Innovating Renovation

A research on empirically based design guidelines that contribute to the innovation of energy efficient renovation projects for architects

Abstract

This paper identifies that in order to actually reach the (inter)national set targets for an energy neutral built environment in 2050, the current approach needs to shift focus. Nowadays the focus is on innovating energy efficient systems for newly built buildings, while these new buildings will only form 20% of the building stock of 2050. So in order to reach an energy neutral built environment in 2050 in the Netherlands, innovation needs to be brought towards the renovation business. To contribute to the innovation of the renovation projects, a framework is developed which assesses the architectural, social and technical effects of existing facade renovation principles. The linked principles and effects formulate design guidelines based on a empirically based case study analysis. To make this knowledge attractive and easily understandable, there is made use of icons which visualize the renovation principles and their effects. In the accessory book, which is the visual elaboration of this research paper, the design guidelines are explained and elaborated upon.

Keywords: facade renovations, existing building stock, energy efficiency, case study analysis, illustrative overview, innovation, architecture

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1. Introduction

1.1 Background information

The energy challenge we are facing today as a society is increasingly becoming part of our common knowledge. A growing number of roofs is covered with PV-panels, hybrid and electric cars are booming and we take better care of our waste. Moreover, we monitor our energy use by apps, wind mill parks are built at sea and energy efficient housing is part of international policies. These are nice developments in the transition towards an energy neutral society, and architecture could play a leading role in this. However, despite these promising developments, the Netherlands is currently not meeting all of the (internationally) set goals (CBS, 2016).

As stated before, architecture could play a role in the transitions towards an energy neutral society. In 2015, the built environment used 22% of the total energy in the Netherlands (RVO, 2016c, p. 21). One of the ambitions of the European Union is to let every *newly built building* from 2020 onwards use no to very little energy (RVO, 2016a). The goal of the Dutch government goes further by aiming for an *energy neutral built environment* in 2050 (RVO, 2016b). Within 35 years the percentage of 22% must be reduced to nearly a zero percent, to meet the set goals. This asks for a new approach within the construction sector, where architects, builders, local governments, housing corporations, policy makers and occupants need to work together.

Currently, the regulations towards new buildings are being sharpened every year to reach these goals in 2050 (RVO, 2016a). Thus, the focus is on newly built energy neutral buildings, of which the amount will increase towards 2050. Yet, it is the existing building stock that actually is responsible for the largest share of energy use. This existing building stock is currently not included in these policy regulations. Although there are several practical reasons for this such as the monitoring of compliance with building regulations, this lack of existing building stock in the regulations is a factor that hinders the progress towards energy efficiency within the built environment. As stated in the report of RVO (2016,c, p.7), the single focus on new buildings will not cut the deal because they are no more than 20% of the total building stock. Thus to actually reach the targets of energy neutrality in the built environment in 2050, the focus should be shifted towards the existing stock (Yücel, 2013).

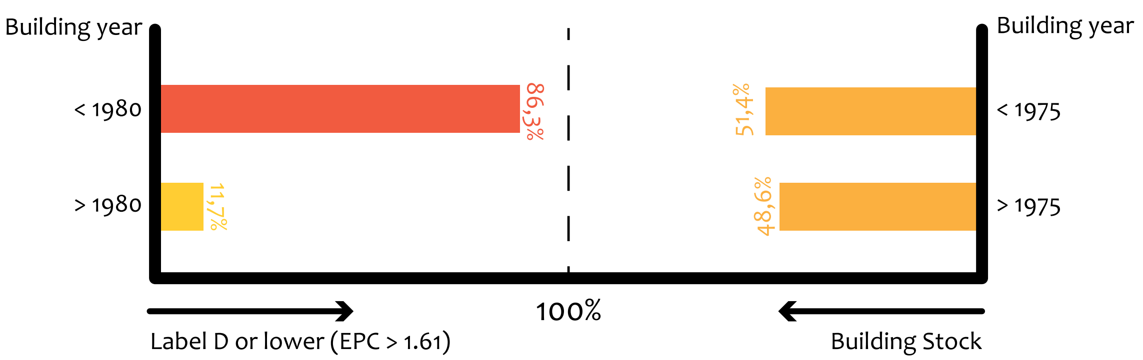

Figure 1: Label D or lower versus total building stock. Own illustration based on Rijksoverheid (2016).

1.2 Problem statement

To monitor and gain insight into the current state of energy performance of the built environment specifically, dwellings in the Netherlands are rated according to an energy label system. These energy labels go from very poor (G-label) to excellent (A+-label) and are obligatory to have when selling or renting a dwelling since 2015 (Rijksoverheid, 2014). Until now 2.742.000 buildings have an energy label which is nearly forty percent of the total building stock (Rijksoverheid, 2016). 42.7% of all labelled dwellings have label D, which is equal to an average energy use, or lower. Of all these 'label D or lower' dwellings, ninety percent is built before 1980 (see figure 1). Combining this with the fact that more than half of the building stock is built before 1975, the need for energy neutral renovations in the Netherlands is urgent and essential for the ambitions of 2050.

There are several methods available that cover the energy challenge of the built environment and the number of these methods is especially increasing for newly built buildings. However, these methods seem not to find their way into renovation projects. The renovation business is in need of methods that deal with all objectives, an integrated approach. Yet, the currently available methods do not touch the complexity of renovation projects because they focus on technical elements and become too specific (Thuvander et al., 2012, p. 1207). According to and Jensen & Maslesa (2015, p. 2), the renovation business is in need for simplified methods which are accessible for all actors within the renovation design process.
If the goal is to reach an energy neutral environment, then all aspects to reach this goal need to be taken into account. Most of all because the influence of the user has a larger impact on the energy use than the technical quality of a building, as is showed in several studies (Janda, 2011; Majcen et al., 2013; Tigchelaar & Leidelmeijer, 2013).

Summarizing, in order to reach the set EU and national targets with regards to an energy neutral built environment, an integrated view on renovation is needed, which is currently not available in existing methods. This is a blocking factor for innovation within renovation projects and the role architecture could play in the transition to an energy neutral society.

1.3 Research question and sub-questions

Thus, this research will look into this opportunity of creating a better overview and will identify all the effects that belong to a single renovation project, in order to create a more innovative and integrated methodology for architects in renovation projects that strive for energy efficiency. Therefore the following research question is formulated:

Which empirically based design guidelines that contribute to the innovation of renovation projects striving for energy efficiency can be formulated for architects?

To create a solid structure around the research question, sub-questions will be used to go further into specific elements of the research. The following sub-questions are formulated in this matter:

a) How to categorize the effects of renovation case studies in a comprehensive framework?
b) What are the important themes within renovation case studies and their possible effects?
c) What are the actual effects of renovation case studies in practice?
d) How are the actual effects linked to the renovation principles?
e) What are the empirically based design guidelines?

1.4 Aim and relevance

The aim of this research paper is to formulate design guidelines which will help the architect to save time in the beginning of the design process. These guidelines will be based on an empirical study to justify the outcome, so case studies will be analysed. A new renovation project has several requirements the design must meet. To reach these requirements, the design guidelines already show which renovation principles are advised to use to create the wished effect belonging to the requirement. In this way, time is saved in the beginning of the design process. Time that can be better spent on the development and innovation of the renovation principles. A renovation principles is a certain way of intervening in a existing building. By spending time on innovating the renovation principles instead of finding the right renovation principles, the overview and thus the renovation principles can grow and evolve. The innovation within the renovation sector is needed, according to Hoppe (2012, p. 800), because the current focus of the implementation of innovative energy systems is on newly built dwellings and not on the existing stock. The innovation will upgrade the way renovation projects and renovation principles contribute in the challenge of an energy efficient built environment.

2. Method

2.1 Database

To make sure the design guidelines are based on a solid basis and empirically found, there will be made use of a database. This database consists out of thirty case studies, an amount that can provide a solid base, representative outcomes and can be analysed within the available timeframe. Besides, by analysing existing and realised projects already some political and financial feasibility of the results is reflected in the end. A larger amount of case studies also gives the possibility to research all the effects, because more topics will be touched in more case studies. A small database can be analysed deeper and can give high quality output, but this output will be very narrow sighted. The selected case studies have a large influence on the outcome of the research and therefore the selection criteria are of importance (see figure 2). The thirty case studies need to have the ambition to create an energetic upgrade for the to-be-renovated building, since this is the starting point of this research. To check whether the building really is energetically upgraded, the energy labels give an solid indication. To make use of the label system, the case studies need to be in the Netherlands. Next to the 25 Dutch case studies, also 5 international case studies are chosen because they hold interesting elements. The database can be found in appendix 1.

Selection criteria
1. Strive for energy performance upgrade
2. Renovation needs to be focussed on the facade
3. Renovated in the last 10 years (>2006)
4. Realised projects
5. Building year
I. Original building year before 1980
II. whereof 5 case studies built before 1945
6. A differentiation of building types
7a. Dutch
I. Nominated for the Dutch national renovation prize or;
II. Part of the *Stroomversnelling* initiative.
7b. at least 5 International
I. Holding at least one interesting element

Figure 2: Selection criteria for renovation projects in database. Own illustration.

2.2 How to use the database to answer the research question?

To be able to answer the research question there must first be indicated which framework will be used to analyse the case studies and what will be the themes, categories and effects that will be used to analyse the renovation projects, as the sub-questions a and b showed. The categorization of effects for a comprehensive framework will be done by a trial and error approach, where five renovation case studies are analysed in several ways to find out which way of analysing will suit the research question best. Each time the five case studies are analysed, the outcome will be evaluated and the way of analysing will be adopted according the findings of the evaluation. When the themes, categories and possible effects are known the total database can be analysed.

With the fixed set of themes, categories and possible effects, each case study of the database will be analysed on the actual effects its renovation principles reaches. The renovation principles refer to the kind of intervention(s) on the building that is/are taken during the renovation process. Examples of the effects of renovation principles are a better energy label, a different composition for the façade or a change in the costs for the occupant. The information of all these effects is found on the website of the renovation architect, builder, owner and/or the initiator of the renovation project (see case study references). All these actual effects will be compared and analysed and linked back to the most used principles that are used per actual effect. A single actual effect together with the most used renovation principles will form a design guideline.

2.3 Communicating the results (to the specific target group)

An important aspect of this research is to make the conclusion, the design guidelines, easily accessible and insightful for architects and other actors. A scientific paper is not the right way to reach this target group, so next to this paper a book is made. The book is a visual extension of this research paper and uses mostly images, in the form of icons, to communicate. Next to the fact that the book gave structure during the analysis, it will act as an inspiration source where architects can gain knowledge on renovation topics. The book consists out of three elements: an explanation of the icons, the design guidelines and the overview with the analysis of all case studies. The way the reader will use the book is the opposite way of how the research is done, see figure 3.

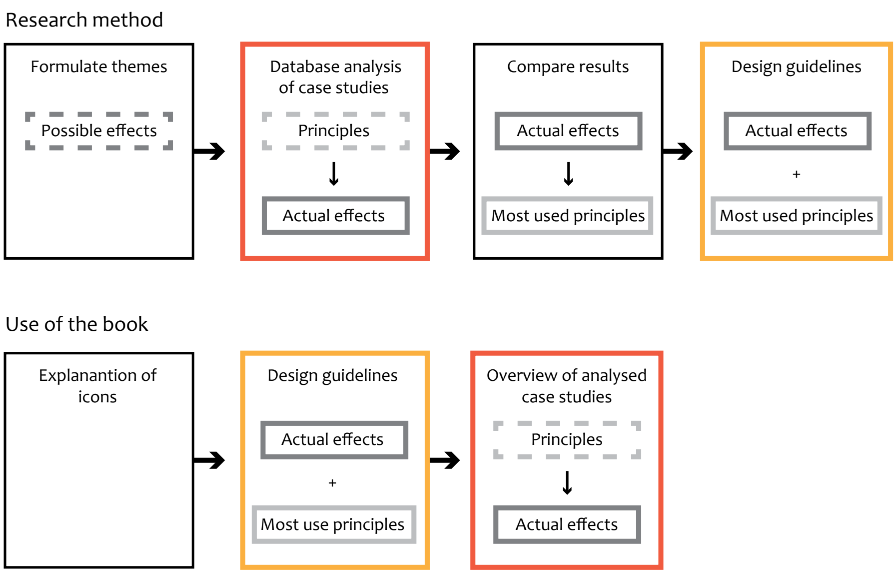

Figure 3: Research method versus the use of the book. Own illustration.

3. Results

3.1 How to categorize the effects of renovation case studies in a comprehensive framework?
To find out how the framework is categorized there is made us of an ongoing process. The trial and error approach made a development of the framework possible, see appendix 2.

3.1.1 First analysis

To find out how the effects are categorized for the analysis of the projects in the database, there is just started with analysing some of the case studies. This is done by describing in keywords what the improvements of the renovation were on different subjects. See appendix 2a for an illustration of the first analysis scheme. The main point to further develop this scheme was the unreadable outcome of the effects. Keywords are not an appropriate way to give insight in the effects, because they are not attractive to present the information.

3.1.2 Specific icon analysis

So the next step consisted out of making the effects visually understandable. There is chosen to translate the keywords of a result into a specific icon. An icon is a self-explaining picture and is therefore better understandable and accessible than keywords. Now each case study has a unique icon for each effect. Yet, capturing the improvement of the renovation in one icon was hard because too much information was tried to be put into one icon. To make visible what the actual improvement of the renovation is, in this version of the framework there is made use of two icons: one icon for the situation before the renovation and one icon for the situation after the renovation. The case studies that were used as analysis try-out were combined in an A5-booklet. The analysis of a single case study in the booklet consists out of 8 pages: one page for the general information of the project, one page for a picture before and after the renovation, four pages for the effects, one page for a drawing and a page for the renovation goal and the used principles. To touch the same topics with every case study, the effects were divided among four themes: organization, social, quality and technical. This led to one theme per page and on every page a maximum of three effects, see also appendix 2b.
Yet, the biggest objections towards this way of analysing were the inconsistency and the incomparability of the icons. By starting the analysis from the qualities of the case study, the icons became very specific and unique for that one case study. That makes it impossible to compare all the case studies and effects along each other. A second reason of objection is the fact that the A5-booklet was too small to add all the effects of a theme in a comprehensive way. A selection of the most important effects of each theme was made per case study, which caused the less important effects not to be added into the booklet. Therefore, there is looked towards an improvement of the framework.

3.1.3 Fixed set of generic icons

Understanding that consistency is of outmost importance for a comprehensive framework, a conducted analysis is made with a fixed structure of icons. The hierarchy of this structure is showed below in figure 4. Within this structure, a fixed set of themes, categories and effects was created. A fixed set ensures that the differentiation of the effects is controlled, because every icon is known in advance. For this fixed set the themes of the A5-booklet were used, and within these four themes 15 categories were named with each their own possible effects. By making use of a fixed set of icons for the answers, again the before and after situation of an effect were no longer needed. Icons can now describe the effect in a generic way, without needing the specific information of the existing situation. This change in the approach of the analysis advanced the consistency as well as the comparability, because all the effects of all the projects make now use of the same set of icons.
From now on the icons will focus on the effect of the facade; the effects of interior renovation were left aside.

<table>
<tr><th>Case studies</th><th>Themes</th><th>Categories</th><th>Possible effects (illustrated with icons)</th></tr>
<tr><td rowspan="12">Case study 1</td><td rowspan="8">Theme A</td><td rowspan="2">Category 1</td><td>Effect a</td></tr>
<tr><td>Effect b</td></tr>
<tr><td rowspan="3">Category 2</td><td>Effect a</td></tr>
<tr><td>Effect b</td></tr>
<tr><td>Effect c</td></tr>
<tr><td rowspan="3">Category 3</td><td>Effect a</td></tr>
<tr><td>Effect b</td></tr>
<tr><td>Effect c</td></tr>
<tr><td rowspan="3">Theme B</td><td>Category 1</td><td>…</td></tr>
<tr><td>Category 2</td><td>…</td></tr>
<tr><td>Category 3</td><td>…</td></tr>
<tr><td>Theme C</td><td>…</td><td></td></tr>
<tr><td>Case study 2</td><td>…</td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td></tr>
</table>

Figure 4: Hierarchy of the analysis structure. Own illustration.

Another important task is to give every theme its own colour, so every theme is recognizable and distinguishable. The final adaptation was the enlargement in size of the page of the book and a smaller size of the icons. In this way there can be more icons fitted on one page, which creates a clearer overview. The total coverage of one project analysis now contains four A4-pages: one with the before and after pictures, one for the general information and two for the effects (appendix 2c).

After the reflection of this analysis, there was concluded that the categories in combination with the effects were still inconsistent. Some categories did not cover the essence of the effect and other categories covered several effects, which was confusing. Lastly, the answer possibilities of each effect were used differently. Some effects had different levels of answer possibilities, for example having icons for worse, no effect and improved. Other effects had different options of answer possibilities, for example different types of circulation systems. A last upgrade of the framework is therefore needed.

3.1.4 A comprehensive framework

To create a better understandable categorization, the structure was critically reviewed. This resulted in three themes over which the fourteen adapted categories were divided. These three themes are: architectural effects, social effects and technical effects. All the effects and their possibilities will be elaborated on by answering the second sub-question. So the framework for analysing the renovation case studies is built up as follows: three themes which hold fourteen categories which together have 52 possible effects. Next to this structure around the effects, the renovation principles are also illustrated with icons. The general information is showed in a table, the building type and structural type are expressed in icons. The general information part is called from now on the fact sheet.

So in the analysis of a case study, firstly the renovation principles are illustrated by the orange icons followed by the fact sheet icons. At last the effects of the five architectural categories are showed in blue icons, the effect of the four social categories are showed in red icons and the green icons represent the effects of the five technical categories. For the final framework see the book.

3.2 What are the categories for analysing renovation projects and what are the possible effects within a category?

Now that it is made clear how the renovation projects will be analysed according the above sketched framework, the important themes and possible effects can be discussed. As indicated above, the three themes consist out of architectural, social and technical categories and have each a fixed set of possible effects.

3.2.1 Architectural categories

The first theme contains icons which resemble architectural effects of the renovation principles. The architectural effects describe the effect the renovation principle has on architectural related topics, which is important information for the architect to take into account when designing a renovation project. The following five architectural categories will be analysed: Composition, Context, Facade Integration, Material and Space. Each category has its own possible effects, which is showed in figure 5.

Theme	Category	Possible effect	Codes
Architectural	Composition	*No effect*	AE-CP-NE
		Horizontal	AE-CP-D
		Vertical	AE-CP-H
		Unity	AE-CP-U
		Diversity	AE-CP-V
	Context	*Worse*	AE-CT-W
		No effect	AE-CT-NE
		Improved	AE-CT-I
		Maximized	AE-CT-M
	Facade Integration	*No integration*	AE-FI-NI
		Energy integration	AE-FI-EI
		HVAC integration	AE-FI-HI
	Material	*No new material*	AE-M-NE
		Concrete	AE-M-C
		Glass	AE-M-G
		Metal	AE-M-M
		Stone	AE-M-S
		Wood	AE-M-W
	Space	*Smaller*	AE-S-S
		No effect	AE-S-NE
		Extend inside envelop	AE-S-EI
		Extend outside envelop	AE-S-EO

Figure 5: Architectural categories and possible effects. Own illustration.

3.2.2 Social effect icons

The second category contains icons which resemble social effects of the renovation principles. The social effects describe the effect the renovation principle has on the occupants of the renovation dwelling, which is important information for the architect to take into account when designing a renovation project (Janda, 2011; Majcen et al., 2013; Tigchelaar & Leidelmeijer, 2013). These four social categories will be analysed: During Construction, Energy Awareness, Finance, Safety. Each category has its own possible effects, which is showed in figure 6.

Theme	Category	Possible effect	Codes
Social	During construction	*Temporarily move out*	SE-DC-M
		Within timeframe	SE-DC-TF
		Without moving out	SE-DC-WM
	Energy awareness	*No awareness*	SE-EA-N
		Little awareness	SE-EA-L
		Much awareness	SE-EA-M
		Active awareness	SE-EA-A
	Finance	*Increasing rent*	SE-F-IR
		Increasing energy costs	SE-F-IE
		No effect	SE-F-NE
		Decreasing energy costs	SE-F-DE
		Decreasing rent	SE-F-DR
	Safety	*Unsafer*	SE-S-U
		No effect	SE-S-NE
		Safer	SE-S-S

Figure 6: Social categories and possible effects. Own illustration.

3.2.3 Technical effect icons

The third category contains icons which resemble technical effects of the renovation principles. The technical effects describe the effect the renovation principle has on the technique used in the renovated dwelling, which is important for the architect during the following renovation project. These five technical categories will be analysed: Energy, Heating, Ventilation & Air Conditioning, Label, Structure and Thermal. Each category has its own possible effects, which is showed in figure 7.

Theme	Category	Possible effect	Codes
Technical	Energy	*Fossil energy*	TE-E-FE
		Renewable energy	TE-E-RE
	HVAC	*Building scale*	TE-H-BS
		Dwelling scale	TE-H-DS
	Energy Label	*Worse*	TE-EL-W
		No effect	TE-EL-NE
		Improved	TE-EL-I
		Maximized	TE-EL-M
	Structure	*Extend*	TE-S-E
		Reinforce	TE-S-RI
		Reuse	TE-S-RU
	Thermal	*Worse*	TE-T-W
		No effect	TE-T-NE
		Improved	TE-T-I
		Maximized	TE-T-M

Figure 7: Technical categories and possible effects. Own illustration.

3.3 What are the actual effects of renovation case studies in practice?

3.3.1. The framework and effects of the case studies

The way of working of the framework is clear as well as the themes and effects that will be tested, so the thirty case studies of the database can be analysed. Every case study is analysed on the effects the indicated renovation principles of each project has. The elaboration of this analysis with project description and specifications resulted in an overview, which can be found in third part of the book. To use all this information in an appropriate way for this research, a matrix in made with the icons of the renovation principles, fact sheet icons and the effect icons. This matrix is only fit to use within the research, because it is lacking the additional information needed to understand the outcome. For the matrix, see also appendix 3.

3.3.2 Conducting a horizontal analysis

To determine what the actual effects of renovation projects in practice are, a horizontal analysis is conducted within the matrix. This means that all the effects are compared mutually within their category. Within the horizontal analysis, links are made between all the effects that occur in all of the projects. So an overview of all the used effects, the actual effects, can be created. Within this horizontal overview can be seen which renovation principles are most used, what the distribution is of building types, which structure is most used and which possibilities of effects are reached the most. It is then interesting to found out why a specific effect is more reached than another effect. This will be discussed for the renovation principles, fact sheet icons and all the 14 effects. See also the case study analysis overview in the book.

Renovation principles

The renovation principles could not be determined in advance, because every case study has another approach. Making use of a fixed set of renovation principles limits the outcome of this research.

In total there are 10 renovation principles indicated: A changed orientation of the building, add insulation on the inside, make an extension, add a prefab new skin, renew the entrance, renew the ground floor, add renewable energy to the building, clean or repair the existing facade, replace the existing windows and replace the existing facade for a new one. The most common used renovation principles are a new prefab skin, the addition of renewable energy and cleaning or repairing the existing facade. The explanation for these most used renovation principles is that within all the case studies there is strived for energy efficiency and these are the most common and cheapest ways to achieve this energy efficiency. The less used renovation principles (changing orientation, renew the entrance and renew the ground floor) describe a intervention on the facade, but do not influence the energy performances and are therefore not frequently used. See appendix 4a, for the complete table.

Typology and structure type

During the selection of the renovation case studies for the database is already taken care of the variety in typologies of the projects. Of the thirty case studies, a row house is the most common typology shortly followed by portico flats and gallery flats. Only one case study is a corridor flat. The reason that row houses have the largest share within the database is that these are easier to renovated than a whole building block and reach therefore easier an energy efficient state. The most used structure type is with 90% load bearing walls, this can be explained by the fact that this is the cheapest, easiest and fastest way to construct dwellings in a mass production. In appendix 4b, the complete table is showed.

Effects of composition
For analysing the composition, five effects were possible and all five effects occurred. The most common effect is the horizontal composition, followed by no new composition and a unity within the facade. The horizontal effect is probably most used because the layers of a multi-storey building are expressed and the connection between row houses is emphasized. Unity is brought to the buildings where the existing architecture is poor and when the composition is nice enough there is no new composition made. When the renovation goes into making a new expression for the building, diversity and vertical are used. Although these two do not occur much. For the complete table, see appendix 4c.

Effects of context
Each project has a positive effect on the context, which is explainable by the fact that a new facade and appearance of a building contributes to a nicer environment. Only a few projects manage to reach a maximal effect, but these are mostly the bad context situations in which improving the appearance is the reason for a renovation. A worse effect and no effect can be left out on the actual effect list. See appendix 4d for the complete table.

Effects of facade integration
The horizontal analysis shows that facade integration is not frequently touched upon. More than half of the projects do not integrate energy or HVAC into the facade. One-third of the projects integrate energy, but this comes down to making solar panels be part of the roof. A reason for absence of integration of technique in the facade is that there is little knowledge about this category and therefore too expensive to investigate for a single project. Another reason is that integration of technique in the facade is not part of the design requirements: technique is seen as a different specialism and is solved separately. The cases that do integrate HVAC systems into the facade show promising prospects. This is another reason why it is important to bring innovation to the renovation business. In appendix 4e, the complete table is showed.

Effects of material
All the materials that in advance were thought of occurred in the renovation projects. Most used material is wood, as cladding material and as material for new window frames. Wood is followed by glass, which is mostly used for making an extension and creating more light within the building. Stone is the third most used material, since brickwork belongs to the Dutch building tradition. For the complete table, see appendix 4f.

Effects of space
The possible effects of space occurred all four in the horizontal analysis. Most of the renovation principles do not have effect on the amount of space. The ones that enlarge the space outside the existing envelop, do this by making an extension or creating a new floor. When the dwelling is insulated on the inside, the space will always decrease. See appendix 4g, for the complete table.

Effects of during construction
The projects that make the occupants move out of the building during construction are about as much as the projects that let the occupants stay within their dwelling. This effect focusses solely on the facade intervention, but if the interiors needs also an upgrade then occupants need to move out temporarily anyway. Just a few projects make sure the renovation is done within a short timeframe, these are usually projects that attached a prefab skin over the existing facade. In appendix 4h, the numbers are illustrated.

Effect of energy awareness
More than half of the projects do not create any awareness for the energy behaviour of the occupants. The one that do only have a little effect caused by the visible PV-panels. There is one project that also provides an app which gives insight in the energy use. The active awareness is not found among these projects, so this effect will not be taken into account for the design guidelines. For the percentages of these effects, see appendix 4i.

Effects of finance
Logically, most of the projects create a decrease in the energy costs since this the aim of most of the renovation case studies. The 'nul-op-de-meter' case studies do not change anything about the finance conditions of the occupants because the savings on energy are used to enable the renovation. Four projects increased the rental prize, because the renovation provided much more quality than the existing situation. A remark on this category is that most effectd are assumed because little information about the costs could be found. Two possible effects were not reached, so increasing energy costs and decreasing rent will fall off. In appendix 4j, the complete table is showed.

Effects of safety
None of the projects create an unsafer atmosphere, so this effect will be left out for the actual effects. Three-quarter of all projects does not change anything about the safety conditions in and around the building. This is explainable by the fact that these case studies are already situated within a safe context. In the eight case studies where the safety situation is improved, it was a focus point of these case studies to change this situation. For the percentages of the effects, see appendix 4k.

Effects of energy
Only one-third of all case studies uses renewable energy, the other case studies continue to make use of conventional way of energy providing. See appendix 4l for the complete table.

Effects of HVAC
All of the projects where the HVAC effect could be indicated have a new dwelling scale HVAC system, except one which has a building scale HVAC system. Smaller and demand driven systems are more energy efficient than large systems, so that is why the existing systems are upgraded or new systems are installed in all the dwellings. For the complete table, see appendix 4m.

Effects of energy label
All Dutch projects reached a better energy label, so the effects worse and no effect can be set aside. When solar panels are added the change of a maximum energy label is higher because a label A can only be obtained when the building produces its own energy. All case studies have better insulation and better insulated windows, which ensures a label B. In appendix 4n, the complete table is showed.

Effects of Structure
Three-quarter of all the structures are reused, mostly because the facade is cleaned or repaired or a new skin is added over the existing facade. When an extension is made, then the structure needs to be adapted for this. Only in a few cases the structure needs to be reinforced. See appendix 4O, for the complete table.

Effects of Thermal

All the projects improve the thermal performance of a dwelling, so the effect worse and no effect will not be taken into account of the actual effects. The case studies that have a maximized thermal performance also have a maximized label. Because all the case studies add or renew the insulation, the performance is boosted. See appendix 4p for the complete table.

3.3.3 Horizontal analysis conclusion

A short evaluation of each category showed the effects that are most used and which are not used. This results in a new overview where the possible effects that not occurred are not present. This actual effect overview can be found in appendix 5 and will differ from figure 5 to 7. Overall can be concluded that the effects that describes a worse or even situation are possible effects but not actual effects.

The outcome of this horizontal analysis is not solid enough to formulate any design guidelines. This horizontal conclusion says something about how often an actual effect occurs within a case study, not how often an actual effect is reached by a renovation principle. To be able to formulate design guidelines, it is important to have a link between how a project is renovated (renovation principle) and what the results of this renovation are (the actual effects).

3.4 How are the actual effects linked to the renovation principles?

3.4.1 Vertical Analysis

Most of the projects make use of two or more renovation principles, so the effect that is reached in a single category within a project has two or more renovation principles as its origin. This means that the effects of each case study need to be linked to the used renovation principles of that project that caused this effect. For example: a renovation case study used two renovation principles, namely add renewable energy and a prefab skin over the existing facade. In the analysis of the possible effects came forward that the first actual effect is the improvement of thermal quality and that the second actual effect is energy is provided by a renewable source. When these actual effects are not linked back to the renovation principles that caused this actual effect, the added solar panels are also responsible for a better thermal quality and a new prefab skin is also responsible for a renewable energy source. It should be clear that this approach is not correct.

3.4.2 Link actual effect to belonging renovation principle

To quickly assess every actual effect of a case study to a *single* renovation principles of that same case study, a code system is developed. This code system shows abbreviations for every actual effect, based on the theme and category the effect is in. See figure 5 to 7 for the code system. With help of this code system all the actual effects are linked to the belonging renovation principles. The overview of these linked actual effects is showed in appendix 6. The interpretation of this overview will formulate the design guidelines, an elaboration of this interpretation is given in the next paragraph.

3.5 What are the empirically based design guidelines?

3.5.1 The final results

The overview, as showed in appendix 6, is translated into tables with percentages to see which renovation principle is most used to reach a certain effect. The elaboration of these results is discussed below.

Composition design guidelines

The most used principle to ensure the composition is not changed, is cleaning or repairing the existing facade followed by adding a prefab skin over the existing facade. If the architect has the wish to change anything about the existing composition, there is advised to use one of the following principles in order: a prefab skin over the existing facade, making an extension or replacing the existing facade. See appendix 7a for the table.

Context design guidelines

If the aim is to improve the context of a building, it is advised to use a prefab skin over the existing facade. A second option is to clean or repair the existing facade and thirdly the replacement of the existing facade is advised to use as a renovation principles. To maximize the context, the facade can best be replaced or the facade needs to be cleaned and/or repaired. The difference in results between these two design guidelines is that row houses (where the prefab skin is most applied) normally already have a nice context. The impact of the renovation is less on a context that already is nice on its own. See appendix 7b for the table.

Facade integration design guidelines

When a requirement within the design is to not integrate technique into the facade, clean and/or repair the existing facade is the most used renovation principles next to replacing the existing facade. For integrating energy systems the combination of a new prefab skin with integrated renewable energy production is the best renovation principle. A new prefab skin on its own is preferably used to integrated HVAC systems. See appendix 7c for the table.

Material design guidelines

If a building is in need for more light or the architect wants to use glass in his design, the design guidelines show that making an extension and replacing the facade are the best possibilities. If there is the wish to use a new material, adding a new prefab skin and replacing the existing facade are the best options. See appendix 7d for the table.

Space design guidelines

The architect must be aware that adding insulation on the inside of the facade, makes the dwelling smaller. When no extra space is needed in the new program of the building, a prefab skin is an advisable renovation principles before using clean/repair the existing facade or replacing the facade. If the space needs to be increase within the envelop a new prefab skin will do the job and if there is the ability to extend outside the envelop making an extension is a better option. See appendix 7e for the table.

During construction design guidelines

By choosing for insulation inside or replace the existing facade, the architect must keep in mind that these principles cause the occupants to temporarily move out. Next to the principles the architect must realise that other renovation interventions, such as renovating the kitchen or bathroom, also means the occupants have to move out regardless of the renovation principle that is used for the facade. If a requirement is to renovate without moving the occupants, adding a prefab skin over the existing facade is the best option. Making an extension is a solid second choice. If the renovation needs to be done within a short timeframe, only the prefab skin principle is applicable. See appendix 7f for the table.

Energy awareness design guidelines
The architect must realise no awareness is created by almost all principles and especially when the following principles are chosen: Clean and/or repair the facade, replace windows or replace the existing facade. A little awareness is chosen by adding PV-panels that are visible (renewable energy principle) or when occupants have self-control over their indoor climate by winter gardens (making an extension). See appendix 7g for the table.

Finance design guidelines
The 'nul-op-de-meter' deal used in the stroomversnelling projects is a solid way to ensure the occupant does not have any disadvantages from the renovation. This means that if the dwelling is renovated, in these projects by a prefab skin and PV-panels (renewable energy principle), the energy savings go the housing corporation to pay for the renovation. It is assumable that the energy costs will drop due to the following renovation principles for facades: Replacing the windows, replacing the skin and insulate inside. The prefab skin is also a good principle but did not come forward in the analysis because the prefab skin was always part of the 'nul-op-de-meter'-deal, as explained above. See appendix 7h for the table.

Safety design guidelines
Assuming that every principles used within an already safe environment has no effect on the safety in this environment, the design guidelines formulated for no effect on safety from the analysis will be left out. This is because adding these design guidelines suggests that only the named principles will reach this effect. For creating a safer environment renew the entrance and renew the ground floor are the most effective principles next to replacing the facade. See appendix 7i for the table.

Energy design guidelines
It goes without saying that only adding renewable energy will provide renewable energy. Though this is important to mention because most of the other principles score high on fossil energy use. Such as cleaning and/or repairing the facade, making an extension and replace the windows. This category also shows that the need for innovative energy system within renovation projects are minimal. See appendix 7j for the table.

HVAC design guideline
Almost all the actual effects of this category were caused by a non-facade intervention. Therefore only one principle popped up as being able to influence the way the building was heated, ventilated and air conditioned. This principles was add a prefab skin. This category makes clear that the renovation business does not follow an integrated approach at the moment. See appendix 7k for the table.

Energy label design guidelines
To gain an improved energy label, the following principles are advised to use: replace the windows, upgrade the existing the facade and/or insulate on the inside. If a maximal result on the energy label is required then a combination of a Prefab Skin with Renewable Energy is the only way to ensure this.
See appendix 7l for the table.

Structure design guidelines
If the structure needs to be reused, this can be best reached by adding a prefab skin or by cleaning or repairing the existing facade. The architect needs to be aware of the fact that placing an extension probably asks for extra structure besides the existing structure. See appendix 7m for the table.

Thermal design guidelines
To improve the thermal quality of a dwelling, replacing windows are the most used principles next to replacing the facade. A third advice is to clean/repair the existing facade. If a maximal result is required the best option is to use a prefab skin. See appendix 7n for the table.

3.5.2 Accessible design guidelines
The design guidelines are described and formulated, but are not yet easily accessible, illustrative or nicely ordered. By answering the main research question, there will be explained how the design guidelines are made accessible for the described target group in order to enable innovation to take place in renovation projects focussed on improving energy efficiency.

4. Conclusion and reflection

4.1 Conclusion

In current times the need for energy neutral renovation in the Netherlands is urgent and essential for the ambitions of 2050 to reach an energy neutral built environment. However, the focus on energy efficient is not yet fully embedded within the policy requirements and therefore often not a main priority. Besides, the currently available methods for reaching energy efficiency do often not touch on the complexity and practical feasibility of renovation projects. Thus, it is important to provide an integrated view on energy efficient renovations to architects and ways in which they can actually innovate within these projects. Therefore, this research paper aims to find a way to bring innovation towards renovation projects by answering the following main question:

Which empirically based design guidelines that contribute to the innovation of renovation projects striving for energy efficiency can be formulated for architects?

First of all, it is important to refer to the main results of this research. These were found by conducting an analysis of thirty realised renovation projects, both horizontally (quantitative analysis of effects per category) and vertically (linking the effects to the renovation principles). Based on these analyses, design guidelines were formulated that function as an accelerator in the process of architects aiming for energy efficiency within renovation projects.

The main design guidelines that were found are: that a prefab skin is a principle that is applicable for many wished effects because it allows a freedom of design. Repairing and/or cleaning the facade and replacing the facade also cover a wide range of effects although integration within these principles is found to be hard to accomplish. More specifically, ensuring nothing will be changed in the composition cleaning and/or repairing the facade is advised to use. When a requirements ask for other a composition of the facade, a prefab skin is the most used principle in practice. Every facade renovation will improve the quality of the context, for a maximal effect the facade needs to be replaced. The case studies show that it is hard to integrate energy and HVAC systems: only adding integrated solar panels on the roof is assessed as a outcome. Innovation needs to be brought to this category to create more principles. Extension outside the envelop is a solid principle to ensure a dwelling has more daylight. A prefab skin is the best option to ensure new materials can be used. Architects need to be aware that insulation on the inside decreases the space of the dwelling and that extensions make a dwelling larger. If there is wished not to move the occupants, a prefab skin is the best option. All the principles that asks for heavy construction work will cause the occupants to move out, like insulating on the inside. Only a little energy awareness can be reached with placing PV-panels or adding a winter garden, the other principles do not influence the energy behaviour of the occupants. The 'nul-op-de-meter' approach is the best way to ensure continuation of the costs, for this approach a prefab skin and solar panels are the most used option. If safety is an issue within a renovation project, it is advised to renew the entrance or the total ground floor. In the case study analysis are only solar panels assessed as

renewable source. A prefab skin give the best possibilities to change the HVAC systems of dwelling with a facade renovation. An label A renovation is reached by combining solar panels with a prefab skin,. A prefab skin also has less impact on the structure, thus the structure can be reused. Adding an extension asks for a self-supporting structure of this extension. At last replacing the windows and add insulation will increase the thermal comfort, for a maximal effect on the thermal quality a prefab skin is advised to use.
These above mentioned design guidelines can help the architect to save time in the beginning of the design process. In practice this means that the architect can immediately choose the fitting renovation principle according the wished effects within the three themes.

An important part of this research that is of added value is the tailoring of the results to the target group of architects. To directly target the right group of users, next to this research paper a non-scientific illustrative book is made where icons are used. The book forms the visual elaboration of this research and shows and explains the design guidelines and gives an overview of all the analysed case studies. The book can be used as a way to quickly gain accessible and usable knowledge on the renovation principles and acts as an inspirational source of energy efficient examples. The integral and broad view on the renovation of facade of existing buildings that is needed, is provided by the book. In this way, innovation will easier finds its way to these themes. The blocking factor for innovation within renovation projects is breached by the simplicity of the book.

By using the results of this research along with the attached book, architects can start to understand what the renovation principles do and bring this knowledge further. Knowledge that is needed in the built environment to innovate on new buildings and definitely on the existing stock and give architecture an important role within the transition towards an energy neutral society.

4.2 Reflection

When reflecting on the research itself, two main aspects need to be discussed. Firstly, the choice for a case study analysis. Because this research was an exploratory study of a relatively new study subject, it made sense to conduct a case study analysis based on actually realised projects. Yet, a limitation of this research is that no qualitative study could be conducted on the actual success of these renovation in terms of all important themes. Besides, some important background information on choices made could not be found in the sources used for the analysis. Therefore, it would have been interesting to also conduct interviews with stakeholders attached to each of the cases to add a more qualitative component to the analysis. However, this was not possible in time and resources available.

Secondly, the choice for a more general analysis of 30 projects instead of a technical in-depth analysis of less projects. There could be argued that some of the findings of this research are relatively general and straightforward because the outcome seems to be logical. Instead, it would also have been interesting to find out how much insulation needs to be added on the inside to improve the thermal quality instead of mentioning that adding insulation is a possibility. However, creating more specific knowledge about technical topics is not what is needed to create an energy neutral built environment as was stated in the introduction. It is the integrated view on renovation that was actually of added-value in this research. Based on the above mentioned limitations, some recommendation for future research are formulated. For example, it would have been interesting to include more projects in the research to increase the representativeness of the results. Besides, in the future it might be of added value to test the book made within the target group of architects, to learn what information is immediately of practical usefulness and which information might need to be changed or added.

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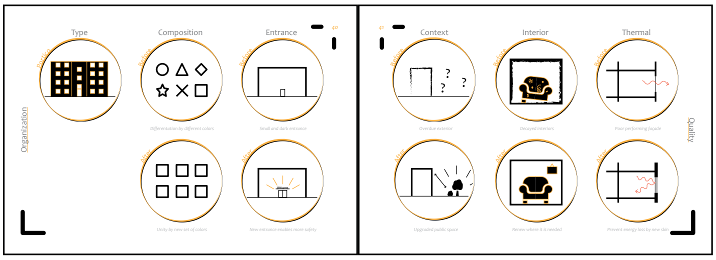
New number	Name project	City	Renovation architect	Owner	Builder	Quantity	Typology	Building year	Realization year
1	De Blauwe Panden	Amsterdam	CASA Architecten	Stichting Ymere	Deurwaarder BV	71	Portico Flat	1900	2013
2	Blok 8 - van der Pekbuurt	Amsterdam	Architectenbureau Hoogeveen BV	Stichting Ymere	Dura Vermeer Van Ieperen	12	Row house	1919	2016
3	Bomenbuurt	Utrecht	Hopstaken Kleindijk Architecten	Mitros	Vios Bouwgroep	122	Row house	1920	2013
4	Symfoniestraat	Den Haag	Staedion	Staedion	Vink + Veenman	47	Row house	1922	2013
5	Vestingstraat	Breda	Bouwhulp Groep	Wonen Breburg	Huybregts Relou	76	Row house	1928	2014
6	Le Sage ten Broekstraat	Tilburg	De Loods Architecten	Tiwos	Ballast Nedam	18	Row house	1951	2015
7	Nicolaas Maesstraat	Zwijndrecht	A3 Architecten	Woonkracht 10	Smits Vastgoedzorg	92	Portico Flat	1953	2016
8	Melissantstraat	Rotterdam	A3 Architecten	Woonstad Rotterdam	Slokker Bouwgroep BV	240	Gallery Flat	1953	2016
9	Rietveldwoningen	Utrecht	A3 Architecten	Bo-Ex	Koopmans Bouw	388	Portico Flat / Gallery	1955	2015
10	Buys Ballotlaan	Soesterberg	Wenink Holtkamp Architecten	Portaal	BAM Woningbouw	109	Row house	1957	2015
11	Finnenburg	Den Haag	CHNL Architecten & adviseurs	Vestia	Bouwcombinatie Finnenburg	204	Portico Flat	1959	2014
12	Quartier du Grand Parc	Bordeaux	Lacaton & Vassal	Aquitanis	-	530	Portico Flat	1960s	2012
13	Home with a Skin	Case study	Prêt-à-Loger	TU Delft	Prêt-à-Loger	1	Row house	1960s	2015
14	Van Speykstraat	Arnhem	Beltman Architecten	Portaal	Dura Vermeer	96	Row house	1960	2014
15	Complex 208	Rotterdam	HP architecten	Havensteder	Dura Vermeer	320	Portico Flat	1960	2014
16	Loevesteinstraat	Breda	Van Aken Architecten	Laurentius Wonen	-	315	Gallery Flat	1961	2012
17	Park Hill	Sheffield	Hawkins\Brown	Sheffield City Council	-	874	Corridor Flat	1961	2011
18	Tour Bois le Prêtre	Paris	Lacaton & Vassal	Paris Habitat	-	96	Corridor Flat	1962	2011
19	Stanleylaan	Utrecht	biq architecten	Bo-Ex	Hemubo BV	48	Portico Flat	1962	2014
20	Purmerlaan	Stadskanaal	De Loods Architecten	Lefier	Ballast Nedam	21	Row house	1964	2015
21	Parallelweg	Melick	2.0 Architecten	Wonen Limburg	VolkerWessels	4	Row house	1965	2014
22	Voermanstraat - Pleiadenlaan	Groningen	JKArchitect	Lefier	Dura Vermeer	49	Portico Flat	1966	2014
23	Burgemeester Versluysstraat	Oud Vossemeer	Gewoon Architecten	Stadlander	VolkerWessels	50	Row house	1968	2016
24	De Valk	Apeldoorn	Groosman	Ons Huis	Draisma	100	Gallery Flat	1969	2007
25	HAB Varbergparken	Varbergvaj	C.F. Møller Architects	Haderslev Social Housing Association	-	508	Gallery Flat	1970s	2015
26	Urban renovation	Lormont	LAN architects	Domofrance	-	704	Corridor Flat	1970s	2015
27	De Lantaarntjes	Ijmuiden	CASA Architecten	Woningbedrijf Velsen	Van Linth Bouwbedrijf	72	Portico Flat	1970	2015
28	Laan van het Kinholt	Emmen	Wenink Holtkamp Architecten	Lefier	BAM Woningbouw	60	Row house	1971	2016
29	Chrysantstraat	Nieuw Buinen	Sacon	Lefier	VolkerWessels	119	Row house	1972	2015
30	Martin Campslaan	Rijswijk	A3 Architecten	Rijswijk Wonen	Smits Vastgoedzorg	274	Gallery Flat	1974	2015

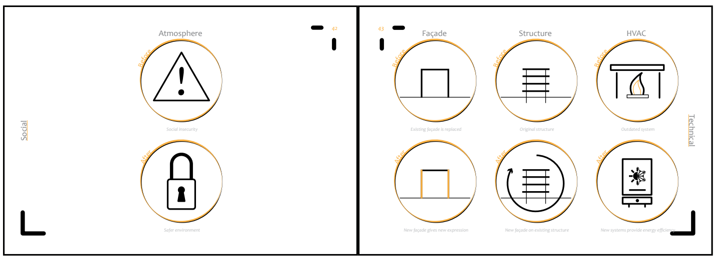
Appendix 2

2a. First Analysis (own illustration)

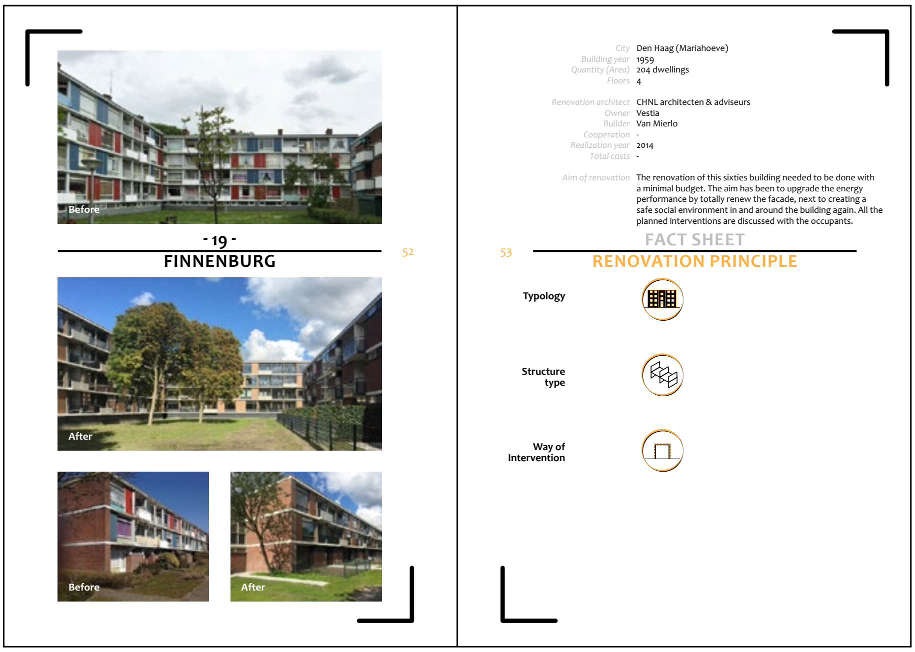
Database number	Improvements: Aesthetic	Comfort	Energetic	Social	Spatial	Structural	Technical	User preference	Energy facts	Renovation aim
4	Renew facade	Renew kitchen Renew bathroom	Tripple glazing Insulated roof PV-panels Solar water heater Closed balconies		Renew entrance Closed balconies		Pre-heated air Slimme meter All electric	Quick renovation	EPC: -0.4 Label: A+ Nul op de meter	Energy efficiency Extend life-cycle
14	Wintergarden Balconies	More light More views More space Renew bathroom	Wintergarden	Keep existing	Wintergarden Balconies	External foundation				Improve quality Improve comfort With a small budget
15	Extend floors Closed terraces Balconies		Closed terraces	Keep existing	Extended floors Renew entrance	External foundation				Improve quality Improve comfort With a small budget
16	Renew facade Staircases		Geothermal heat PV panels Solar water heater	New usergroup	New plans		Heat-cold storage Demand driven ventilation		EPC: 0,25 Label: A+	Historic value Energy efficiency Living quality
19	Renew facade	Safety Renew kitchen Renew bathroom	Insulated skin	Safety			Central heating Installations			Energy efficiency Architectural quality With a small budget

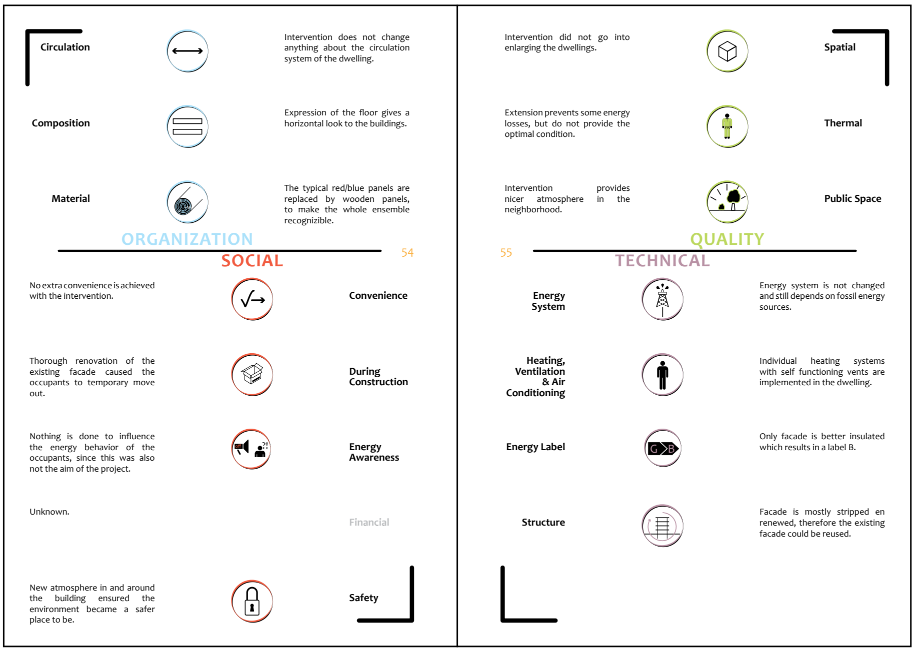
2b. A5-booklet (own illustration)





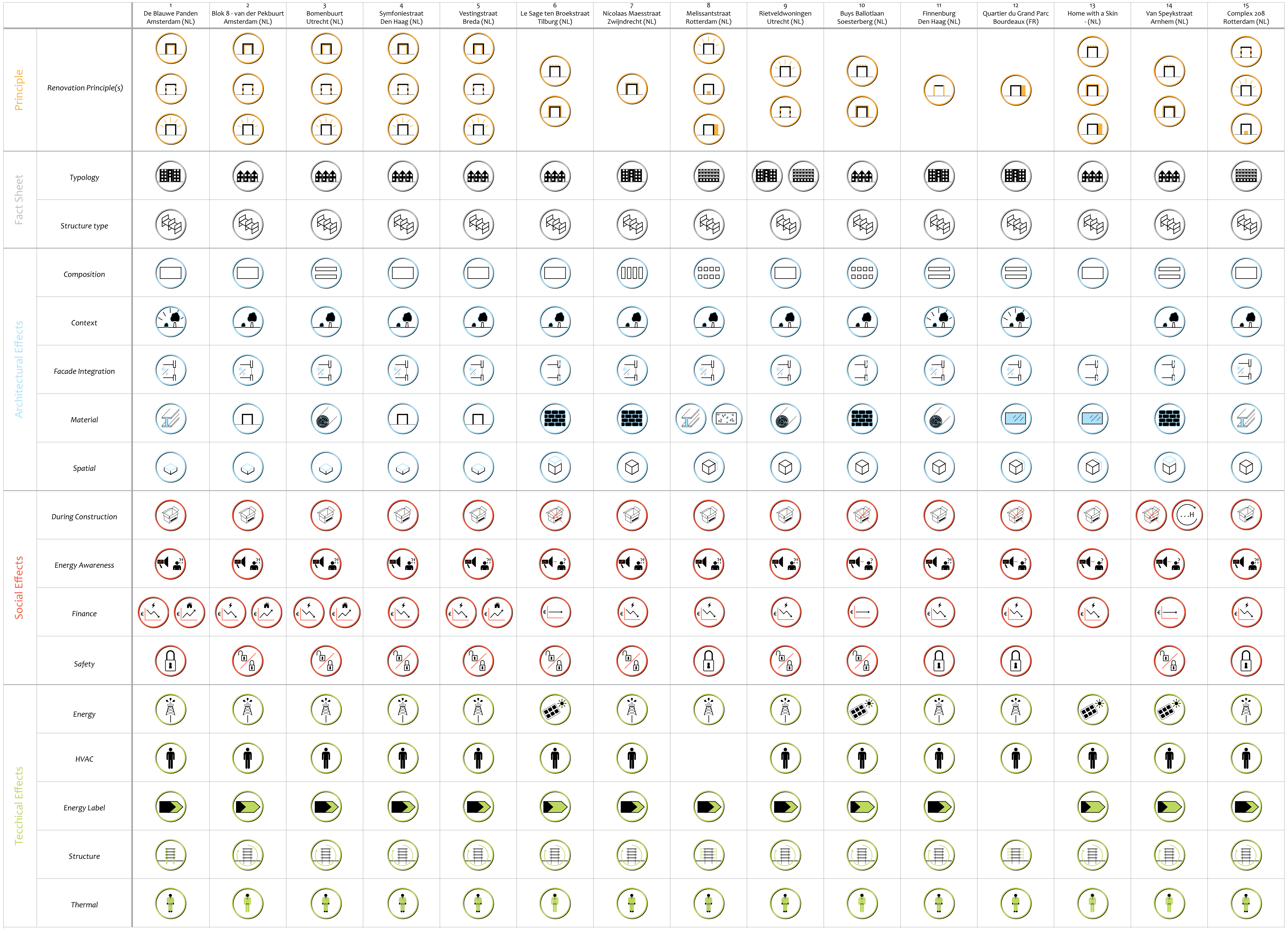
2c. Fixed set of generic icons (own illustration)





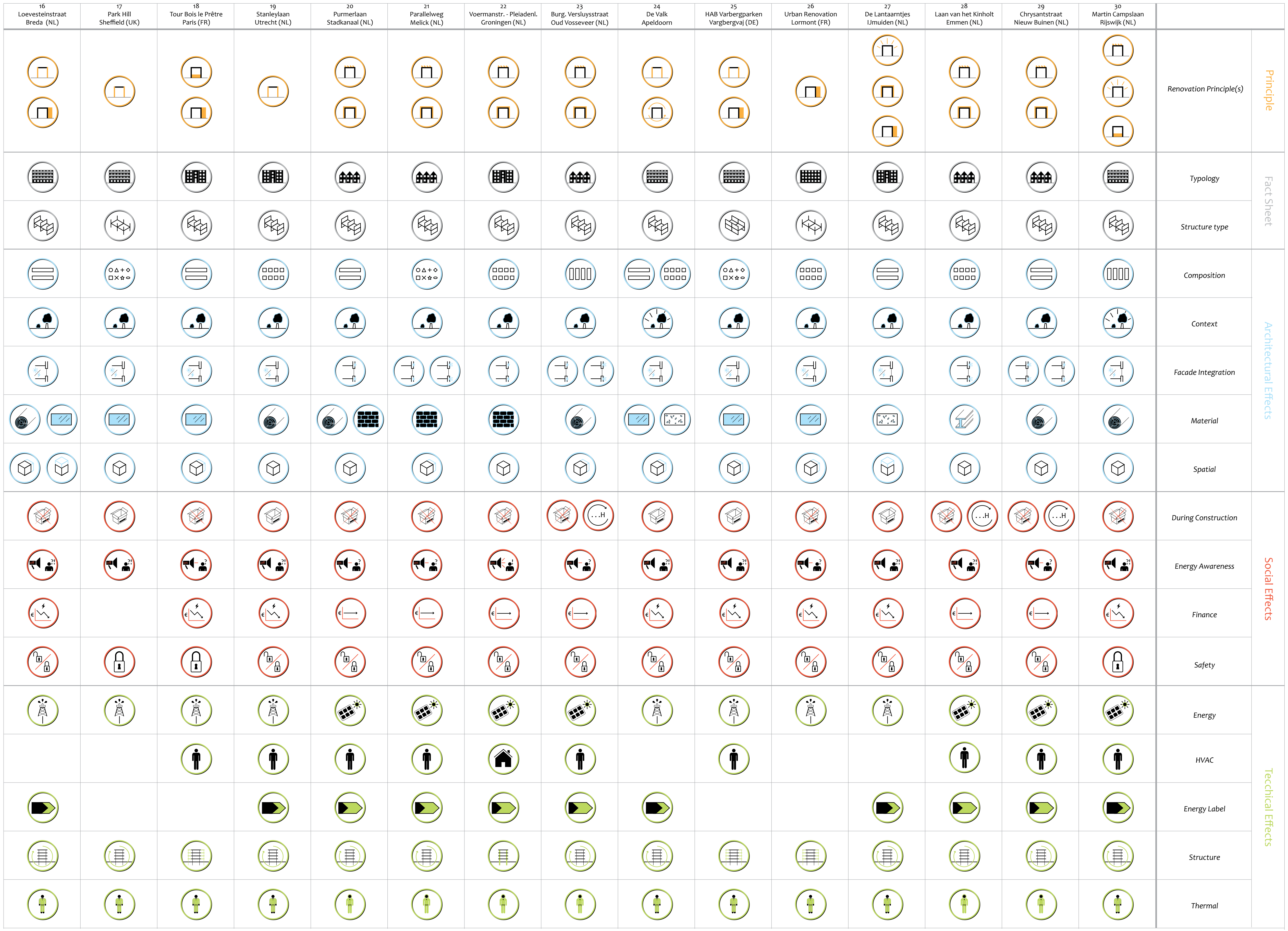
Appendix 3

Database of selected case studies, case studies 1-15



Appendix 3

Database of selected case studies, case studies 16-30



Appendix 4

4a. Results horizontal analysis Renovation Principles

Renovation Principle										
RP-CO	*RP-II*	*RP-ME*	*RP-PS*	*RP-RE*	*RP-RGF*	*RP-ARE*	*RP-CRF*	*RP-RW*	*RP-RF*	
1	**5**	**8**	**12**	**2**	**2**	**11**	**10**	**7**	**6**	*64*
1,6%	**7,8%**	**12,5%**	**18,8%**	**3,1%**	**3,1%**	**17,2%**	**15,6%**	**10,9%**	**9,4%**	*100%*

4b. Results horizontal analysis Typology

Typology				
FS-T-C	*FS-T-G*	*FS-T-P*	*FS-T-RH*	
1	**8**	**9**	**13**	*31*
3,2%	**25,8%**	**29,0%**	**41,9%**	*100,0%*

4b. Results horizontal analysis Structure

Structure			
FS-S-C	*FS-S-F*	*FS-S-W*	
2	**1**	**27**	*30*
6,7%	**3,3%**	**90,0%**	*100,0%*

4c. Results horizontal analysis Composition

Composition					
AE-CP-D	*AE-CP-H*	*AE-CP-NE*	*AE-CP-U*	*AE-CP-V*	
3	**10**	**8**	**7**	**3**	*31*
9,7%	**32,3%**	**25,8%**	**22,6%**	**9,7%**	*100,0%*

4d. Results horizontal analysis Context

Context				
AE-CT-W	*AE-CT-NE*	*AE-CT-I*	*AE-CT-M*	
0	**0**	**25**	**5**	*30*
0,0%	**0,0%**	**83,3%**	**16,7%**	*100,0%*

4e. Results horizontal analysis Context

Facade Integration			
AE-FI-NI	*AE-FI-EI*	*AE-FI-HI*	
19	**10**	**4**	*33*
57,6%	**30,3%**	**12,1%**	*100,0%*

4f. Results horizontal analysis Material

Material						
AE-M-NE	*AE-M-C*	*AE-M-G*	*AE-M-M*	*AE-M-S*	*AE-M-W*	
3	**3**	**8**	**4**	**7**	**9**	*34*
8,8%	**8,8%**	**23,5%**	**11,8%**	**20,6%**	**26,5%**	*100,0%*

4g. Results horizontal analysis Space

Space				
AE-S-S	*AE-S-NE*	*AE-S-EI*	*AE-S-EO*	
5	**12**	**4**	**10**	*31*
16,1%	**38,7%**	**12,9%**	**32,3%**	*100,0%*

4h. Results horizontal analysis During Construction

During Construction			
SE-DC-M	*SE-DC-TF*	*SE-DC-WM*	
16	**4**	**14**	*34*
47,1%	**11,8%**	**41,2%**	*100,0%*

4i. Results horizontal analysis Energy Awareness

Energy Awareness				
SE-EA-N	*SE-EA-L*	*SE-EA-M*	*SE-EA-A*	
18	**11**	**1**	**0**	*30*
60,0%	**36,7%**	**3,3%**	**0,0%**	*100,0%*

4j. Results horizontal analysis Energy Awareness

Finance					
SE-F-IR	*SE-F-IE*	*SE-F-NE*	*SE-F-DE*	*SE-F-DR*	
4	**0**	**9**	**20**	**0**	*33*
12,1%	**0,0%**	**27,3%**	**60,6%**	**0,0%**	*100,0%*

4k. Results horizontal analysis Safety

Safety			
SE-S-U	*SE-S-NE*	*SE-S-S*	
47,44133	**30,95965**	**37,08215**	*115,483*
41,1%	**26,8%**	**32,1%**	*100,0%*

4l. Results horizontal analysis Energy

Energy		
TE-E-FE	*TE-E-RE*	
19	**11**	*30*
63,3%	**36,7%**	*100,0%*

4m. Results horizontal analysis HVAC

HVAC		
TE-H-BS	*TE-H-DS*	
1	**23**	*24*
4,2%	**95,8%**	*100,0%*

4n. Results horizontal analysis Energy Label

Label				
TE-EL-W	*TE-EL-NE*	*TE-EL-I*	*TE-EL-M*	
0	**0**	**14**	**11**	*25*
0,0%	**0,0%**	**56,0%**	**44,0%**	*100,0%*

4O. Results horizontal analysis Structure

Structure			
TE-S-E	*TE-S-RI*	*TE-S-RU*	
5	**2**	**23**	*30*
16,7%	**6,7%**	**76,7%**	*100,0%*

4p. Results horizontal analysis Thermal

Thermal				
TE-T-W	*TE-T-NE*	*TE-T-I*	*TE-T-M*	
0	**0**	**19**	**11**	*30*
0,0%	**0,0%**	**63,3%**	**36,7%**	*100,0%*

Appendix 5

Actual effect overview

Theme	Category	Possible effect
Architectural	Composition	*No effect*
		Horizontal
		Vertical
		Unity
		Diversity
		Improved
		Maximized
	Facade Integration	*No integration*
		Energy integration
		HVAC integration
	Material	*No new material*
		Concrete
		Glass
		Metal
		Stone
		Wood
	Space	*Smaller*
		No effect
		Extend inside envelop
		Extend outside envelop
Social	During construction	*Temporarily move out*
		Within timeframe
		Without moving out
	Energy awareness	*No awareness*
		Little awareness
		Much awareness
	Finance	*Increasing rent*
		No effect
		Decreasing energy costs
		No effect
		Safer
Technical	Energy	*Fossil energy*
		Renewable energy
	HVAC	*Building scale*
		Dwelling scale
		Improved
		Maximized
	Structure	*Extend*
		Reinforce
		Reuse
		Improved
		Maximized

Appendix 6

Matrix of vertical analysis, case studie 1-15

Projects	Principle	Composition	Context	Facade integration	Material	Space	During Construction	Energy Awareness	Finance	Safety	Energy	HVAC	Energy Label	Structure	Thermal
1	RP-II					AE-S-S	SE-DC-M	SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-RW				AE-M-M			SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-CRF	AE-CP-NE	AE-CT-M	AE-FI-NI				SE-EA-N	SE-F-IR	SE-S-S	TE-E-FE			TE-S-RI	
	none											TE-H-DS			
2	RP-II					AE-S-S	SE-DC-M	SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-M		TE-T-M
	RP-RW							SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-M		TE-T-M
	RP-CRF	AE-CP-NE	AE-CT-I	AE-FI-NI	AE-M-NE			SE-EA-N	SE-F-IR	SE-S-NE	TE-E-FE			TE-S-RU	
	none											TE-H-DS			
3	RP-II					AE-S-S	SE-DC-M	SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-RW	AE-CP-H			AE-M-W			SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-CRF		AE-CT-I	AE-FI-NI				SE-EA-N	SE-F-IR	SE-S-NE	TE-E-FE			TE-S-RU	
	none											TE-H-DS			
4	RP-II					AE-S-S	SE-DC-M	SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-RW							SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-CRF	AE-CP-NE	AE-CT-I	AE-FI-NI	AE-M-NE			SE-EA-N		SE-S-NE	TE-E-FE			TE-S-RU	
	none											TE-H-DS			
5	RP-II					AE-S-S	SE-DC-M	SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-RW							SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		
	RP-CRF	AE-CP-NE	AE-CT-I	AE-FI-NI	AE-M-NE			SE-EA-N	SE-F-IR	SE-S-NE	TE-E-FE			TE-S-RU	
	none											TE-H-DS			
6	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-NE	AE-CT-I	AE-FI-EI	AE-M-S	AE-S-EI	SE-DC-WM		SE-F-NE	SE-S-NE			TE-EL-M	TE-S-RU	TE-T-M
	none											TE-H-DS			
7	RP-PS	AE-CP-V	AE-CT-I	AE-FI-NI	AE-M-S	AE-S-NE		SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	none						SE-DC-M					TE-H-DS			
8	RP-CRF		AE-CT-I	AE-FI-NI				SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-RE							SE-EA-N		SE-S-S	TE-E-FE				
	RP-ME	AE-CP-U			AE-M-M AE-M-C	AE-S-EO		SE-EA-N			TE-E-FE			TE-S-E	
	none						SE-DC-M					T-H-DS			
9	RP-CRF	AE-CP-NE	AE-CT-I	AE-FI-NI		AE-S-NE		SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	RP-RW				AE-M-W			SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	none						SE-DC-M					T-H-DS			
10	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-U	AE-CT-I	AE-FI-EI	AE-M-S	AE-S-NE	SE-DC-WM		SE-F-NE	SE-S-NE			TE-EL-M	TE-S-RU	TE-T-M
	none											TE-H-DS			
11	RP-RF	AE-CP-H	AE-CT-M	AE-FI-NI	AE-M-W	AE-S-NE	SE-DC-M	SE-EA-N	SE-F-DE	SE-S-S	TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	none											TE-H-DS			
12	RP-ME	AE-CP-H	AE-CT-M	AE-FI-NI	AE-M-G	AE-S-EO	SE-DC-WM	SE-EA-L	SE-F-DE	SE-S-S	TE-E-FE			TE-S-E	TE-T-I
	none											TE-H-DS			
13	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-DE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-NE		AE-FI-EI			SE-DC-M		SE-F-DE				TE-EL-M	TE-S-RU	TE-T-M
	RP-ME				AE-M-G	AE-S-EO			SE-F-DE			TE-H-DS	TE-EL-M	TE-S-RU	
	none														
14	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-DE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-H	AE-CT-I	AE-FI-EI	AE-M-S	AE-S-EI	SE-DC-WM SE-DC-TF		SE-F-DE	SE-S-NE			TE-EL-M	TE-S-RU	TE-T-M
	none											TE-H-DS			
15	RP-RW				AE-M-M			SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I		TE-T-I
	RP-CRF	AE-CP-NE	AE-CT-I	AE-FI-NI		AE-S-NE		SE-EA-N	SE-F-DE		TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	RP-RE							SE-EA-N		SE-S-S	TE-E-FE				
	none						SE-DC-M					TE-H-DS			

Appendix 6

Matrix of vertical analysis, case studie 16-30

Projects	Principle	Composition	Context	Facade integration	Material	Space	During Construction	Energy Awareness	Finance	Safety	Energy	HVAC	Energy Label	Structure	Thermal
16	RP-RF	AE-CP-H	AE-CT-I	AE-FI-NI	AE-M-W AE-M-G			SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE		TE-EL-I		TE-T-I
	RP-ME	AE-CP-H	AE-CT-I		AE-M-W AE-M-G	AE-S-EO AE-S-EI	SE-DC-WM	SE-EA-N		SE-S-NE	TE-E-FE			TE-S-RU	
	none														
17	RP-RF	AE-CP-D	AE-CT-I	AE-FI-NI	AE-M-G	AE-S-NE	SE-DC-M	SE-EA-N		SE-S-S	TE-E-FE			TE-S-RU	TE-T-I
	none														
18	RP-RGF									SE-S-S	TE-E-FE				
	RP-ME	AE-CP-H	AE-CT-I	AE-FI-NI	AE-M-G	AE-S-EO	SE-DC-WM	SE-EA-L	SE-F-DE		TE-E-FE			TE-S-E	TE-T-I
	none											TE-H-DS			
19	RP-RF	AE-CP-U	AE-CT-I	AE-FI-NI	AE-M-W	AE-S-NE	SE-DC-M	SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	none											TE-H-DS			
20	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-H	AE-CT-I	AE-FI-EI	AE-M-W AE-M-S	AE-S-NE	SE-DC-WM		SE-F-NE	SE-S-NE			TE-EL-M	TE-S-RU	TE-T-M
	none											TE-H-DS			
21	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-D	AE-CT-I	AE-FI-HI AE-FI-EI	AE-M-S	AE-S-EO	SE-DC-WM		SE-F-NE	SE-S-NE		TE-H-DS	TE-EL-M	TE-S-RU	TE-T-M
	none														
22	RP-ARE			AE-FI-EI				SE-EA-M	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-U	AE-CT-I	AE-FI-EI	AE-M-S	AE-S-NE	SE-DC-WM		SE-F-NE	SE-S-NE			TE-EL-M	TE-S-RI	TE-T-M
	none											TE-H-BS			
23	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-V	AE-CT-I	AE-FI-HI AE-FI-EI	AE-M-W	AE-S-EO	SE-DC-WM SE-DC-TF		SE-F-NE	SE-S-NE		TE-H-DS	TE-EL-M	TE-S-RU	TE-T-M
	none														
24	RP-RF	AE-CP-H AE-CP-U	AE-CT-M	AE-FI-NI	AE-M-G AE-M-C		SE-DC-M	SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	RP-CO		AE-CT-M			AE-S-EO	SE-DC-M	SE-EA-N			TE-E-FE			TE-S-RU	
	none														
25	RP-RF	AE-CP-D	AE-CT-I	AE-FI-NI			SE-DC-M	SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE				TE-T-I
	RP-ME				AE-M-G	AE-S-EO		SE-EA-N			TE-E-FE			TE-S-E	
	none											TE-H-DS			
26	RP-ME	AE-CP-U	AE-CT-I	AE-FI-NI	AE-M-G	AE-S-EO	SE-DC-WM	SE-EA-L	SE-F-DE	SE-S-NE	TE-E-FE			TE-S-E	TE-T-I
	none														
27	RP-CRF		AE-CT-I	AE-FI-NI			SE-DC-M	SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	RP-PS	AE-CP-H	AE-CT-I	AE-FI-NI	AE-M-C			SE-EA-N	SE-F-DE	SE-S-NE	TE-E-FE		TE-EL-I	TE-S-RU	TE-T-I
	RP-ME					AE-S-EI		SE-EA-N		SE-S-NE	TE-E-FE			TE-S-RU	
	none														
28	RP-ARE							SE-EA-N	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-U	AE-CT-I	AE-FI-HI	AE-M-M	AE-S-NE	SE-DC-WM SE-DC-TF	SE-EA-N	SE-F-NE	SE-S-NE		TE-H-DS	TE-EL-M	TE-S-RU	TE-T-M
	none														
29	RP-ARE			AE-FI-EI				SE-EA-L	SE-F-NE		TE-E-RE		TE-EL-M		
	RP-PS	AE-CP-H	AE-CT-I	AE-FI-HI AE-FI-EI	AE-M-W	AE-S-NE	SE-DC-WM SE-DC-TF		SE-F-NE	SE-S-NE		TE-H-DS	TE-EL-M	TE-S-RU	TE-T-M
	none														
30	RP-ARE							SE-EA-N	SE-F-DE		TE-E-RE		TE-EL-I		
	RP-CRF	AE-CP-V	AE-CT-M	AE-FI-NI	AE-M-W	AE-S-NE	SE-DC-WM	SE-EA-N	SE-F-DE				TE-EL-I	TE-S-RU	TE-T-I
	RP-RGF		AE-CT-M					SE-EA-N		SE-S-S					
	none											TE-H-DS			

Appendix 7

7a. Results formulating design guidelines Composition

Composition	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
AE-CP-NE	0	0	6	0	0	2	0	0	0	0	0	*8*
	0%	0%	75%	0%	0%	25%	0%	0%	0%	0%	0%	*100%*
AE-CP-D	0	0	0	0	0	1	0	0	2	0	0	*3*
	0%	0%	0%	0%	0%	33%	0%	0%	67%	0%	0%	*100%*
AE-CP-H	0	0	0	0	3	4	0	0	3	1	0	*11*
	0%	0%	0%	0%	27%	36%	0%	0%	27%	9%	0%	*100%*
AE-CP-U	0	0	0	0	2	3	0	0	2	0	0	*7*
	0%	0%	0%	0%	29%	43%	0%	0%	29%	0%	0%	*100%*
AE-CP-V	0	0	1	0	0	2	0	0	0	0	0	*3*
	0%	0%	33%	0%	0%	67%	0%	0%	0%	0%	0%	*100%*
												32

7b. Results formulating design guidelines Context

Context	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
AE-CT-W	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
AE-CT-NE	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
AE-CT-I	0	0	8	0	3	11	0	0	4	0	0	*26*
	0%	0%	31%	0%	12%	42%	0%	0%	15%	0%	0%	*100%*
AE-CT-M	0	1	2	0	1	0	0	1	2	0	0	*7*
	0%	14%	29%	0%	14%	0%	0%	14%	29%	0%	0%	*100%*
												33

7c. Results formulating design guidelines Facade Integration

Facade Integration	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
AE-FI-NI	0	0	10	0	3	2	0	0	6	0	0	*21*
	0%	0%	48%	0%	14%	10%	0%	0%	29%	0%	0%	*100%*
AE-FI-EI	9	0	0	0	0	9	0	0	0	0	0	*18*
	50%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	*100%*
AE-FI-HI	0	0	0	0	0	4	0	0	0	0	0	*4*
	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	*100%*
												43

7d. Results formulating design guidelines Material

Material	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
AE-M-NE	0	0	3	0	0	0	0	0	0	0	0	*3*
	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
AE-M-C	0	0	0	0	1	1	0	0	1	0	0	*3*
	0%	0%	0%	0%	33%	33%	0%	0%	33%	0%	0%	*100%*
AE-M-G	0	0	0	0	6	0	0	0	3	0	0	*9*
	0%	0%	0%	0%	67%	0%	0%	0%	33%	0%	0%	*100%*
AE-M-M	0	0	0	0	1	1	0	0	0	2	0	*4*
	0%	0%	0%	0%	25%	25%	0%	0%	0%	50%	0%	*100%*
AE-M-S	0	0	0	0	0	7	0	0	0	0	0	*7*
	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	*100%*
AE-M-W	0	0	1	0	1	3	0	0	3	2	0	*10*
	0%	0%	10%	0%	10%	30%	0%	0%	30%	20%	0%	*100%*
												36

7e. Results formulating design guidelines Space

Space	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
AE-S-S	0	0	0	5	0	0	0	0	0	0	0	*5*
	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	*100%*
AE-S-NE	0	0	3	0	0	6	0	0	3	0	0	*12*
	0%	0%	25%	0%	0%	50%	0%	0%	25%	0%	0%	*100%*
AE-S-EI	0	0	0	0	2	2	0	0	0	0	0	*4*
	0%	0%	0%	0%	50%	50%	0%	0%	0%	0%	0%	*100%*
AE-S-EO	0	1	0	0	7	2	0	0	0	0	0	*10*
	0%	10%	0%	0%	70%	20%	0%	0%	0%	0%	0%	*100%*
												31

7f. Results formulating design guidelines During Construction

During Construction	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
SE-DC-M	0	1	1	5	0	1	0	0	5	0	4	*17*
	0%	6%	6%	29%	0%	6%	0%	0%	29%	0%	24%	*100%*
SE-DC-TF	0	0	0	0	0	4	0	0	0	0	0	*4*
	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	*100%*
SE-DC-WM	0	0	1	0	4	9	0	0	0	0	0	*14*
	0%	0%	7%	0%	29%	64%	0%	0%	0%	0%	0%	*100%*
												35

7g. Results formulating design guidelines Energy Awareness

Energy Awareness	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
SE-EA-N	2	1	10	5	4	3	2	1	6	7	0	*41*
	5%	2%	24%	12%	10%	7%	5%	2%	15%	17%	0%	*100%*
SE-EA-L	8	0	0	0	3	0	0	0	0	0	0	*11*
	73%	0%	0%	0%	27%	0%	0%	0%	0%	0%	0%	*100%*
SE-EA-M	1	0	0	0	0	0	0	0	0	0	0	*1*
	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
SE-EA-A	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
												53

7h. Results formulating design guidelines Finance

Finance	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
SE-F-IR	0	0	4	0	0	0	0	0	0	0	0	*4*
	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
SE-F-IE	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
SE-F-NE	8	0	0	0	0	8	0	0	0	0	0	*16*
	50%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	*100%*
SE-F-DE	3	0	5	5	4	4	0	0	5	7	0	*33*
	9%	0%	15%	15%	12%	12%	0%	0%	15%	21%	0%	*100%*
SE-F-DR	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
												53

7i. Results formulating design guidelines Safety

Safety	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
SE-S-U	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
SE-S-NE	0	0	6	0	3	11	0	0	4	0	0	*24*
	0%	0%	25%	0%	13%	46%	0%	0%	17%	0%	0%	*100%*
SE-S-S	0	0	1	0	1	0	2	2	2	0	0	*8*
	0%	0%	13%	0%	13%	0%	25%	25%	25%	0%	0%	*100%*
												32

7j. Results formulating design guidelines Energy

Energy	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
TE-E-FE	0	1	9	5	7	2	2	1	6	7	0	*40*
	0%	3%	23%	13%	18%	5%	5%	3%	15%	18%	0%	*100%*
TE-E-RE	11	0	0	0	0	0	0	0	0	0	0	*11*
	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*100%*
												51

7k. Results formulating design guidelines HVAC

HVAC	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
TE-H-BS	0	0	0	0	0	0	0	0	0	0	1	*1*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	*100%*
TE-H-DS	0	0	0	0	1	4	0	0	0	0	19	*24*
	0%	0%	0%	0%	4%	17%	0%	0%	0%	0%	79%	*100%*
												25

7l. Results formulating design guidelines Energy Label

Energy Label	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
TE-EL-W	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
TE-EL-NE	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
TE-EL-I	1	0	5	4	0	2	0	0	4	6	0	*22*
	5%	0%	23%	18%	0%	9%	0%	0%	18%	27%	0%	*100%*
TE-EL-M	10	0	0	1	1	10	0	0	0	1	0	*23*
	43%	0%	0%	4%	4%	43%	0%	0%	0%	4%	0%	*100%*
												45

7m. Results formulating design guidelines Structure

Structure	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
TE-S-E	0	0	0	0	5	0	0	0	0	0	0	*5*
	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	*100%*
TE-S-RI	0	0	1	0	0	1	0	0	0	0	0	*2*
	0%	0%	50%	0%	0%	50%	0%	0%	0%	0%	0%	*100%*
TE-S-RU	0	1	8	0	3	11	0	0	4	0	0	*27*
	0%	4%	30%	0%	11%	41%	0%	0%	15%	0%	0%	*100%*
												34

7n. Results formulating design guidelines Thermal

Thermal	RP-ARE	RP-CO	RP-CRF	RP-II	RP-ME	RP-PS	RP-RE	RP-RGF	RP-RF	RP-RW	None	*Total*
TE-T-W	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
TE-T-NE	0	0	0	0	0	0	0	0	0	0	0	*0*
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
TE-T-I	0	0	5	4	3	2	0	0	6	6	0	*26*
	0%	0%	19%	15%	12%	8%	0%	0%	23%	23%	0%	*100%*
TE-T-M	0	0	0	1	0	10	0	0	0	1	0	*12*
	0%	0%	0%	8%	0%	83%	0%	0%	0%	8%	0%	*100%*
												38