ren.ch/CCEM_Retrofit/PDF/Summary 20Report 202011 20CCEM-Retrofit.pdf
- CCEM, & SuRHiB. (2012). *Annual Activity Report 2012*. CCEM. Sustainable Renovation of Historical Sustainable Renovation of Historical Buildings Pages: 53-55

- GBPN. (2013). *What is deep renovation definition?*
- Gemeente Amsterdam & CWM. (2013). *De Schoonheid van Amsterdam*.
- Gemeente Amsterdam & DMB. (2009). *Welstandsnota voor Stadsdeel Geuzenveld-Slotermeer*. (Not published)
- ICOMOS. (2011). *Guidance on Heritage Impact Assessments for Cultural World Heritage Properties*.
- IEA. (2013). *Technology roadmap: Energy efficient building envelopes*. Paris: OECD/IEA.
- Institut Wohnen und Umwelt GmbH. (2014). EPISCOPE and TABULA. Retrieved from http://episcope.eu/index.php?id=97
- RVO, 2014. Energielabel. Retrieved 10 19, 2014, from Rijksdienst voor Ondernemend Nederland: http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/energielabel-installatiekeuringen/energielabel
- RVO (2014b). Technieken voor een energieneutrale woning (2ENIN1401). Retrieved from: http://www.rvo.nl/sites/default/files/2014/06/Technieken 20energieneutralewoning 20juni 202014.pdf
- RVO (2014c). *Rekenmethodiek definitief energielabel inclusief indeling energielabelklassen* (E.2013.1132.00.R002). Author.
- Van Agtmaal, P., Bosch, N., Dubbeldarn, F., De Heus, L., & Som, G. (2013). *PLAN Amsterdam* (Jaargang 19, nr 4). Dienst Ruimtelijke Ordening (DRO).
- Van Schagen Architekten (2008). *Bestek Dudokhaken.*

On-line sources

- Concept BIO. (n.d.). BBC label – BBC Effinergie® - A low-energy building. Retrieved December 16, 2014, from http://www.concept-bio.eu/label-bbc-bbc-effinergie.php
- CWM. (2014). *Commissie*. Retrieved from http://www.welstand.amsterdam.nl/commissie
- ISCES (2013). *About*. Retrieved from: http://isces.icomos.org/
- Gemeente Amsterdam (2014) *Welstandscriteria erfgoed*. Retrieved from: http://amsterdam.welstandinbeeld.nl/welstandscriteriaerfgoed/
- RVO (2015). *EPC van 0.4 voor woningbouw*. Retrieved May 15, 2015, from: http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/energieprestatie/ontwerpen/epc-04-woningbouw
- RVO (2015b). *Database Energy Efficient Built.* Retrieved April 10, 2015, from: http://www.rvo.nl/initiatieven/overzicht/27008?query-content=renovatie&f[0]=bouwtype%3A27185
- Van Eesterenmuseum. (2014). Geuzenveld. Retrieved from http://vaneesterenmuseum.nl/de-tuinsteden/andere-tuinsteden/westelijke-tuinsteden-2/geuzenveld/

Figures

Figure 5-1. Geuzenveld and the Dudokbuurt [Dudok Neighbourhood]

Figure 5-2. View from the Courtyard, Gallery (left) and Portico (right). Source: Personal archive

Figure 6-1. Geuzenveld, garden city. Section designed by W. M. Dudok. Source: New-west Archive, BWT_10984

Figure 6-2. Sketch of the Raadhuis in Hilversum. Source: Van Bergeijk, H., 2001, p. 64

Figure 6-3. Bird-eye perspective of the Geuzenveld housing complex, known as Dudokhaken. Source: Van Bergeijk, H., 2001, p. 131

Figure 7-1. Evolution of the Dudokhaken. Source: Unknown, TGOOI and Personal archive

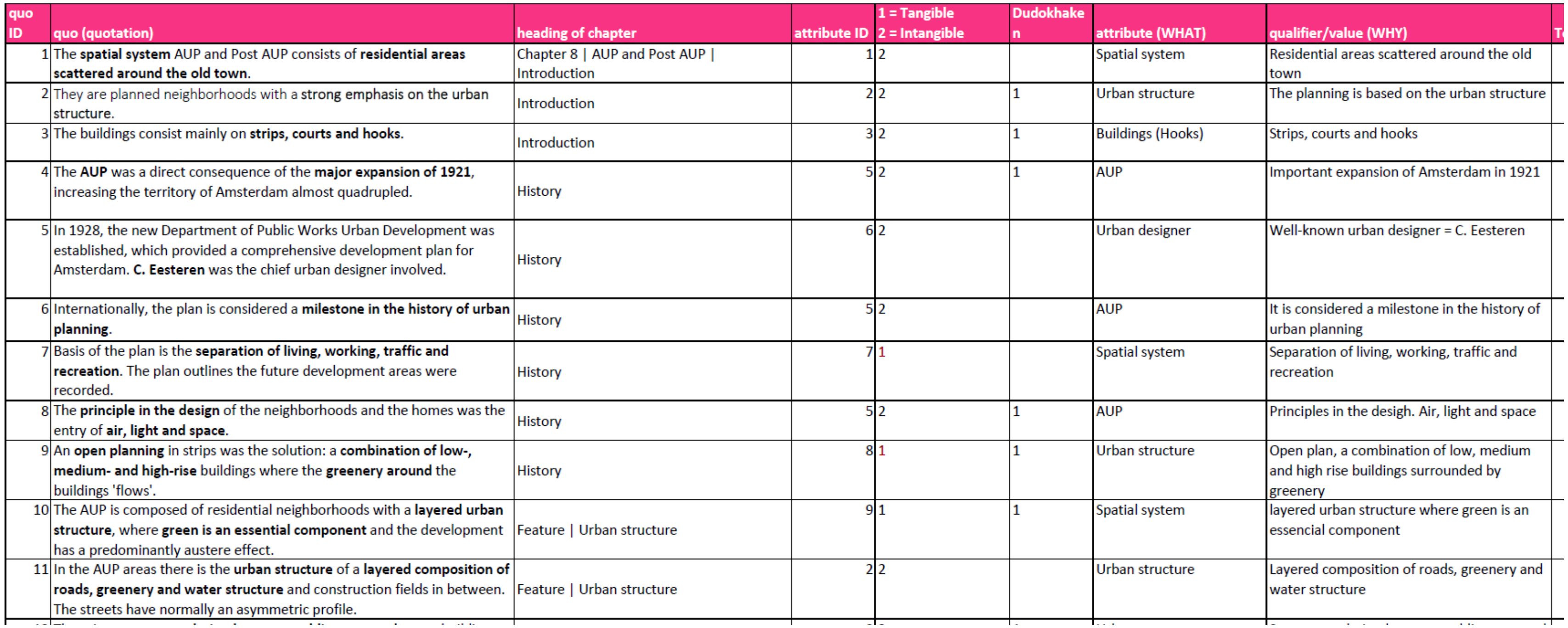
Figure 7-2. North Façade, Pre-case (Original). Source: New-west Archive, BWT_10984

Figure 7-3. West Façade, Pre-Case (Original). Source: New-west Archive, BWT_10984

Figure 7-4. North Façade, Base-Case (Current). Source: Van Schagen Architekten

APPENDICES

APPENDIX A – SQ1

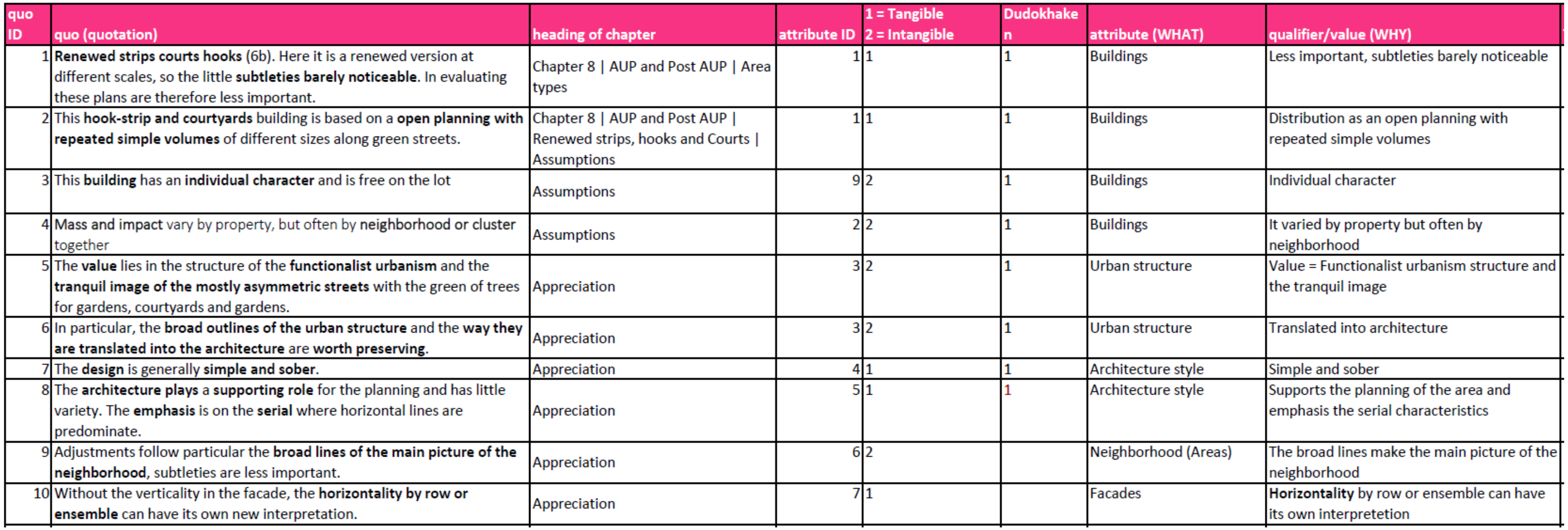


quo ID	quo (quotation)	heading of chapter	attribute ID	1 = Tangible 2 = Intangible	Dudokhaken	attribute (WHAT)	qualifier/value (WHY)
1	The **spatial system** AUP and Post AUP consists of **residential areas scattered around the old town.**	Chapter 8 | AUP and Post AUP | Introduction	1	2		Spatial system	Residential areas scattered around the old town
2	They are planned neighborhoods with a **strong emphasis on the urban** structure.	Introduction	2	2	1	Urban structure	The planning is based on the urban structure
3	The buildings consist mainly on **strips, courts and hooks.**	Introduction	3	2	1	Buildings (Hooks)	Strips, courts and hooks
4	The **AUP** was a direct consequence of the **major expansion of 1921**, increasing the territory of Amsterdam almost quadrupled.	History	5	2	1	AUP	Important expansion of Amsterdam in 1921
5	In 1928, the new Department of Public Works Urban Development was established, which provided a comprehensive development plan for Amsterdam. **C. Eesteren** was the chief urban designer involved.	History	6	2		Urban designer	Well-known urban designer = C. Eesteren
6	Internationally, the plan is considered a **milestone in the history of urban planning**.	History	5	2		AUP	It is considered a milestone in the history of urban planning
7	Basis of the plan is the **separation of living, working, traffic and recreation**. The plan outlines the future development areas were recorded.	History	7	1		Spatial system	Separation of living, working, traffic and recreation
8	The **principle in the design** of the neighborhoods and the homes was the entry of **air, light and space**.	History	5	2	1	AUP	Principles in the desigh. Air, light and space
9	An **open planning** in strips was the solution: a **combination of low-, medium- and high-rise** buildings where the **greenery around** the buildings 'flows'.	History	8	1	1	Urban structure	Open plan, a combination of low, medium and high rise buildings surrounded by greenery
10	The AUP is composed of residential neighborhoods with a **layered urban structure**, where **green is an essential component** and the development has a predominantly austere effect.	Feature | Urban structure	9	1	1	Spatial system	layered urban structure where green is an essencial component
11	In the AUP areas there is the **urban structure** of a **layered composition of roads, greenery and water structure** and construction fields in between. The streets have normally an asymmetric profile.	Feature | Urban structure	2	2		Urban structure	Layered composition of roads, greenery and water structure

Figure 0-1. Example of quotes and attributes identified for the Urban Scale (A)

quo ID	quo (quotation)	heading of chapter	attribute ID	1 = Tangible 2 = Intangible	Dudokhaken	attribute (WHAT)	qualifier/value (WHY)
1	**Geuzenveld** was a response to Slotermeer, because Van Eesteren had the idea of one more metropolitan residential area with more housing.	A. **History** and location in the city	1	2	1	Neighborhood	One more metropolitan residential area with more housing.
2	Almost all the buildings in Geuzenveld are the **work of six young but leading architectural firms**. They have designed every single neighborhood, locally complemented by other architects. These offices were Bijvoet, Merkelbach & Elling, Dudok, Van Tijen & Maaskant, Van den Broek & Bakema en Wegener-Sleeswijk.	A. **History** and location in the city	2	2	1	Architects	Bijvoet, Merkelbach & Elling, Dudok, Van Tijen & Maaskant, Van den Broek & Bakema en Wegener-Sleeswijk.
3	The approach of the **architect becomes a much bigger role** in Geuzenveld than in Slotermeer.	A. **History** and location in the city	2	2	1	Architects	Bigger role than in Slotermeer
4	The architects have to explore **new building typologies and construction techniques**.	A. **History** and location in the city	2	1	1	Architects	New typologies and techniques
5	In 1962 and **Geuzenveld** and **Slotermeer** were both ready. In 1987, the **Location Investigation Team** was (LOT) was founded with the purpose to identify construction sites throughout the city.	A. **History** and location in the city	1	2		Neighborhood	Ready in 1962, it was founded the LOT
6	It is in the **center of Geuzenveld** were most of the stacked construction were risen.	B. Characteristics of the spatial system | Urban structure | **Strip, hook and courtyard building**	3	1	1	Strip, hook and C	**Location** in the center of the neighbourhood
7	Most of the realized housing projects in Geuzenveld showed an **architectural entity with its own characteristics**.	B. Characteristics of the spatial system | Urban structure | **Strip, hook and courtyard building**	3	1	1	Strip, hook and C	**characteristics** Architectural entity with its own characteristics
8	In many housing there is **space reserved for local shops**, often on a **street corner**.	B. Characteristics of the spatial system| Urban structure | **Strip, hook and courtyard building**	3	1		Strip, hook and C	**Shops**, at street corner
9	Geuzenveld has a large number of schools and churches as **facilities between** the included **residential buildings**.	B. Characteristics of the spatial system| Urban structure | **Social facilities**	4	1		Facilities	**Location** in between residential buildings
10	This large number is indicative of the **classification** within the **society during construction**.	B. Characteristics of the spatial system| Urban structure | **Social facilities**	4	2		Facilities	**Classification** within the society

Figure 0-2. Example of quotes and attributes identified for the Neighbourhood Scale (B)



quo ID	quo (quotation)	heading of chapter	attribute ID	1 = Tangible 2 = Intangible	Dudokhaken	attribute (WHAT)	qualifier/value (WHY)
1	**Renewed strips courts hooks** (6b). Here it is a renewed version at different scales, so the little **subtleties barely noticeable**. In evaluating these plans are therefore less important.	Chapter 8 | AUP and Post AUP | Area types	1	1	1	Buildings	Less important, subtleties barely noticeable
2	This **hook-strip and courtyards** building is based on a **open planning with repeated simple volumes** of different sizes along green streets.	Chapter 8 | AUP and Post AUP | Renewed strips, hooks and Courts | Assumptions	1	1	1	Buildings	Distribution as an open planning with repeated simple volumes
3	This **building** has an **individual character** and is free on the lot	Assumptions	9	2	1	Buildings	Individual character
4	**Mass and impact** vary by property, but often by **neighborhood or cluster** together	Assumptions	2	2	1	Buildings	It varied by property but often by neighborhood
5	The **value** lies in the structure of the **functionalist urbanism** and the **tranquil image of the mostly asymmetric streets** with the green of trees for gardens, courtyards and gardens.	Appreciation	3	2	1	Urban structure	Value = Functionalist urbanism structure and the tranquil image
6	In particular, the **broad outlines of the urban structure** and the **way they are translated into the architecture** are **worth preserving**.	Appreciation	3	2	1	Urban structure	Translated into architecture
7	The **design** is generally **simple and sober**.	Appreciation	4	1	1	Architecture style	Simple and sober
8	The **architecture plays** a **supporting role** for the planning and has little variety. The **emphasis** is on the **serial** where horizontal lines are predominate.	Appreciation	5	1	1	Architecture style	Supports the planning of the area and emphasis the serial characteristics
9	Adjustments follow particular the **broad lines of the main picture of the neighborhood**, subtleties are less important.	Appreciation	6	2		Neighborhood (Areas)	The broad lines make the main picture of the neighborhood
10	Without the verticality in the facade, the **horizontality by row or ensemble** can have its own new interpretation.	Appreciation	7	1		Facades	**Horizontality** by row or ensemble can have its own interpretetion

Figure 0-3. Example of quotes and attributes identified for the Typology Scale (C)

quo ID	quo (quotation)	heading of chapter	attribute ID	1 = Tangible 2 = Intangible	Dudokhaken	attribute (WHAT)	qualifier/value (WHY)
1	Order 2: **High value**. An **architectural unity** with the period characteristic architectural design and / or typology, which also makes an important contribution to the composition of the subdivision unit and the area	Welstandscriteria voor Erfgoed | HOOFDSTUK 5 | Waarderingskaart AUP en Post-AUP	1	2	1	High value / Architectural unity	Important contribution to the composition of the subdivision unit and the area
2	The **facades** adjacent to public accessible areas have **windows**	Frequent small building plans | Additions [AUP]	2	1	1	Façade	**Elements.** Public facades should have windows
3	**Materials and colors** tuned the main building (at a rear side possibly a conservatory)	Frequent small building plans | Additions [AUP]	3	1		Materials and colors	Tuned to the main buildings
4	Additions per façade constitute a **single whole facade**	Frequent small building plans | Additions [AUP]	2	2	1	Façade	Integrity of façade
5	Additions placed directly against the **main mass** (or increase an existing construction)	Frequent small building plans | Additions [AUP]	2	1		Façade	Volume. Integrity of public façade
6	**Design** tuning to original property	Frequent small building plans | Additions [AUP]	4	2	1	High value / Architectural unity	Original character of the buildings important
7	For serial housing with similar principal shape a **similar extensions** in the **block or the neighborhood**	Frequent small building plans | Additions [High value]	4	2	1	High value / Architectural unity	Similar extensions to the block or the neighborhood
8	The **size, scale, design, materials and colors** should be carefully selected according to the cultural and historical value of the property and area	Frequent small building plans | Additions [WA2]	5	1	1	High value / Architectural unity	Carefully selected according to the cultural and historical value of the property and area
9	Fit within the **consistency** and **rhythm** of the ensemble and the environment with **emphasis on the relationship between repetitions** and specializations	Frequent small building plans | Frame change [AUP]	6	1	1	Frame	Gives consistency and rhythm, emphasis on the relationship between repetitions and specializations
10	**Frames and frame layout lines** to existing frames and maintain **consistency in the façades outline**	Frequent small building plans | Frame change [AUP]	6	1	1	Frame	Gives consistency in the façade outline

Figure 0-4. Example of quotes and attributes identified for the Building Scale (D)

APPENDIX B – SQ2

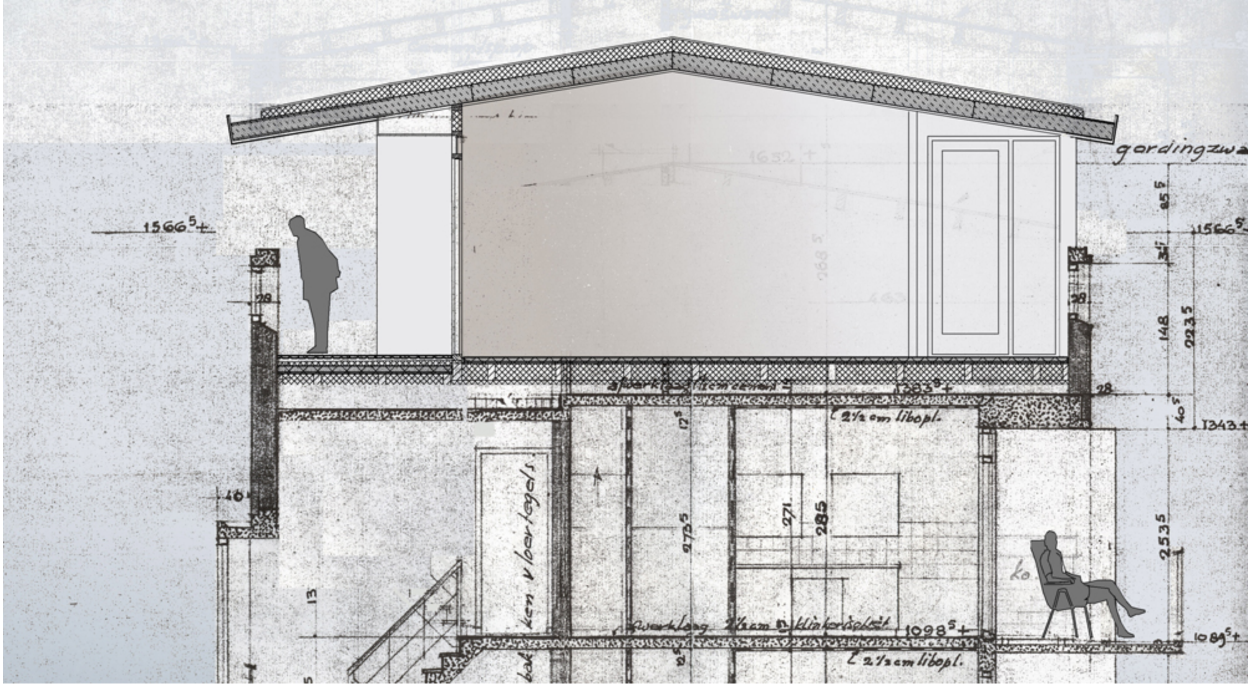


Figure 0-5. On-top dwelling,(Source: Van Schagen Architekten)

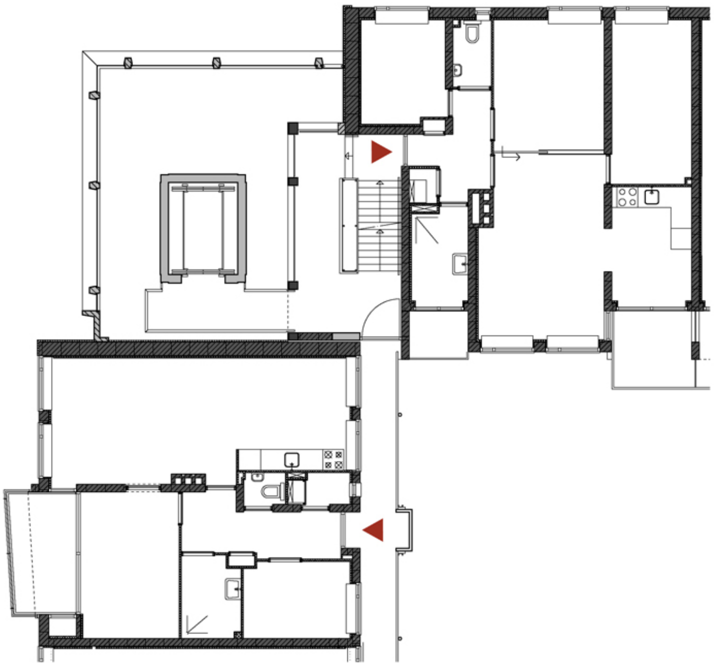


Figure 0-6. Lift addition, (Source: Van Schagen Architekten)

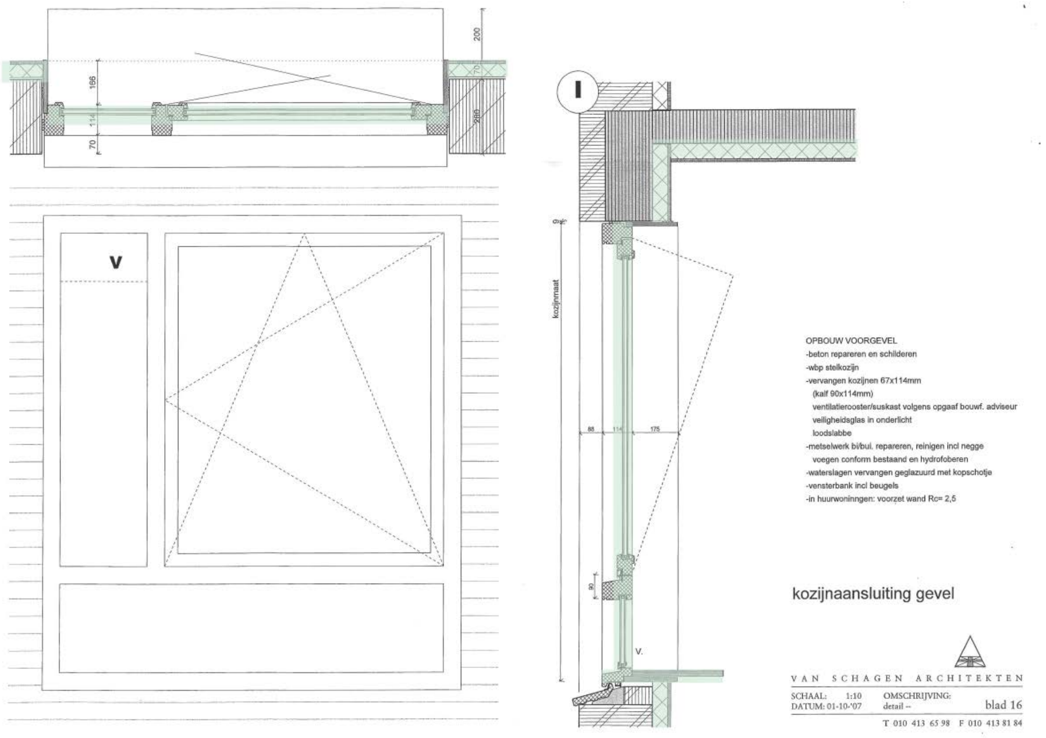
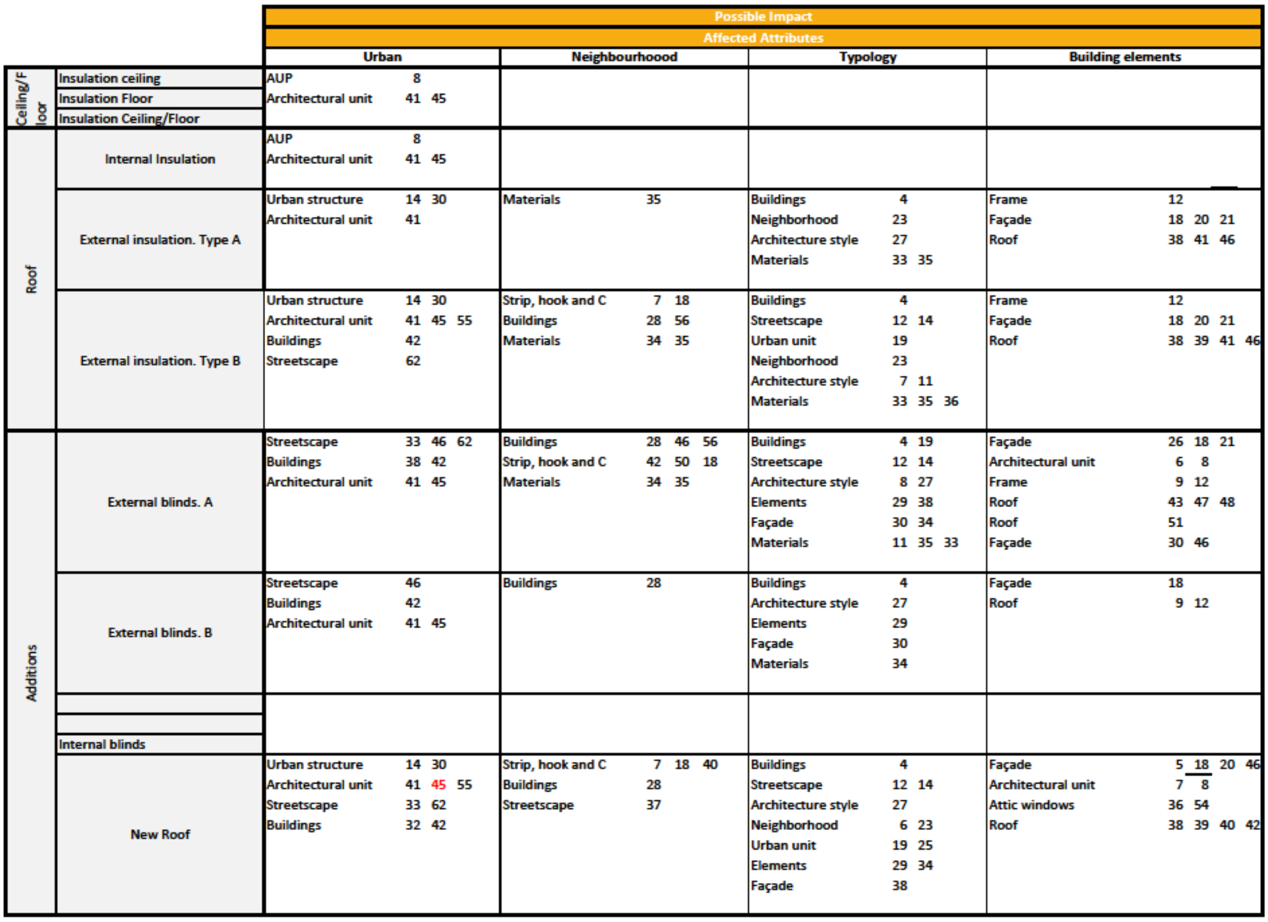


Figure 0-7. Detail, inside insulation and new window, (Source: Van Schagen Architekten)

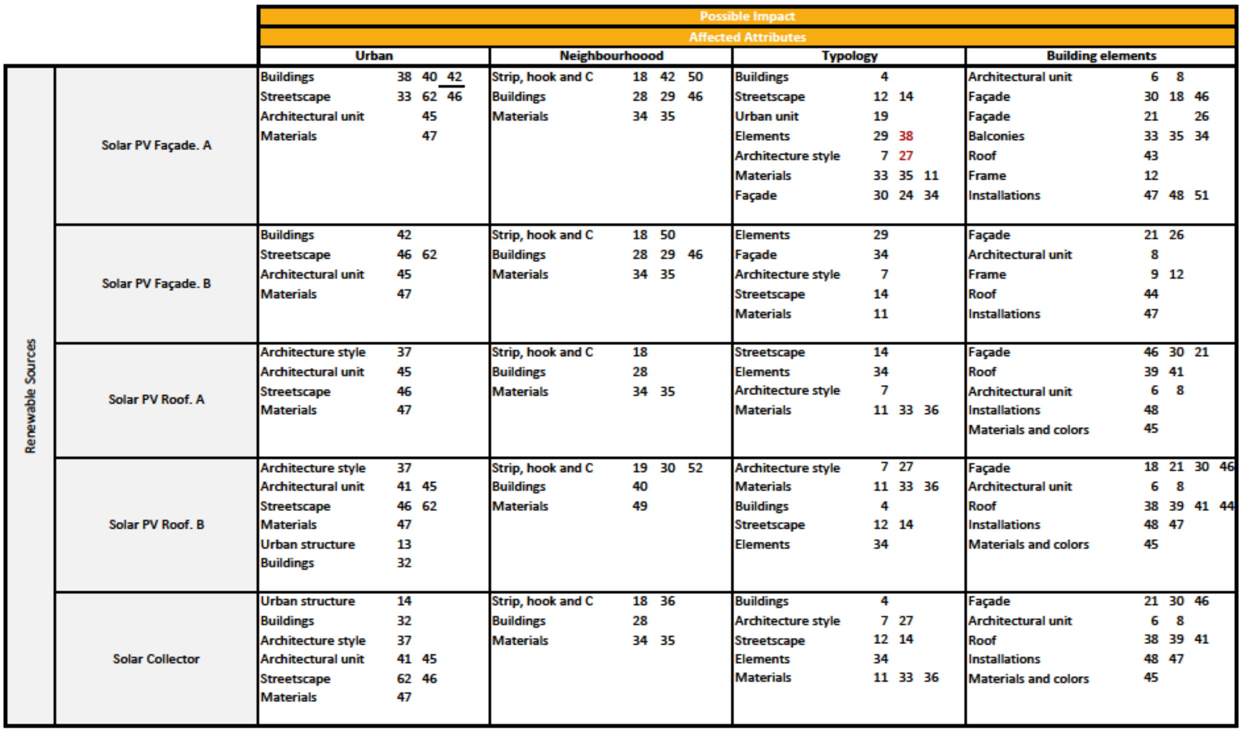
		Possible Impact			
		Affected Attributes			
		Urban	**Neighbourhoood**	**Typology**	**Building elements**
Windows	HR++				
	Triple	Streetscape 33 46 62	Buildings 28 56 Strip, hook and C 18 50	Façade 24 28 30 34 Elements 29	Façade 29 Frame 9 13
	Grids	Urban structure 12 Streetscape 33 46 62 Architectural unit 41 45	Strip, hook and C 18 40 50 Buildings 28 56 Streetscape 37	Buildings 4 Architecture style 8 27 Streetscape 12 19 Façade 29 34	Façade 18 20 28 Frame 9 10 15 11
	Ratio Wall-window	AUP 8 Streetscape 33 46 62 Buildings 38 42 Architectural unit 41	Buildings 28 56 Strip, hook and C 40 42 50	Buildings 4 Streetscape 12 14 Urban unit 19 Façade 24 28 30 34 Architecture style 27 Elements 38 29	Façade 18 20 26 46 Frame 9 10 17
Walls	External insulation. Type A	AUP 8 Urban structure 17 64 Materials 47 Streetscape 46 Architectural unit 41 55	Strip, hook and C 18 40 Materials 35	Buildings 4 6 Streetscape 12 16 Architecture style 27 Materials 33 35	Façade 5 18 20 29 Frame 9 12 Architectural unit 7
	External insulation. Type B	AUP 8 Urban structure 14 17 64 Architectural unit 41 42 45 55 Streetscape 46 62 Materials 47	Strip, hook and C 7 18 40 Buildings 28 56 Materials 34 35	Buildings 4 6 Urban unit 19 Streetscape 12 14 16 Architecture style 27 11 Materials 33 35	Materials and colors 3 Façade 5 18 20 29 Architectural unit 23 24 31 Façade 21 25 27
	Internal. Type A	AUP 8			
	Internal. Type B	Architectural unit 41 45			
	Cavity Wall*				

Table 4A. Attributes affected by each intervention



		Possible Impact			
		Affected Attributes			
		Urban	Neighbourhoood	Typology	Building elements
Ceiling/Floor	Insulation ceiling Insulation Floor Insulation Ceiling/Floor	AUP 8 Architectural unit 41 45			
Roof	Internal Insulation	AUP 8 Architectural unit 41 45			
	External insulation. Type A	Urban structure 14 30 Architectural unit 41	Materials 35	Buildings 4 Neighborhood 23 Architecture style 27 Materials 33 35	Frame 12 Façade 18 20 21 Roof 38 41 46
	External insulation. Type B	Urban structure 14 30 Architectural unit 41 45 55 Buildings 42 Streetscape 62	Strip, hook and C 7 18 Buildings 28 56 Materials 34 35	Buildings 4 Streetscape 12 14 Urban unit 19 Neighborhood 23 Architecture style 7 11 Materials 33 35 36	Frame 12 Façade 18 20 21 Roof 38 39 41 46
Additions	External blinds. A	Streetscape 33 46 62 Buildings 38 42 Architectural unit 41 45	Buildings 28 46 56 Strip, hook and C 42 50 18 Materials 34 35	Buildings 4 19 Streetscape 12 14 Architecture style 8 27 Elements 29 38 Façade 30 34 Materials 11 35 33	Façade 26 18 21 Architectural unit 6 8 Frame 9 12 Roof 43 47 48 Roof 51 Façade 30 46
	External blinds. B	Streetscape 46 Buildings 42 Architectural unit 41 45	Buildings 28	Buildings 4 Architecture style 27 Elements 29 Façade 30 Materials 34	Façade 18 Roof 9 12
	Internal blinds				
	New Roof	Urban structure 14 30 Architectural unit 41 45 55 Streetscape 33 62 Buildings 32 42	Strip, hook and C 7 18 40 Buildings 28 Streetscape 37	Buildings 4 Streetscape 12 14 Architecture style 27 Neighborhood 6 23 Urban unit 19 25 Elements 29 34 Façade 38	Façade 5 18 20 46 Architectural unit 7 8 Attic windows 36 54 Roof 38 39 40 42

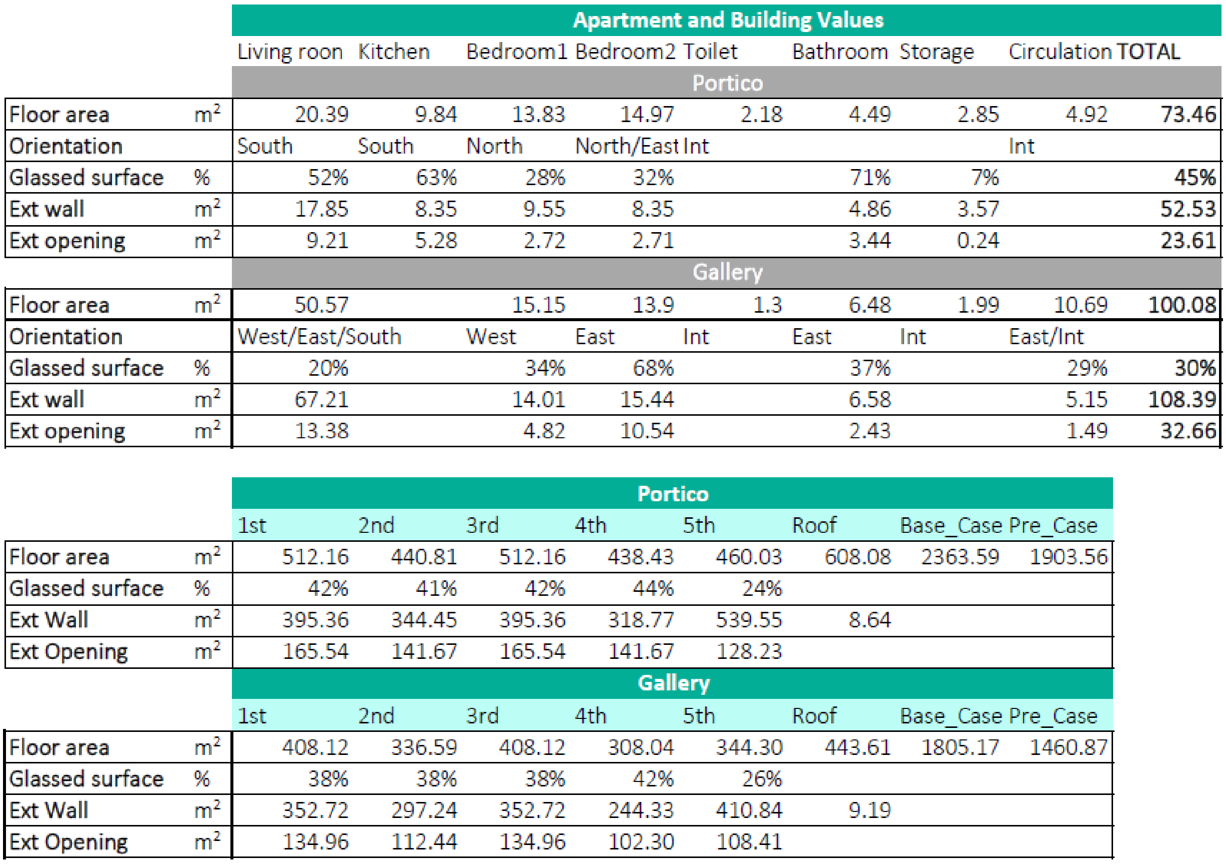
Table 4B. Attributes affected by each intervention



		Possible Impact			
		Affected Attributes			
		Urban	Neighbourhoood	Typology	Building elements
Renewable Sources	Solar PV Façade. A	Buildings 38 40 42 Streetscape 33 62 46 Architectural unit 45 Materials 47	Strip, hook and C 18 42 50 Buildings 28 29 46 Materials 34 35	Buildings 4 Streetscape 12 14 Urban unit 19 Elements 29 38 Architecture style 7 27 Materials 33 35 11 Façade 30 24 34	Architectural unit 6 8 Façade 30 18 46 Façade 21 26 Balconies 33 35 34 Roof 43 Frame 12 Installations 47 48 51
	Solar PV Façade. B	Buildings 42 Streetscape 46 62 Architectural unit 45 Materials 47	Strip, hook and C 18 50 Buildings 28 29 46 Materials 34 35	Elements 29 Façade 34 Architecture style 7 Streetscape 14 Materials 11	Façade 21 26 Architectural unit 8 Frame 9 12 Roof 44 Installations 47
	Solar PV Roof. A	Architecture style 37 Architectural unit 45 Streetscape 46 Materials 47	Strip, hook and C 18 Buildings 28 Materials 34 35	Streetscape 14 Elements 34 Architecture style 7 Materials 11 33 36	Façade 46 30 21 Roof 39 41 Architectural unit 6 8 Installations 48 Materials and colors 45
	Solar PV Roof. B	Architecture style 37 Architectural unit 41 45 Streetscape 46 62 Materials 47 Urban structure 13 Buildings 32	Strip, hook and C 19 30 52 Buildings 40 Materials 49	Architecture style 7 27 Materials 11 33 36 Buildings 4 Streetscape 12 14 Elements 34	Façade 18 21 30 46 Architectural unit 6 8 Roof 38 39 41 44 Installations 48 47 Materials and colors 45
	Solar Collector	Urban structure 14 Buildings 32 Architecture style 37 Architectural unit 41 45 Streetscape 62 46 Materials 47	Strip, hook and C 18 36 Buildings 28 Materials 34 35	Buildings 4 Architecture style 7 27 Streetscape 12 14 Elements 34 Materials 11 33 36	Façade 21 30 46 Architectural unit 6 8 Roof 38 39 41 Installations 48 47 Materials and colors 45

Table 4C. Attributes affected by each intervention

APPENDIX C – SQ3



		Apartment and Building Values								
		Living roon	Kitchen	Bedroom1	Bedroom2	Toilet	Bathroom	Storage	Circulation	TOTAL
		Portico								
Floor area	m²	20.39	9.84	13.83	14.97	2.18	4.49	2.85	4.92	**73.46**
Orientation		South	South	North	North/East	Int			Int	
Glassed surface	%	52%	63%	28%	32%		71%	7%		**45%**
Ext wall	m²	17.85	8.35	9.55	8.35		4.86	3.57		**52.53**
Ext opening	m²	9.21	5.28	2.72	2.71		3.44	0.24		**23.61**
		Gallery								
Floor area	m²	50.57		15.15	13.9	1.3	6.48	1.99	10.69	**100.08**
Orientation		West/East/South		West	East	Int	East	Int	East/Int	
Glassed surface	%	20%		34%	68%		37%		29%	**30%**
Ext wall	m²	67.21		14.01	15.44		6.58		5.15	**108.39**
Ext opening	m²	13.38		4.82	10.54		2.43		1.49	**32.66**

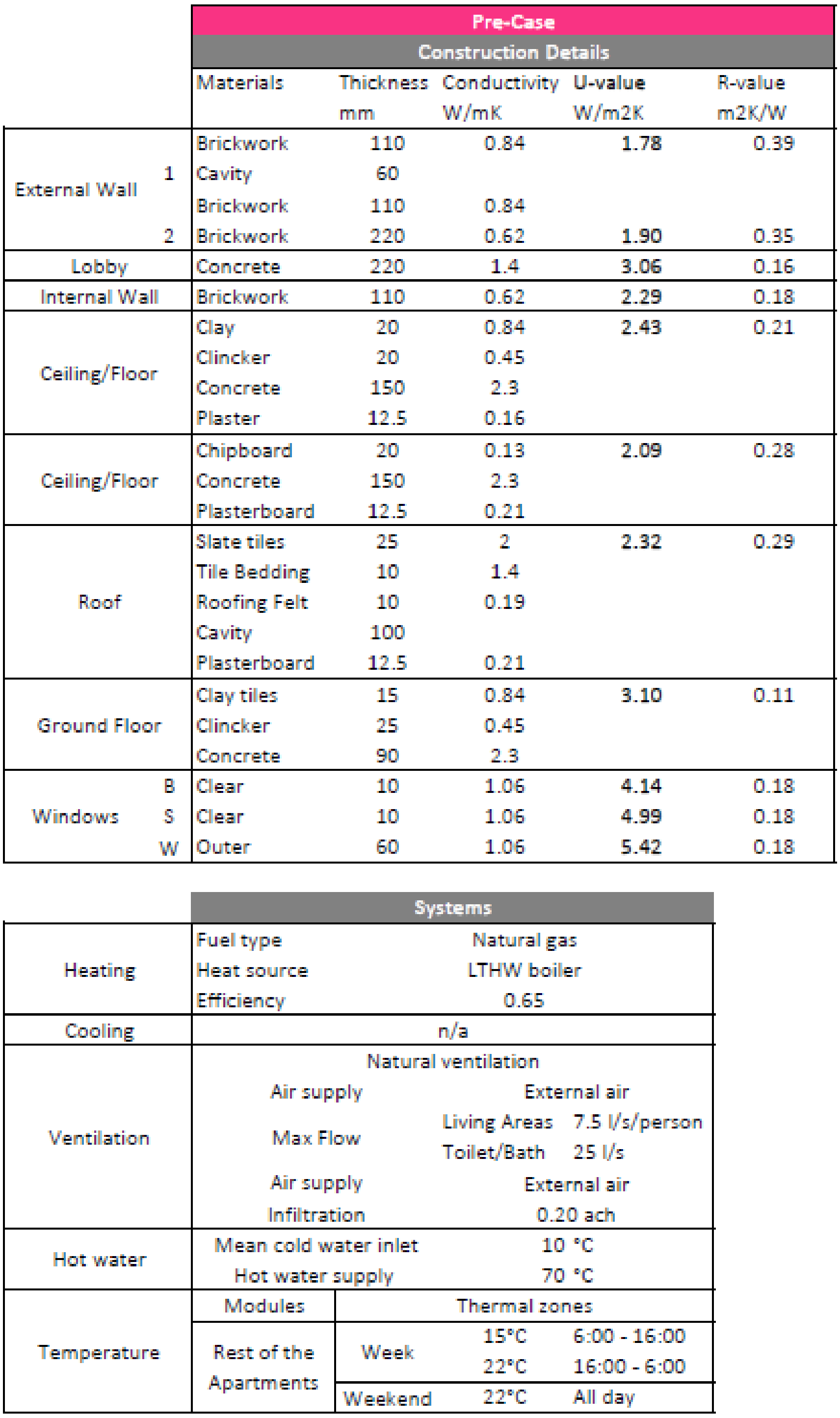
		Portico							
		1st	2nd	3rd	4th	5th	Roof	Base_Case	Pre_Case
Floor area	m²	512.16	440.81	512.16	438.43	460.03	608.08	2363.59	1903.56
Glassed surface	%	42%	41%	42%	44%	24%			
Ext Wall	m²	395.36	344.45	395.36	318.77	539.55	8.64		
Ext Opening	m²	165.54	141.67	165.54	141.67	128.23			
		Gallery							
		1st	2nd	3rd	4th	5th	Roof	Base_Case	Pre_Case
Floor area	m²	408.12	336.59	408.12	308.04	344.30	443.61	1805.17	1460.87
Glassed surface	%	38%	38%	38%	42%	26%			
Ext Wall	m²	352.72	297.24	352.72	244.33	410.84	9.19		
Ext Opening	m²	134.96	112.44	134.96	102.30	108.41			

Figure 0-8. Values used for Simulation

		Occupancy Profile			
		Week		Weekend	
1. Living Room	T	22 °C			
	💡	0:00 - 18:00	0	0:00 - 14:00	0
		18:00 - 24:00	1	14:00 - 24:00	1
	🧍	0:00 - 14:00	0	0:00 - 16:00	0
		14:00 - 24:00	1	16:00 - 24:00	1
	Misc	0:00 - 18:00	0.1	0:00 - 14:00	0.1
		18:00 - 24:00	1	14:00 - 24:00	1
2. Bedroom	T	20 °C			
	💡	0:00 - 7:00	0	0:00 - 9:00	0
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 23:00	0	10:00 - 24:00	0
		23:00 - 24:00	1		
	🧍	0:00 - 8:00	1	0:00 - 9:00	1
		8:00 - 23:00	0	9:00 - 24:00	0
		23:00 - 24:00	1		
	Misc	0:00 - 7:00	0	0:00 - 9:00	0
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 23:00	0	10:00 - 24:00	0
		23:00 - 24:00	1		
3. Ancillary	T	18 °C			
	💡	0:00 - 7:00	0	0:00 - 9:00	0
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 20:00	0	10:00 - 14:00	0
		20:00 - 21:00	1	14:00 - 15:00	1
		21:00 - 24:00	0	15:00 - 20:00	0
				20:00 - 21:00	1
				21:00 - 24:00	0
	🧍	0:00 - 7:00	0.1	21:00 - 9:00	0.1
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 20:00	0.1	10:00 - 15:00	0.1
		20:00 - 21:00	1	15:00 - 16:00	1
		21:00 - 24:00	0.1	16:00 - 20:00	0.1
				20:00 - 21:00	1
				21:00 - 24:00	0.1
	Misc	0:00 - 7:00	0.1	21:00 - 9:00	0.1
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 20:00	0.1	10:00 - 15:00	0.1
		20:00 - 21:00	1	15:00 - 16:00	1
		21:00 - 24:00	0.1	16:00 - 20:00	0.1
				20:00 - 21:00	1
				21:00 - 24:00	0.1

		Occupancy Profile			
		Week		Weekend	
4. Bathroom	T	24 °C			
	💡	0:00 - 7:00	0	0:00 - 9:00	0
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 19:00	0	10:00 - 19:00	0
		19:00 - 20:00	1	19:00 - 20:00	1
		20:00 - 24:00	0	20:00 - 24:00	0
	🧍	0:00 - 7:00	0	0:00 - 9:00	0
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 19:00	0	10:00 - 19:00	0
		19:00 - 21:00	1	19:00 - 21:00	1
		21:00 - 24:00	0	21:00 - 24:00	0
	Misc	0:00 - 7:00	0	0:00 - 9:00	0
		7:00 - 8:00	1	9:00 - 10:00	1
		8:00 - 19:00	0	10:00 - 19:00	0
		19:00 - 21:00	1	19:00 - 21:00	1
		21:00 - 24:00	0	21:00 - 24:00	0
5. Toilet	T	15 °C			
	💡	0:00 - 8:00	0	0:00 - 9:00	0
		8:00 - 9:00	1	9:00 - 10:00	1
		8:00 - 19:00	0	10:00 - 19:00	0
		19:00 - 20:00	1	19:00 - 21:00	1
		21:00 - 24:00	0	21:00 - 24:00	0
	🧍	0:00 - 8:00	0	0:00 - 9:00	0
		8:00 - 9:00	1	9:00 - 10:00	1
		8:00 - 19:00	0	10:00 - 19:00	0
		19:00 - 20:00	1	19:00 - 21:00	1
		21:00 - 24:00	0	21:00 - 24:00	0
Default	T	22 °C - 15 °C			
	💡	Average			
	🧍	0:00 - 14:00	0	0:00 - 16:00	0
		14:00 - 24:00	1	16:00 - 24:00	1
	Misc	0:00 - 18:00	0.1	0:00 - 14:00	0.1
		18:00 - 24:00	1	14:00 - 24:00	1

Figure 0-9. Occupancy profile of the thermal zones



Pre-Case

Construction Details

		Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	R-value m2K/W
External Wall		Brickwork	110	0.84	1.78	0.39
	1	Cavity	60			
		Brickwork	110	0.84		
	2	Brickwork	220	0.62	1.90	0.35
Lobby		Concrete	220	1.4	3.06	0.16
Internal Wall		Brickwork	110	0.62	2.29	0.18
Ceiling/Floor		Clay	20	0.84	2.43	0.21
		Clincker	20	0.45		
		Concrete	150	2.3		
		Plaster	12.5	0.16		
Ceiling/Floor		Chipboard	20	0.13	2.09	0.28
		Concrete	150	2.3		
		Plasterboard	12.5	0.21		
Roof		Slate tiles	25	2	2.32	0.29
		Tile Bedding	10	1.4		
		Roofing Felt	10	0.19		
		Cavity	100			
		Plasterboard	12.5	0.21		
Ground Floor		Clay tiles	15	0.84	3.10	0.11
		Clincker	25	0.45		
		Concrete	90	2.3		
Windows	B	Clear	10	1.06	4.14	0.18
	S	Clear	10	1.06	4.99	0.18
	W	Outer	60	1.06	5.42	0.18

Systems

Heating	Fuel type		Natural gas	
	Heat source		LTHW boiler	
	Efficiency		0.65	
Cooling	n/a			
Ventilation	Natural ventilation			
	Air supply		External air	
	Max Flow		Living Areas	7.5 l/s/person
			Toilet/Bath	25 l/s
	Air supply		External air	
	Infiltration		0.20 ach	
Hot water	Mean cold water inlet		10 °C	
	Hot water supply		70 °C	
Temperature	Modules	Thermal zones		
	Rest of the Apartments	Week	15°C	6:00 - 16:00
			22°C	16:00 - 6:00
		Weekend	22°C	All day

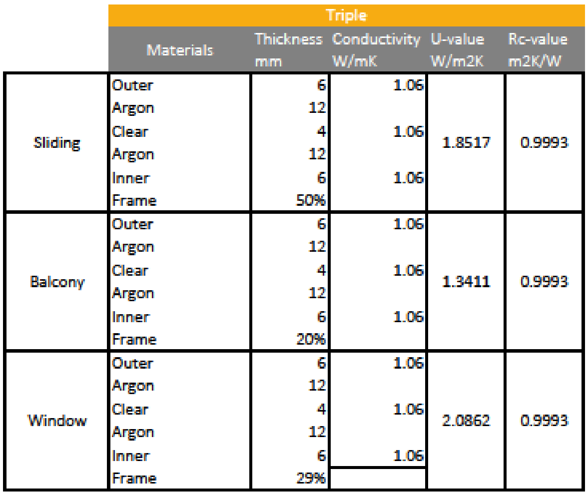
Figure 0-10. Construction details and systems of the Pre-Case

		Base-Case Construction Details				
		Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	R-value m2K/W
External Wall	1	Brickwork	110	0.84	1.78	0.39
		Cavity	60			
		Brickwork	110	0.84		
	2	Brickwork	220	0.62	1.90	0.35
Lobby		Concrete	220	1.4	3.06	0.16
Internal Wall		Brickwork	110	0.62	2.29	0.18
Ceiling/Floor		Clay	20	0.84	2.43	0.21
		Clincker	20	0.45		
		Concrete	150	2.3		
		Plaster	12.5	0.16		
Ceiling/Floor		Chipboard	20	0.13	2.09	0.28
		Concrete	150	2.3		
		Plasterboard	12.5	0.21		
Roof		Slate tiles	25	2	2.32	0.29
		Tile Bedding	10	1.4		
		Roofing Felt	10	0.19		
		Cavity	100			
		Plasterboard	12.5	0.21		
Ground Floor		Clay tiles	15	0.84	3.10	0.11
		Clincker	25	0.45		
		Concrete	90	2.3		
Windows	B	Clear	10	1.06	4.14	0.18
	S	Clear	10	1.06	4.99	0.18
	W	Outer	60	1.06	5.42	0.18

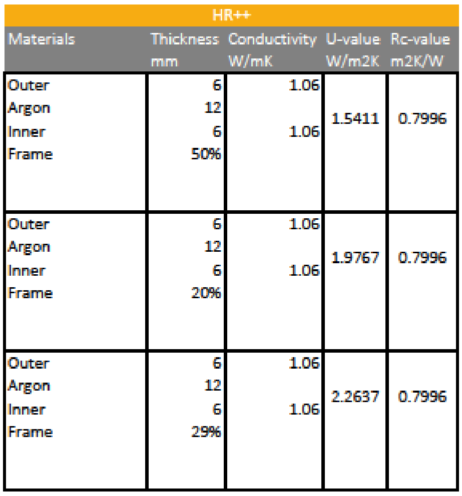
	Systems			
Heating	Fuel type	Natural gas		
	Heat source	District heating		
	Efficiency	0.58		
Cooling	Mechanical ventilation			
Ventilation	Natural ventilation + Mechanical extraction			
	Air supply	External air		
	Max Flow	Living Areas	7.5 l/s/person	
		Toilet/Bath	25 l/s	
	Air supply	External air		
	Infiltration	0.12 ach		
Hot water	Mean cold water inlet	10 °C		
	Hot water supply	70 °C		
Temperature	Modules	Thermal zones		
	Rest of the Apartments	Week	15°C	6:00 - 16:00
			22°C	16:00 - 6:00
		Weekend	22°C	All day

Figure 0-11. Construction details and systems of the Base-Case

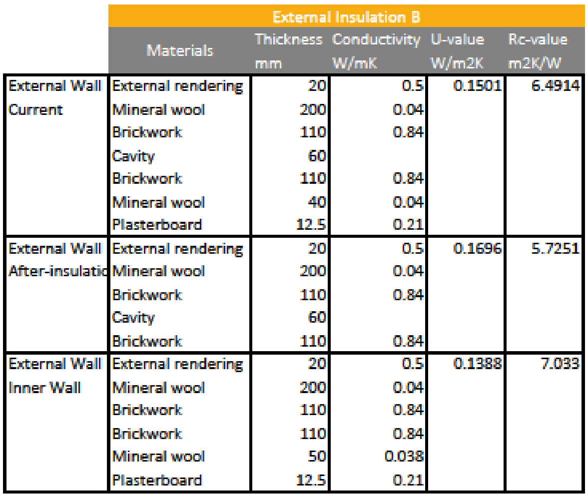
Values used for Sensitivity analysis



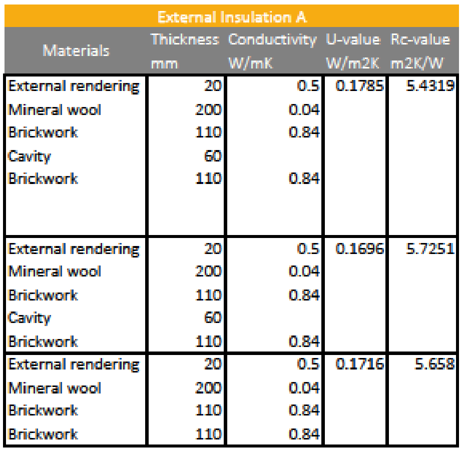
	Triple				
	Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
Sliding	Outer	6	1.06	1.8517	0.9993
	Argon	12			
	Clear	4	1.06		
	Argon	12			
	Inner	6	1.06		
	Frame	50%			
Balcony	Outer	6	1.06	1.3411	0.9993
	Argon	12			
	Clear	4	1.06		
	Argon	12			
	Inner	6	1.06		
	Frame	20%			
Window	Outer	6	1.06	2.0862	0.9993
	Argon	12			
	Clear	4	1.06		
	Argon	12			
	Inner	6	1.06		
	Frame	29%			



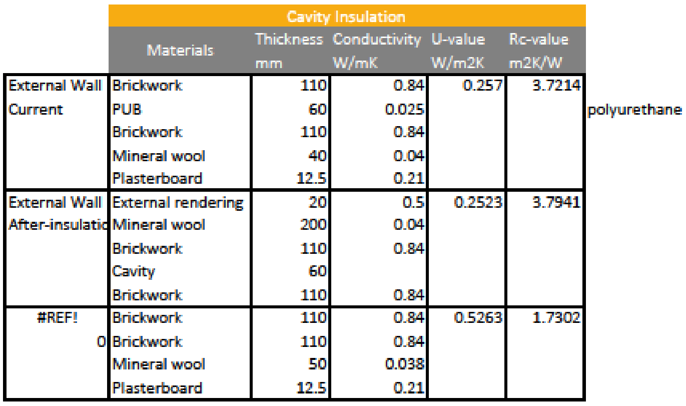
HR++				
Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
Outer	6	1.06	1.5411	0.7996
Argon	12			
Inner	6	1.06		
Frame	50%			
Outer	6	1.06	1.9767	0.7996
Argon	12			
Inner	6	1.06		
Frame	20%			
Outer	6	1.06	2.2637	0.7996
Argon	12			
Inner	6	1.06		
Frame	29%			



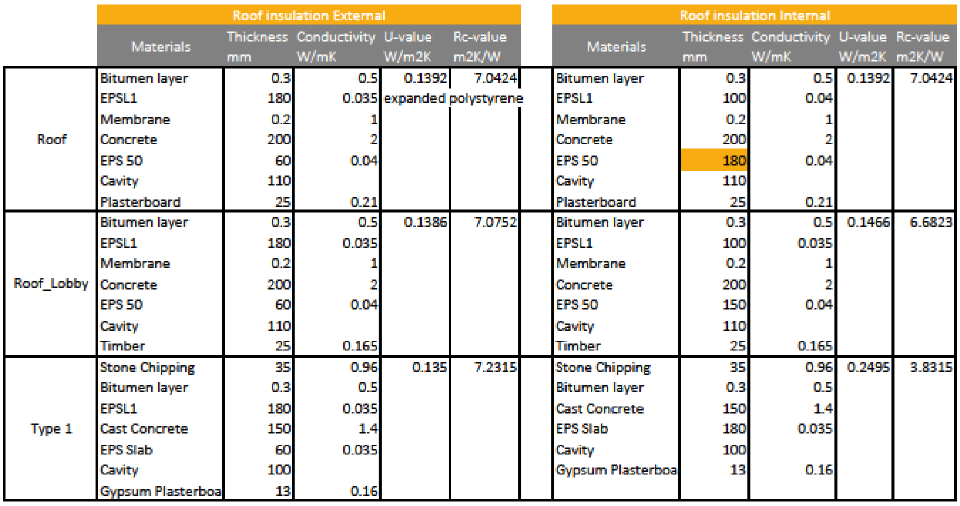
	External Insulation B				
	Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
External Wall Current	External rendering	20	0.5	0.1501	6.4914
	Mineral wool	200	0.04		
	Brickwork	110	0.84		
	Cavity	60			
	Brickwork	110	0.84		
	Mineral wool	40	0.04		
	Plasterboard	12.5	0.21		
External Wall After-insulatio	External rendering	20	0.5	0.1696	5.7251
	Mineral wool	200	0.04		
	Brickwork	110	0.84		
	Cavity	60			
	Brickwork	110	0.84		
External Wall Inner Wall	External rendering	20	0.5	0.1388	7.033
	Mineral wool	200	0.04		
	Brickwork	110	0.84		
	Brickwork	110	0.84		
	Mineral wool	50	0.038		
	Plasterboard	12.5	0.21		



External Insulation A				
Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
External rendering	20	0.5	0.1785	5.4319
Mineral wool	200	0.04		
Brickwork	110	0.84		
Cavity	60			
Brickwork	110	0.84		
External rendering	20	0.5	0.1696	5.7251
Mineral wool	200	0.04		
Brickwork	110	0.84		
Cavity	60			
Brickwork	110	0.84		
External rendering	20	0.5	0.1716	5.658
Mineral wool	200	0.04		
Brickwork	110	0.84		
Brickwork	110	0.84		

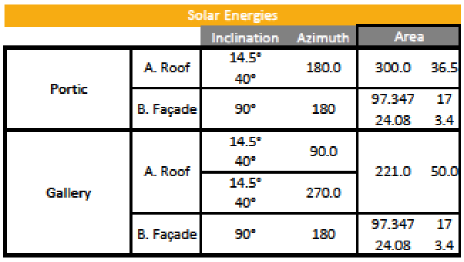


	Cavity Insulation					
	Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W	
External Wall Current	Brickwork	110	0.84	0.257	3.7214	
	PUB	60	0.025			polyurethane
	Brickwork	110	0.84			
	Mineral wool	40	0.04			
	Plasterboard	12.5	0.21			
External Wall After-insulatio	External rendering	20	0.5	0.2523	3.7941	
	Mineral wool	200	0.04			
	Brickwork	110	0.84			
	Cavity	60				
	Brickwork	110	0.84			
#REF!	Brickwork	110	0.84	0.5263	1.7302	
0	Brickwork	110	0.84			
	Mineral wool	50	0.038			
	Plasterboard	12.5	0.21			

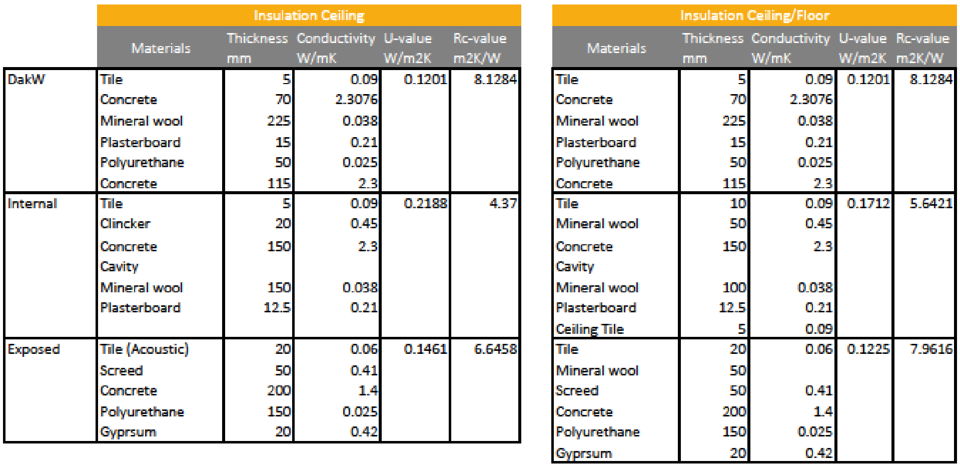


	Roof insulation External				
	Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
Roof	Bitumen layer	0.3	0.5	0.1392	7.0424
	EPSL1	180	0.035	expanded polystyrene	
	Membrane	0.2	1		
	Concrete	200	2		
	EPS 50	60	0.04		
	Cavity	110			
	Plasterboard	25	0.21		
Roof_Lobby	Bitumen layer	0.3	0.5	0.1386	7.0752
	EPSL1	180	0.035		
	Membrane	0.2	1		
	Concrete	200	2		
	EPS 50	60	0.04		
	Cavity	110			
	Timber	25	0.165		
Type 1	Stone Chipping	35	0.96	0.135	7.2315
	Bitumen layer	0.3	0.5		
	EPSL1	180	0.035		
	Cast Concrete	150	1.4		
	EPS Slab	60	0.035		
	Cavity	100			
	Gypsum Plasterboa	13	0.16		

Roof insulation Internal				
Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
Bitumen layer	0.3	0.5	0.1392	7.0424
EPSL1	100	0.04		
Membrane	0.2	1		
Concrete	200	2		
EPS 50	180	0.04		
Cavity	110			
Plasterboard	25	0.21		
Bitumen layer	0.3	0.5	0.1466	6.6823
EPSL1	100	0.035		
Membrane	0.2	1		
Concrete	200	2		
EPS 50	150	0.04		
Cavity	110			
Timber	25	0.165		
Stone Chipping	35	0.96	0.2495	3.8315
Bitumen layer	0.3	0.5		
Cast Concrete	150	1.4		
EPS Slab	180	0.035		
Cavity	100			
Gypsum Plasterboa	13	0.16		

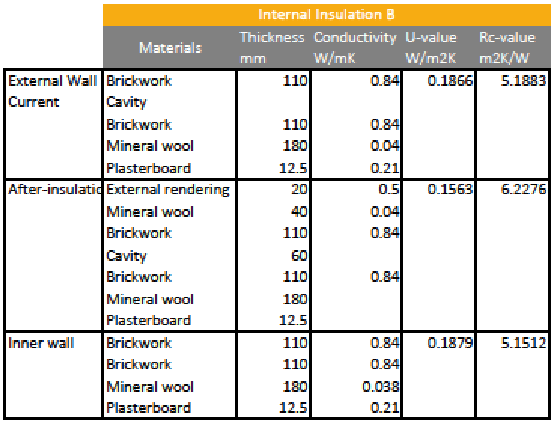


Solar Energies					
		Inclination	Azimuth	Area	
Portic	A. Roof	14.5° 40°	180.0	300.0	36.5
	B. Façade	90°	180	97.347 24.08	17 3.4
Gallery	A. Roof	14.5° 40°	90.0	221.0	50.0
		14.5° 40°	270.0		
	B. Façade	90°	180	97.347 24.08	17 3.4

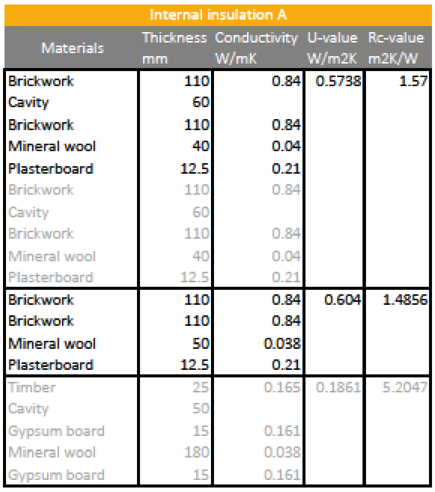


	Insulation Ceiling				
	Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
DakW	Tile	5	0.09	0.1201	8.1284
	Concrete	70	2.3076		
	Mineral wool	225	0.038		
	Plasterboard	15	0.21		
	Polyurethane	50	0.025		
	Concrete	115	2.3		
Internal	Tile	5	0.09	0.2188	4.37
	Clincker	20	0.45		
	Concrete	150	2.3		
	Cavity				
	Mineral wool	150	0.038		
	Plasterboard	12.5	0.21		
Exposed	Tile (Acoustic)	20	0.06	0.1461	6.6458
	Screed	50	0.41		
	Concrete	200	1.4		
	Polyurethane	150	0.025		
	Gyprsum	20	0.42		

Insulation Ceiling/Floor				
Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
Tile	5	0.09	0.1201	8.1284
Concrete	70	2.3076		
Mineral wool	225	0.038		
Plasterboard	15	0.21		
Polyurethane	50	0.025		
Concrete	115	2.3		
Tile	10	0.09	0.1712	5.6421
Mineral wool	50	0.45		
Concrete	150	2.3		
Cavity				
Mineral wool	100	0.038		
Plasterboard	12.5	0.21		
Ceiling Tile	5	0.09		
Tile	20	0.06	0.1225	7.9616
Mineral wool	50			
Screed	50	0.41		
Concrete	200	1.4		
Polyurethane	150	0.025		
Gyprsum	20	0.42		

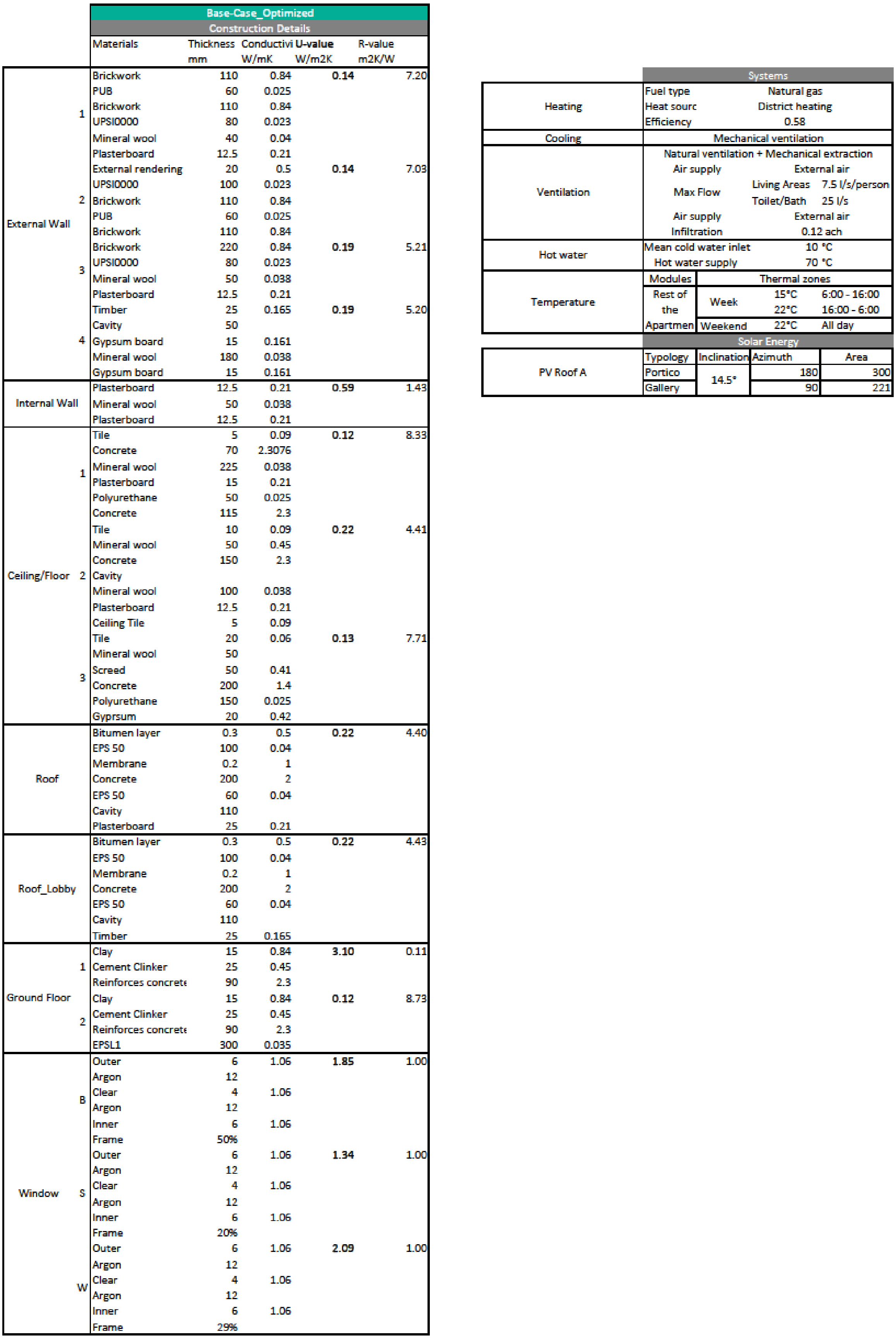


	Internal Insulation B				
	Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
External Wall Current	Brickwork	110	0.84	0.1866	5.1883
	Cavity				
	Brickwork	110	0.84		
	Mineral wool	180	0.04		
	Plasterboard	12.5	0.21		
After-insulatio	External rendering	20	0.5	0.1563	6.2276
	Mineral wool	40	0.04		
	Brickwork	110	0.84		
	Cavity	60			
	Brickwork	110	0.84		
	Mineral wool	180			
	Plasterboard	12.5			
Inner wall	Brickwork	110	0.84	0.1879	5.1512
	Brickwork	110	0.84		
	Mineral wool	180	0.038		
	Plasterboard	12.5	0.21		



Internal insulation A				
Materials	Thickness mm	Conductivity W/mK	U-value W/m2K	Rc-value m2K/W
Brickwork	110	0.84	0.5738	1.57
Cavity	60			
Brickwork	110	0.84		
Mineral wool	40	0.04		
Plasterboard	12.5	0.21		
Brickwork	110	0.84		
Cavity	60			
Brickwork	110	0.84		
Mineral wool	40	0.04		
Plasterboard	12.5	0.21		
Brickwork	110	0.84	0.604	1.4856
Brickwork	110	0.84		
Mineral wool	50	0.038		
Plasterboard	12.5	0.21		
Timber	25	0.165	0.1861	5.2047
Cavity	50			
Gypsum board	15	0.161		
Mineral wool	180	0.038		
Gypsum board	15	0.161		

APPENDIX D - MQ



Base-Case_Optimized

Construction Details

		Materials	Thickness mm	Conductivi W/mK	**U-value** W/m2K	R-value m2K/W
External Wall	1	Brickwork	110	0.84	**0.14**	7.20
		PUB	60	0.025		
		Brickwork	110	0.84		
		UPSI0000	80	0.023		
		Mineral wool	40	0.04		
		Plasterboard	12.5	0.21		
	2	External rendering	20	0.5	**0.14**	7.03
		UPSI0000	100	0.023		
		Brickwork	110	0.84		
		PUB	60	0.025		
		Brickwork	110	0.84		
	3	Brickwork	220	0.84	**0.19**	5.21
		UPSI0000	80	0.023		
		Mineral wool	50	0.038		
		Plasterboard	12.5	0.21		
	4	Timber	25	0.165	**0.19**	5.20
		Cavity	50			
		Gypsum board	15	0.161		
		Mineral wool	180	0.038		
		Gypsum board	15	0.161		
Internal Wall		Plasterboard	12.5	0.21	**0.59**	1.43
		Mineral wool	50	0.038		
		Plasterboard	12.5	0.21		
Ceiling/Floor	1	Tile	5	0.09	**0.12**	8.33
		Concrete	70	2.3076		
		Mineral wool	225	0.038		
		Plasterboard	15	0.21		
		Polyurethane	50	0.025		
		Concrete	115	2.3		
	2	Tile	10	0.09	**0.22**	4.41
		Mineral wool	50	0.45		
		Concrete	150	2.3		
		Cavity				
		Mineral wool	100	0.038		
		Plasterboard	12.5	0.21		
		Ceiling Tile	5	0.09		
	3	Tile	20	0.06	**0.13**	7.71
		Mineral wool	50			
		Screed	50	0.41		
		Concrete	200	1.4		
		Polyurethane	150	0.025		
		Gyprsum	20	0.42		
Roof		Bitumen layer	0.3	0.5	**0.22**	4.40
		EPS 50	100	0.04		
		Membrane	0.2	1		
		Concrete	200	2		
		EPS 50	60	0.04		
		Cavity	110			
		Plasterboard	25	0.21		
Roof_Lobby		Bitumen layer	0.3	0.5	**0.22**	4.43
		EPS 50	100	0.04		
		Membrane	0.2	1		
		Concrete	200	2		
		EPS 50	60	0.04		
		Cavity	110			
		Timber	25	0.165		
Ground Floor	1	Clay	15	0.84	**3.10**	0.11
		Cement Clinker	25	0.45		
		Reinforces concrete	90	2.3		
	2	Clay	15	0.84	**0.12**	8.73
		Cement Clinker	25	0.45		
		Reinforces concrete	90	2.3		
		EPSL1	300	0.035		
Window	B	Outer	6	1.06	**1.85**	1.00
		Argon	12			
		Clear	4	1.06		
		Argon	12			
		Inner	6	1.06		
		Frame	50%			
	S	Outer	6	1.06	**1.34**	1.00
		Argon	12			
		Clear	4	1.06		
		Argon	12			
		Inner	6	1.06		
		Frame	20%			
	W	Outer	6	1.06	**2.09**	1.00
		Argon	12			
		Clear	4	1.06		
		Argon	12			
		Inner	6	1.06		
		Frame	29%			

	Systems			
Heating	Fuel type	Natural gas		
	Heat sourc	District heating		
	Efficiency	0.58		
Cooling	Mechanical ventilation			
Ventilation	Natural ventilation + Mechanical extraction			
	Air supply	External air		
	Max Flow	Living Areas	7.5 l/s/person	
		Toilet/Bath	25 l/s	
	Air supply	External air		
	Infiltration	0.12 ach		
Hot water	Mean cold water inlet	10 °C		
	Hot water supply	70 °C		
Temperature	Modules	Thermal zones		
	Rest of the Apartmen	Week	15°C	6:00 - 16:00
			22°C	16:00 - 6:00
		Weekend	22°C	All day

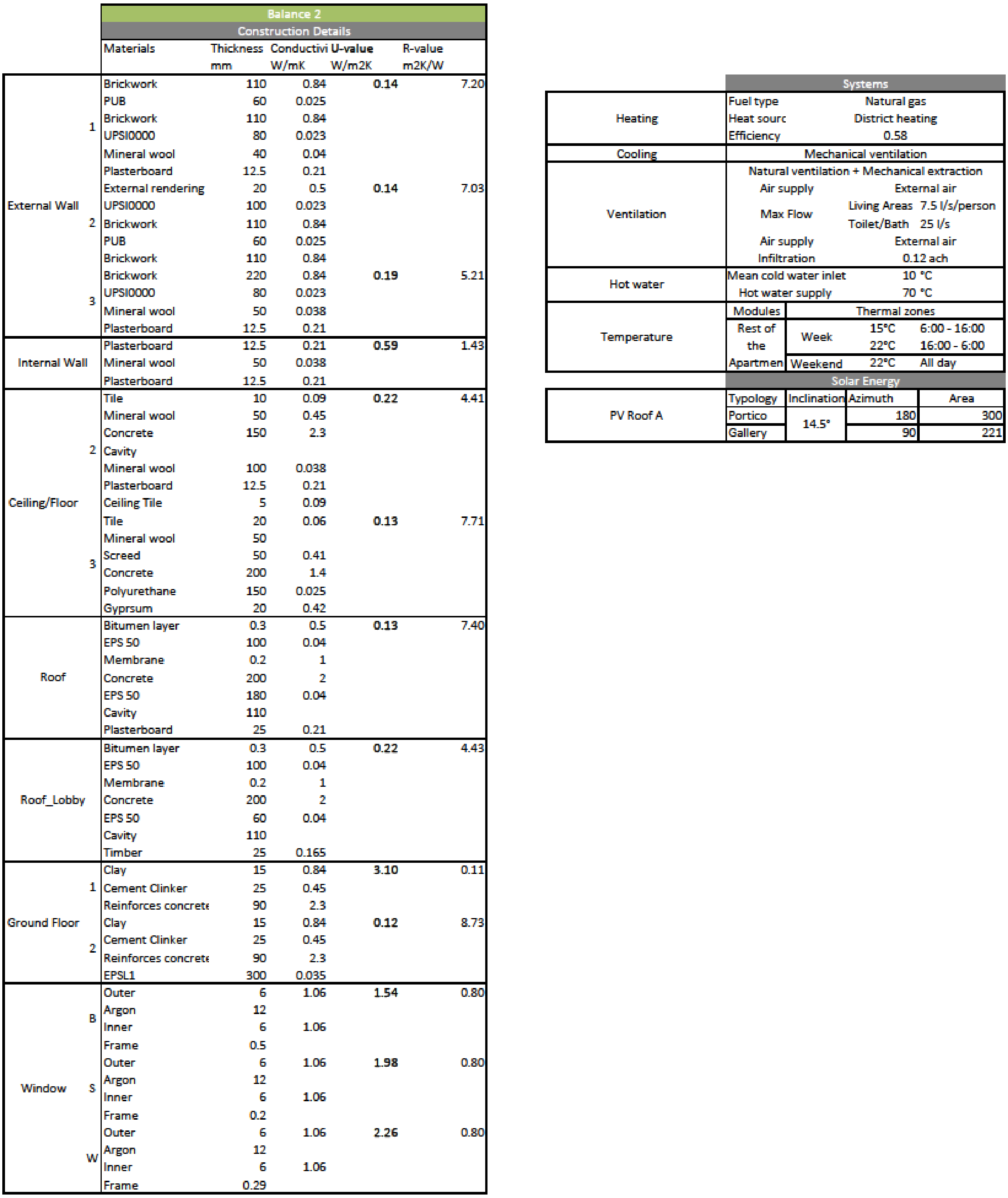
	Solar Energy			
PV Roof A	Typology	Inclination	Azimuth	Area
	Portico	14.5°	180	300
	Gallery		90	221

Figure 0-12. Construction details and systems of the Optimized

		Balance 1				
		Construction Details				
		Materials	Thickness mm	Conductivi W/mK	U-value W/m2K	R-value m2K/W
External Wall	1	Brickwork	110	0.84	**0.14**	7.20
		PUB	60	0.025		
		Brickwork	110	0.84		
		UPSI0000	80	0.023		
		Mineral wool	40	0.04		
		Plasterboard	12.5	0.21		
	2	External rendering	20	0.5	**0.14**	7.03
		UPSI0000	100	0.023		
		Brickwork	110	0.84		
		PUB	60	0.025		
		Brickwork	110	0.84		
	3	Brickwork	220	0.84	**0.19**	5.21
		UPSI0000	80	0.023		
		Mineral wool	50	0.038		
		Plasterboard	12.5	0.21		
Internal Wall		Plasterboard	12.5	0.21	**0.59**	1.43
		Mineral wool	50	0.038		
		Plasterboard	12.5	0.21		
Ceiling/Floor	2	Tile	10	0.09	**0.22**	4.41
		Mineral wool	50	0.45		
		Concrete	150	2.3		
		Cavity				
		Mineral wool	100	0.038		
		Plasterboard	12.5	0.21		
		Ceiling Tile	5	0.09		
	3	Tile	20	0.06	**0.13**	7.71
		Mineral wool	50			
		Screed	50	0.41		
		Concrete	200	1.4		
		Polyurethane	150	0.025		
		Gyprsum	20	0.42		
Roof		Bitumen layer	0.3	0.5	**0.13**	7.40
		EPS 50	100	0.04		
		Membrane	0.2	1		
		Concrete	200	2		
		EPS 50	180	0.04		
		Cavity	110			
		Plasterboard	25	0.21		
Roof_Lobby		Bitumen layer	0.3	0.5	**0.22**	4.43
		EPS 50	100	0.04		
		Membrane	0.2	1		
		Concrete	200	2		
		EPS 50	60	0.04		
		Cavity	110			
		Timber	25	0.165		
Ground Floor	1	Clay	15	0.84	**3.10**	0.11
		Cement Clinker	25	0.45		
		Reinforces concrete	90	2.3		
	2	Clay	15	0.84	**0.12**	8.73
		Cement Clinker	25	0.45		
		Reinforces concrete	90	2.3		
		EPSL1	300	0.035		
Window	B	Outer	6	1.06	**1.85**	1.00
		Argon	12			
		Clear	4	1.06		
		Argon	12			
		Inner	6	1.06		
		Frame	50%			
	S	Outer	6	1.06	**1.34**	1.00
		Argon	12			
		Clear	4	1.06		
		Argon	12			
		Inner	6	1.06		
		Frame	20%			
	W	Outer	6	1.06	**2.09**	1.00
		Argon	12			
		Clear	4	1.06		
		Argon	12			
		Inner	6	1.06		
		Frame	29%			

	Systems			
Heating	Fuel type	Natural gas		
	Heat sourc	District heating		
	Efficiency	0.58		
Cooling	Mechanical ventilation			
Ventilation	Natural ventilation + Mechanical extraction			
	Air supply	External air		
	Max Flow	Living Areas	7.5 l/s/person	
		Toilet/Bath	25 l/s	
	Air supply	External air		
	Infiltration	0.12 ach		
Hot water	Mean cold water inlet	10 °C		
	Hot water supply	70 °C		
Temperature	Modules	Thermal zones		
	Rest of the Apartmen	Week	15°C	6:00 - 16:00
			22°C	16:00 - 6:00
		Weekend	22°C	All day

Figure 0-13. Construction details and systems of the Balance1



		Balance 2				
		Construction Details				
		Materials	Thickness mm	Conductivi W/mK	U-value W/m2K	R-value m2K/W
External Wall	1	Brickwork	110	0.84	0.14	7.20
		PUB	60	0.025		
		Brickwork	110	0.84		
		UPSI0000	80	0.023		
		Mineral wool	40	0.04		
		Plasterboard	12.5	0.21		
	2	External rendering	20	0.5	0.14	7.03
		UPSI0000	100	0.023		
		Brickwork	110	0.84		
		PUB	60	0.025		
		Brickwork	110	0.84		
	3	Brickwork	220	0.84	0.19	5.21
		UPSI0000	80	0.023		
		Mineral wool	50	0.038		
		Plasterboard	12.5	0.21		
Internal Wall		Plasterboard	12.5	0.21	0.59	1.43
		Mineral wool	50	0.038		
		Plasterboard	12.5	0.21		
Ceiling/Floor	2	Tile	10	0.09	0.22	4.41
		Mineral wool	50	0.45		
		Concrete	150	2.3		
		Cavity				
		Mineral wool	100	0.038		
		Plasterboard	12.5	0.21		
		Ceiling Tile	5	0.09		
	3	Tile	20	0.06	0.13	7.71
		Mineral wool	50			
		Screed	50	0.41		
		Concrete	200	1.4		
		Polyurethane	150	0.025		
		Gyprsum	20	0.42		
Roof		Bitumen layer	0.3	0.5	0.13	7.40
		EPS 50	100	0.04		
		Membrane	0.2	1		
		Concrete	200	2		
		EPS 50	180	0.04		
		Cavity	110			
		Plasterboard	25	0.21		
Roof_Lobby		Bitumen layer	0.3	0.5	0.22	4.43
		EPS 50	100	0.04		
		Membrane	0.2	1		
		Concrete	200	2		
		EPS 50	60	0.04		
		Cavity	110			
		Timber	25	0.165		
Ground Floor	1	Clay	15	0.84	3.10	0.11
		Cement Clinker	25	0.45		
		Reinforces concrete	90	2.3		
	2	Clay	15	0.84	0.12	8.73
		Cement Clinker	25	0.45		
		Reinforces concrete	90	2.3		
		EPSL1	300	0.035		
Window	B	Outer	6	1.06	1.54	0.80
		Argon	12			
		Inner	6	1.06		
		Frame	0.5			
	S	Outer	6	1.06	1.98	0.80
		Argon	12			
		Inner	6	1.06		
		Frame	0.2			
	W	Outer	6	1.06	2.26	0.80
		Argon	12			
		Inner	6	1.06		
		Frame	0.29			

	Systems			
Heating	Fuel type	Natural gas		
	Heat sourc	District heating		
	Efficiency	0.58		
Cooling	Mechanical ventilation			
Ventilation	Natural ventilation + Mechanical extraction			
	Air supply	External air		
	Max Flow	Living Areas	7.5 l/s/person	
		Toilet/Bath	25 l/s	
	Air supply	External air		
	Infiltration	0.12 ach		
Hot water	Mean cold water inlet	10 °C		
	Hot water supply	70 °C		
Temperature	Modules	Thermal zones		
	Rest of the Apartmen	Week	15°C	6:00 - 16:00
			22°C	16:00 - 6:00
		Weekend	22°C	All day
	Solar Energy			
PV Roof A	Typology	Inclination	Azimuth	Area
	Portico	14.5°	180	300
	Gallery		90	221

Figure 0-14. Construction details and systems of the Balance 2

“Only when understanding our place,
we may be able to participate creatively
and contribute to its history.”
- Norberg ESchulz, 1980