RE-FACE
REFURBISHMENT STRATEGIES FOR THE TECHNICAL
IMPROVEMENT OF OFFICE FACADES

Proefschrift

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form or by any means without the prior permission in writing from the author.
To my wife Christiane and our baby.
Preface

This thesis is written at the Technical University of Delft, Faculty of Architecture, at the Chair Design of Construction.

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Thiemo Ebbert
Delft, December 2009
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1. Introduction

1.1. Background

The reduction of energy consumption is one of the most acute and relevant problems of today's society. Based on European directives, the national governments have lanced highly motivated goals on energy efficiency. The Netherlands have set the target to improve energy efficiency by 33% compared to the base year 1990 until the year 2020. Also, renewable energy is to hold a share of 10% by then (Nederlandse Regering 2008). The British government wants to reduce carbon dioxide emissions by 34% from 2009 till 2020 and aims for a reduction of 80% by 2050 (UK Government 2009). The German government has set even higher goals. By 2020 the emission of greenhouse gasses shall be reduced by 40% compared to 1990 (Deutsche Bundesregierung 2007). Such high aims cannot be achieved by only raising the demands for industry and new constructions. In Germany, for example, currently 41% of all final energy is consumed for conditioning existing buildings, which resembles approximately 1 million GWh/a. Of this amount, the buildings of the tertiary sector (trade and administration) make out 38% or 15% of the total national energy consumption (AGEB 2008).

Looking at the existing building stock, one can easily see the urgent need for improvement. Currently, two thirds of the office-stock in Western Europe is older than 30 years (Russig 1999). Particularly the buildings of the time of economic prosperity of the 1960s and 1970s hold a large share of this stock and are poorly insulated. At this age of 30 years, façades and technical installations reach the end of their technical life-span. Gaskets become brittle, insulated glass leaks due to permanent thermal expansion and contraction. Metal parts corrode and moving components of mechanical devices wear out. Consequently, these buildings show a poor performance in terms of user comfort and energy consumption. Also, the organisational concepts and architectural designs of that era are not accepted by today’s office staff any more. This situation has led to a high risk of vacancy in office buildings and a major refurbishment backlog. New concepts are needed for the treatment of existing office buildings.

1.2. Problem Definition

By now, everyone related to the building world is conscious of the problem that a great many office buildings urgently need to be improved. Many certification tools, such as 'Breeam' (UK, NL), LEED' (USA), and 'DGNB' (GER), have been developed, which judge a building project for its sustainability and energy performance. However, having the certification tool at hand does not help to find the most appropriate technical solution.
Refurbishment in general - and façade refurbishment in particular - is a very complicated planning task. Buildings always demand individual technical solutions. The refurbishment has to deal with existing structural conditions and a given design. Too little is known about the building stock and its technical possibilities, which results in costly planning and rather rigorous refurbishment approaches. Usually, outdated office buildings are either demolished, or they are substantially refurbished by removing the façade, technical installations, and all finishings. Intermediate solutions are very rare, which leads to two possible consequences: On the one hand, building owners worry about the impact of refurbishment and the economic consequences. Therefore, many buildings with a high refurbishment potential are not being touched and kept in the poor technical state as long as possible. On the other hand, many buildings are demolished, which are still structurally good. Such demolition is not only a waste of capital and embodied energy. It also leads to a loss of architectural identity. Current practice is lacking innovative and practical refurbishment concepts for office façades, which support the refurbishment of offices on a wider basis, as well as the indication, to which extend these are applicable to different existing façade types.

1.3. Research mission

It is undisputable that the design planning of a building starts with many different alternative concepts. Usually these alternatives are chosen upon intuition of the planner in the first place. Thus, particularly technically complicated refurbishment projects consume a lot of energy and investment in the early planning stages. The planning team is often lacking the necessary overview of the challenges of office façade refurbishment. This research helps to reduce the number of possible alternative planning solutions before the project actually commences. The reduced number of promising options facilitates the early planning phase, helps cutting costs, and leads to more appropriate solutions for each building project. Thus, more buildings can be refurbished, and as such, can be done with better understanding for the original structure.

Much research has been done on the architectural history of buildings, on the development of new technical building components, on innovative façades, even on the refurbishment of individual office buildings, and the transformation of vacant offices to other functions. Nevertheless, a general overview is missing, which informs about the volume and quality of the existing office stock. Furthermore, the general technical tasks and the application of different refurbishment strategies to certain existing structures need to be evaluated, in order to provide the basis for further research on specialised aspects.

This thesis is filling these gaps of knowledge, by developing and applying different strategies for the refurbishment of office façades. It proves that façade refurbishment is possible and feasible in more
cases than currently expected. Thus it is going to answer the following research question:

Which refurbishment strategies are generally suitable for the most important types of office façades and how can we assign these?

The denominations ‘refurbishment strategies’ and ‘important types’ of office façades are defined as follows: Refurbishment strategies mean technical approaches for the building physical improvement of a façade. This contains the addition or replacement of building components and the technical detailing, as well as the combination of façade construction and building services. The types of office façades are defined by their structural composition and position of the thermal layer. Their importance for the building market is evaluated by their quantity in the assessed national building stocks.

In order to find the answer to this question, the research not only has to cover the technical aspects of office façades, but also the analysis of the building market. The results of this research can thus also support product managers in their search for new markets. However, the main result will be a set of design proposals and solutions suitable for different original office façade types.

1.4. Scope of the research

This thesis deals with the technical refurbishment of Western European post-war office façades. It has been chosen to take a look at office buildings erected between 1950 and 1980, because they make out almost two thirds of the existing building stock (Hoffmann 2006). Furthermore, the office buildings erected before 1980 consume on average three times the energy of new constructions. (Knissel 1999) Thus, these buildings provide a very big energy savings potential. Furthermore, very much research has been done on the improvement of residential buildings. Also, the ‘classic refurbishment’ of older monumental buildings has been widely assessed. The demands for post-war office refurbishment differ strongly from these other fields, and only little strategic research has been done for these.

The assessment of building types has been restricted to Germany, the United Kingdom and the Netherlands, because these countries can be found in the same North Western European oceanic climate zone, which lets expect comparable façade types. Also, the historical development of office work can be compared in these countries. The USA and Asia, for example, have different regulations for office work that permit working zones without window access. Eastern Europe on the contrary, has a tradition of communist building construction, which has resulted almost solely in pre-fabricated buildings. The market analysis touches this market by evaluating the building stock in former Eastern Germany.
It has been chosen to focus this research on façade construction, because the building envelope provides a major potential for improvement of the building’s performance. It creates the thermal barrier and is often responsible for ventilation. This is also the reason to integrate the technical building services into the scope of this research. Both, façade construction and building services reach the end of their technical lifespan at the age of 30 years (IEMB 2006). The façade refurbishment provides the opportunity to also renew the building services. Thus, the best technical improvement of the building performance can be achieved.

Of course, the façade creates the outer impression of the building. Nevertheless, this research focuses on the technical qualities of the building skin rather than on the design. Naturally, the concepts presented in this thesis are driven by the architect’s way of thinking of the author, but they do not represent finished designs. The proposed solutions have to be open to a variety of designs, in order to assure their adaptability to different buildings. The practise shows that many different designs can be created based on a limited number of technical façade types.

1.5. Outline of this thesis

To generate the desired answers to the main research question, several sub-questions have to be answered. The research project is based on four aspects:

- Why and how are façades of office buildings currently refurbished? (Chapter 2)
- Which types of office façades exist in Western Europe? How are these types distributed per country and per construction period? What are their main refurbishment challenges (Chapter 3)
- How can different refurbishment proposals be evaluated? (Chapter 4)
- Which are promising refurbishment strategies for typical office façades? (Chapter 5)
- How can we easily assign the most promising strategies to a given refurbishment job? (Chapter 6)

This thesis presents the research process step by step. Chapter 2 delivers the necessary background information on the topic of refurbishment, which contains a brief definition of the development of post war office façades and the motivation for refurbishment. This information is gathered by literature studies and interviews with
different stake holders of the office real-estate market. Furthermore, this chapter analyses realised refurbishment projects in order to find out, how existing office façades are currently treated and where the major technical restrictions lie. The result of this analysis is a general overview of promising refurbishment strategies for office façades.

The second point of focus is to find out, which buildings are in need for refurbishment. Chapter 3 firstly takes a close look at the actual market situation for refurbishment by assessing the existing stock of office real-estate in the Netherlands, Germany and the United Kingdom. Secondly, a systematic is developed which covers the possible existing office façades. With this systematic, it is possible to sort the existing façade constructions into 22 main types. Spot-checks of the most valuable office locations in cities of different economic power in the three countries verify this system and show the distribution of façades types in practice. These spot-checks give an impression of the façade structures, which were common in certain eras and in different Western European countries.

A proper inventory of the to-be-refurbished building is essential for the success of refurbishment planning. Therefore, Chapter 4 gives insight into the important aspects of façade refurbishment based on literature studies, the evaluation of already refurbished projects and interviews with project stakeholders. Furthermore, it analyses and compares three different existing tools of building assessment. For the task of façade refurbishment this chapter explains methods of calculating quantifiable aspects such as the energy consumption and life-cycle costs. Furthermore, it develops a tool which evaluates and visualises qualitative aspects, such as building process, consequences for the building function, and indoor comfort. This tool is to be used to compare different refurbishment proposals for one project.

Chapter 5 covers the central work of this research. Following the method of research-driven design, five office buildings have been chosen that stand representative for a larger share of the façade types. For each of these case studies, several refurbishment solutions have been designed and evaluated according to the aspects described before. The case studies deliver the most promising solutions for each façade type and point out the major potentials and restrictions. Furthermore, two product orientated solutions have been invented for the most common façade types of post-and-beam curtain walls and load bearing window façades. These concepts aim to bring a façade (and the building services) to today’s standards without interfering with the buildings’ interior. Thus a building can be refurbished while being in operation.

The experiences of these practical case studies are the base for chapter 6, which brings the different façade types and the possible refurbishment strategies together. It sums up the refurbishment strategies in general and provides the decision making tool, which
indicates the most promising approaches for common problems with exiting office façades. The thesis concludes with a ‘strategic map’, which indicated how the results of this study lead to shortcuts in the planning process of façade refurbishment.

Figure 1.1: Organisation of this thesis
1.6. References

AGEB (2008). Energieflussbild 2007 für die Bundesrepublik Deutschland. A. Energiebilanzen. Essen, GER.


2. **State of the art – Office refurbishment in current practice**

There is much discussion about the topic of office refurbishment. Politics as well as the public see the need to improve the existing building stock. Before this thesis goes deep into the quest for systematic refurbishment strategies, it is essential to define the framework for this research. This chapter therefore provides the necessary background knowledge of the ‘state of the art in office refurbishment’.

The first part answers the question: ‘Why do we have to refurbish the office stock?’ It elaborates the relevance of the topic for the sustainable development of today’s society. The second part gives the definition of ‘What’ refurbishment actually means. To do so, the different terms, which occur in the field, are briefly defined. Only with these definitions it will later be possible to describe the actual solutions.

When planning to refurbish a building, one has to be familiar with the historical background of the building and the architectonic and functional ideals behind the visible design. Therefore, the third section of this chapter looks at the development of office buildings and their façades in Western Europe since 1945. It also presents some of the most promising façade concepts of today, which are an inspiration for the development of refurbishment strategies. The fourth section then looks at the motivations for refurbishment. This question has to be divided into the two steps ‘Why should we reconsider an exiting building?’ and ‘Why do we refurbish and not demolish?’, because the answer to the first question does not directly imply the answer for the second one. Once the decision is taken to refurbish a building, many solutions are possible. The last section of this chapter, therefore, presents the general refurbishment concepts which are applied to office buildings today. These strategies are sorted into a framework of technical properties, which is the basis for the future research on this topic. This chapter is supported by appendix A, which contains a collection of best-practise examples.

2.1. **Relevance of refurbishment for a sustainable society**

The refurbishment of buildings has a social, ecological and economical importance. These are the three aspects of sustainability, as they were defined by the World Commission on Environment and Development in their report ‘Our Common Future’ from 1987 (World Commission on Environment and Development 1987). All three aspects influence each other. For example, the use of fossil energy sources leads to destruction of the environment. At the same time, resources become scarce and thus expensive. Scarce resources and environment change lead directly to social conflicts. Thus, the refurbishment of office façades is an important means to improve the sustainability of a society. In the following, this importance is explained in more detail.
2.1.1. Ecologic relevance
The climate change and rise of global temperature is widely accepted as factual among scientists. Since the year 1900 the average global temperature has risen by 0.8 degrees. Today there is 35% more carbon dioxide in the atmosphere than in 1880 (Stulz 2007). The Potsdam Institute for Climate Impact Research (PIK) calculated the CO\textsubscript{2} concentration in the air as to be the highest in the past 800,000 years. PIK also estimated the consequences of climate change until the end of this century. If humanity does not cut the production of greenhouse gases immediately and massively, the average global temperature will rise by 5°C. The sea level is expected to rise between 50cm and 150cm. If glaciers in Greenland and Antarctica melt, the sea level will rise up to 15 meters. Global weather constellations and ocean currents will change, which will lead to changed local climate conditions with more extreme temperatures and weather phenomena (Pachauri et al. 2007). Only, the limitation of the global temperature rise to 2°C can avoid the most severe effects. This goal can only be reached by restricting greenhouse gas emissions to 50% of the level of 1990 by the year 2050 (Stock 2005).

The building industry has to take its share in this task. Currently, building production consumes 50% of the global natural resources and produces 60% of all waste on earth (Hegger et al. 2008). In Germany, for example, buildings consume 41% of all final energy, which resembles approximately 1 million GWh/a. Of this amount, the buildings of the tertiary sector (trade and administration) make out 38% or 15% of the total national energy demand (ARGE 2008). These facts lead to the conclusion, that refurbishment of buildings can significantly reduce material and energy consumption, not only in construction, but also during the operational phase. In comparison to new constructions a lot of building material, and thus embodied energy, can be saved. In operation, a refurbished building can then save up to 75% of energy.

Already in 1998 Caleb Management Services published a report for the ‘European Alliance of Companies for Energy Efficiency in Buildings’ (EuroACE). This report assessed the potential for carbon dioxide reduction in the building stock of the 15 countries being members of the EU at that time. It came to the conclusion that a Europe-wide domestic window upgrading program could save \( 94 \times 10^6 \) tonnes of CO\textsubscript{2} emissions each year. Another \( 25 \times 10^6 \) tonnes could be saved with the same measures in commercial, public and industrial buildings. Improved thermal insulation of commercial buildings could account for \( 20 \times 10^6 \) tonnes of CO\textsubscript{2}. Even more significant, the implication of energy management systems in commercial buildings could save 20% of the energy use, which resembles \( 67 \times 10^6 \) tonnes of CO\textsubscript{2} emissions. Applying all measures that were available at that time, the study concluded that the European Union of 15 states could reduce their CO\textsubscript{2} emissions by \( 400 \times 10^6 \) tonnes annually or 12,5% (Ashford et al. 1998).
The European Union has taken up this task and published the Directive on the energy performance of buildings in 2002, which defines the minimal demands for buildings (European Commission 2002). National governments have transferred these demands to national laws. The Dutch government has set a target to achieve an improvement of energy efficiency by 33% compared to the base year of 1995 and a 10% share of renewable energy in primary energy production until 2020 (Nederlandse Regering 2008). The German government has set the goal to reduce greenhouse gas emissions until 2020 by 40% compared to 1990 (Deutsche Bundesregierung 2007).

These goals are to be achieved by the introduction of different forms of energy labelling (LEED, BREEAM, DGNG) which make the consumption of a building transparent for the user. These can thus decide for a certain building upon a comparable basis. Next to the focus on energy and material consumption, these labels also value the location of a building and its connection to public transport. Refurbishment can score well because a refurbished building consumes less material and energy than a new construction. Furthermore, refurbishment reduces urban sprawl. Instead of consuming valuable natural space, the working activity is condensed in already built up area.

2.1.2. Economic relevance
Buildings are stored capital; money is bound in dead materials. While façades and technical installations may reach the end of their technical life span at the age of 30 years, the load bearing structure can last for a century. Thus, demolition would be a waste of capital. Currently the economic problem is, that no refurbishment strategies are available that value this capital.

The operational cost of a building is strongly related to its energy consumption. The energy prices have risen by more than 40% in the past 10 years (Friedrich et al. 2007). Crude oil prices have doubled since the year 2000 (Tecson 2009). This directly leads to higher operational costs. Research has shown that tenants would accept higher rental rates, if the operational costs, which can be influenced by the user himself, were lower. In personal communication, real estate developers expressed the economic refurbishment target: The total rent including utilities has to remain at the same level, but the share of the base rent must be bigger. Consequently the developers expressed the wish to refurbish many more buildings. However, they are lacking innovative ideas for a fast solution, which causes less impact than an entire disassembly of the building (Schlüter et al. 2006).

A building that provides optimal indoor quality, contributes to the well being of the users, and thus their productivity. The University of Berkeley has conducted a field study on this topic by measuring the effectiveness of work and the days of absenteeism. The study encountered an increase of individual productivity of up to 15% in a building with optimal indoor climate. The average increase has been
7.1%. These effects are related to the improved thermal comfort, individual influence on ventilation and heating/cooling, and the quality of natural daylight (Kats et al. 2003).

Moreover, the profitability of a building rises, if the aesthetic appeal is improved together with the functionality, energy performance, and indoor comfort. The mentioned sustainability ratings are used as an indicator of these features by possible tenants. Thus, a shift is visible among tenants to predominantly rent those buildings, which provide a good sustainability rating. Only on the one hand, this deals with energy costs. On the other hand, the image of a company benefits from a ‘green building’. Developers see the tendency that ‘green buildings’ will be much better marketable in the future than those with poorer performance (Roux Deutschland 2008).

2.1.3. Socio-cultural relevance
Office employees spend up to 90% of their time inside buildings. Obviously, these buildings have to provide a high quality environment for a safe and healthy living. The façade of a building is one of the most important building components to provide this environment. On the one hand, it is the protective shell that separates the outdoor climate from the indoor space that is conditioned to the optimal comfort. On the other hand, the façade is the connection to the outside world, which lets through natural daylight and fresh air, both vitally necessary for the human organism.

After a long period of use many office façades do not comply with these demands any more. Hence, the refurbishment has to improve the qualities and the design of the façade and the building services to provide a work surrounding, which supports the well being of each person inside the building. This job does not only cover technical features, but also the perception of a room, ergonomics, the use physiologically harmless materials, and the possibility to individually adjust the personal environment.

Furthermore, the façade of an office building is responsible for its architectural value. It is the visible statement to the outside world and gives the ‘face’ to a building. In this function it steps into a dialogue with its urban environment. Each building is part of the public space, either as a landmark standing out of the texture of a city, or as part of a naturally grown neighbourhood. The street elevations of buildings are the walls of the public space, which is the living environment for many more people than the ones who spend time inside the building. In this respect, each building, even that which is not officially listed as a monument, is a document of building history and the socio-cultural development of a location. For example, the buildings of the 1950s are a symbol for the new beginning after WWII. The great variety of materials, designs and constructions used in the façades of the 1960s and 1970s shows the creative atmosphere and tendency to experiment, which was present in that time of economic prosperity.
When these buildings today are in need for refurbishment, the task is to keep this history alive and preserve its value for society. In practise this means that each project has to be valued for its qualities and potentials. The refurbishment then fulfills two important tasks. On the one hand, it preserves the design qualities and socio-cultural values of a building, a street atmosphere, or a neighbourhood. On the other hand, after three, four, or five decades of experience with architectural ideals and urban concepts, today's planners are able to revise older concepts and repair mistakes of previous generations. For example, poorly designed urban surroundings, vacancy, which often occurs when buildings do not fulfill the current demands, and misuse of properties lead to a lack of acceptance by neighbours, vandalism and social problems.

Hence, the refurbished building has to meet today’s demands and provide a functional and attractive contribution to society. The 'Ministry of Finance' in The Hague is a good example, in which the designers both improved the interior and the urban surrounding. Originally dark passageways under the building and private courtyards have been opened and transferred to spacious atria, which form the public space for social activities in the neighbourhood. The building design itself refers to the original concept by combing the characteristic façade elements with new components. The original service platforms along the façade are closed with glass screens, which provide sound insulation and are part of the climate concept. Every user is now able to open windows individually and arrange their environment to personal needs. The architectural design thus grows from its roots in the 1970s to the future by giving the property a new life-cycle.

2.2. Definition of terms

Working on the topic of ‘refurbishment’, one comes across a long list of different expressions. Often these expressions describe similar processes. This is because there are no general definitions of these terms. Giebeler (2008) sees two major reasons for the amount of different terms. On the one hand, the impact of a certain process on the building substance can range from minor repairs the replacement of an entire building. On the other hand reconsidering a building can have very different motivations, such as aesthetical, technical, or functional improvement (Giebeler et al. 2008). For this research project it is essential to clarify the expressions commonly used. Based on Giebeler (2008), and common dictionaries, this chapter defines the different and most common terms. These definitions are ordered by extent and complexity of the interference with the original built structure.

Additionally, this section clarifies the terms and abbreviations for the different types of floor surfaces, which are used by real estate companies and planners. For the market analysis of the Netherlands,
Germany and the UK, it is necessary to find out, which areas are used in statistics of different sources. Therefore, the abbreviations in the three different languages are also shown.

2.2.1. Reconstruction
‘Reconstruction’ means returning a damaged or lost building to a known earlier state. The replication of buildings may on the one hand be desired, because the destruction of a monument is considered as a major loss by many inhabitants of the region. On the other hand politics may aim to correct preliminary planning errors. A third reason to reconstruct a historic building (-part) can be found in marketing arguments, if, for example, the façade of a monument is reconstructed to cover a building of entirely different use. Strictly seen, a reconstruction equals a new construction with a special design and, in rare cases, the use of traditional construction methods. The rules for new construction apply. As original drawings are rare, the reconstruction is often based on images and thus implements a new design process.

2.2.2. Restoration
Building restoration describes the process of the renewal and refurbishment of the fabric of a building. The phrase covers a wide span of activities, from the cleaning of the interior or exterior of a building to the rebuilding of damaged or derelict buildings. It aims to preserve a certain historic state of design and quality. In this aspect it is very close to reconstruction. The major difficulty and source for discussion among stakeholders is the definition of the ‘original state’. The “Neues Museum” in Berlin is a good example, in which the architect David Chipperfield tried to preserve not only the classicist monument but also the damages of WWII and traces of 60 years of decay after being destroyed.

Figure 2.1
The façade of the historic palace in Braunschweig (GER) has been reconstructed to cover a shopping mall (Becker 2007)
2.2.3. Demolition
When the load bearing frame of a building is not sufficient for the desired future function, either in terms of capacity or floor layout, a building is likely to be demolished. Nevertheless, the consequences have to be weighed. The demolition process itself does not demand much architectural planning. Specialised companies usually take over the entire project from planning to realisation. The most important factors in the demolition process are safety, logistics and the treatment of waste.

2.2.4. Deconstruction
The term ‘deconstruction’ is defined as demolition of a building with the goal of minimising the amount of materials going to landfills. This approach is applied by removing components by material type and segregating them for reuse or recycling. It aims to reuse as many components as possible and prepare the rest for mono-fraction recycling.

2.2.5. Renovation
Renovation causes the least intervention with the built structure. It does not remove or add elements. The term ‘renovation’ mainly occurs in rental contracts and covers the measures a tenant has to take to maintain the existing quality and properties of a premise in order to use it in the intended way. This includes painting, the replacement of wallpapers or carpets, and minor technical repairs.

2.2.6. Maintenance and repair
‘Maintenance and repair’ is the next level after renovation. It covers the repair and if necessary replacement of building components and technical equipment. Usually these means can be taken by the facility management without the need for extensive planning.
2.2.7. Refurbishment
Refurbishment means the process of major maintenance and repair of components that are either technically or aesthetically out of date. It is a bigger interference than renovation. The extent of a refurbishment can differ strongly. Three levels are distinguished.

Partial refurbishment or Retrofitting
A partial refurbishment only treats certain building components or zones, such as the façade, a defined floor, or the removal of certain toxic materials. This process tends to be the most difficult form of refurbishment, as it usually takes place while the building is in use. It demands a very good management and communication in order to reduce nuisance and disturbance. Retrofitting is a technical term that refers to the addition of new technologies or features to older systems, for example the strengthening of technical components, such as water, electro, or HVAC installations, to improve the building performance. Thus, the retrofitting of components is also part of a general refurbishment.

General refurbishment
A general refurbishment treats the entire building. In this case the building usually is vacated. The refurbishment tries not to interfere with the building structure. Demolition is limited to interior finishes. Technical components are adjusted to current needs but not entirely replaced. A refurbishment under these conditions without a change of building function does usually not demand a special building application. Under German law, for example, the building may be provided with the legal right to safeguard existing standards, which usually expires in case of transformation or substantial refurbishment (Giebeler et al. 2008).

![Figure 2.4](image-url)
Substantial refurbishment of a housing block in Amsterdam (NL)
Substantial refurbishment
In a substantial refurbishment, the building is deconstructed down to its carcase and rebuild from that situation. Often this situation influences the load bearing structure. It usually demands a new building permit, as existing standards do not apply any more. Commonly, the interior, façade, and installations are renewed, which provides a reliable almost-new building. For construction companies this solution makes it easier to take warranties. Only, the technical problems of the carcase remain: load bearing capacity, sound transport, and humidity barriers.

2.2.8. Conversion
In contrast to refurbishment, the conversion of a building often involves major changes of function and building layout. This often demands an adaptation of the load bearing structure too, which implements the need for an intensive structural analysis and may cause a change in access and evacuation routes.

2.2.9. Guttering
Guttering is in fact the exact opposite of façade refurbishment. When a building is gutted, the outside walls or at least the street façades are preserved because of their high socio-cultural value. Behind these façades the entire building is demolished and rebuilt. The new construction equals that of a new building with certain limitations in construction logistics and references to the old façade. This solution is controversially discussed in terms of monumental protection, as it only preserves the impression of a historic street front and not the actual history of the building.

2.2.10. Extension
Extension means a new building that is connected to an initial structure. The connection point often implements a local conversion of the old building, which demands a structural interference. The planning has to take into account that old and new structure tend to subside to different extents.

2.2.11. Transformation
A change of use or function of a building always implements a new building application. Usually a transformation provokes changes in the building layout, structure, or interior, and thus a general or substantial refurbishment. As different functions have other requirements, not every building may be suitable for transformation. Especially in the Netherlands, the problem of transformation has been widely researched, as the Dutch market provides an oversupply of office space and a severe lack of residential buildings (Voort et al. 2007).
2.2.12. Definition of floor areas
Different share holders use different key figures for the assessment of the building market. National statistics offices and real-estate companies in Germany and the UK quote figures in ‘Net Occupiable Floor Area’ (NOA). Dutch real-estate companies prefer the so-called ‘Verhuurbare Vloeroppervlakte’ (VVO), which translates to ‘Lettable Floor Area’ (LFA) in English. For the spot-check assessment of buildings, which will be described in chapter 3, the ‘Gross Floor Area’ (GFA) is the only measurable figure. Figure 2.6 shows the definition of these types of areas as published by the German Engineers Association (VDI). In comparison, the definition of the Dutch floor spaces by the Dutch Norm Institution (NEN) is shown in Figure 2.7. The difference between NOA and LFA results from the definition that LFA also counts corridors and circulation areas.

The national institutions have calculated the average relation of the different types of floor areas. Table shows this relation for office and administration buildings. Gross Floor Area (GFA) equals 100%. According to Norm 3807 by the German Association of Engineers (VDI) the average relation of net occupiable area (NOA) in office- and

![Figure 2.6](image1.png)
Definition of floor areas according to the German Association of Engineers (VDI 3807 1994)

![Figure 2.7](image2.png)
Definition of floor areas according to the Dutch Norm NEN 2580 (NEN 2007)
administration buildings to the gross floor area (GFA) is 61%. The usable Floor Area (UFA) equals on average 48% of the GFA (VDI 3807 1994). For the Dutch market, NYFER published an average relation between lettable floor area (LFA) and GFA of 85% (NYFER 2003). For this research the same relations will be used for the British market.

<table>
<thead>
<tr>
<th>Language</th>
<th>Description</th>
<th>Abbreviation</th>
<th>Relation</th>
<th>Source</th>
</tr>
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<tr>
<td>English</td>
<td>Gross Floor Area</td>
<td>GFA</td>
<td>100 %</td>
<td></td>
</tr>
<tr>
<td>Dutch</td>
<td>Bruto Vloer Oppervlak</td>
<td>BVO</td>
<td>100 %</td>
<td></td>
</tr>
<tr>
<td>German</td>
<td>Bruttogeschossfläche</td>
<td>BGF</td>
<td>100 %</td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>Net Floor Area</td>
<td>NFA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dutch</td>
<td>Netto Vloer Oppervlak</td>
<td>NVO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>German</td>
<td>Nettogrundfläche</td>
<td>NGF</td>
<td>87 %</td>
<td>(VDI 3807 1994)</td>
</tr>
<tr>
<td>English</td>
<td>Lettable Floor Area</td>
<td>LFA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dutch</td>
<td>Verhuurbare Vloer Oppervlak</td>
<td>VVO</td>
<td>85 %</td>
<td>(NYFER 2003)</td>
</tr>
<tr>
<td>German</td>
<td>Mietfläche</td>
<td>MF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>Net Occupiable Floor Area</td>
<td>NOA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dutch</td>
<td>Gerealiseerd Nuttig Oppervlak</td>
<td>GNO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>German</td>
<td>Nutzfläche</td>
<td>NF</td>
<td>61 %</td>
<td>(VDI 3807 1994)</td>
</tr>
<tr>
<td>English</td>
<td>Usable Floor Area</td>
<td>UFA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dutch</td>
<td>Functioneel Nuttig Oppervlak</td>
<td>FNO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>German</td>
<td>Hauptnutzfläche</td>
<td>HNF</td>
<td>48 %</td>
<td>(VDI 3807 1994)</td>
</tr>
</tbody>
</table>

2.3. The development of post-war Western European office façades

The Second World War was a severe break in Europe’s building history. In 1945 many Western European cities were destroyed. Most countries were financially ruined and suffered a massive housing crisis. Then again, the end of the war marked a starting point, which created certain optimism in European societies. The need to rebuild cities was often considered as an opportunity to try totally new concepts and thus rectify mistakes of the past.

The post war building activity, relevant for office refurbishment, can be divided into three major phases: the reconstruction phase from 1950 to 1965, the phase of economic prosperity from 1965 to 1980 and the current phase since 1980. These phases are characterised by certain economical, political, social, and technical developments. Even architectural styles coincide partly with these phases. Post-War office architecture in Western Europe until today is practically based on two different ideals and their interactions. On the one hand, the devastated city centres fuelled concepts for a rigorously new design based on modernist style. On the other hand, Historicism styles were not at all dead and many people desired the re-erection of historical
and traditional houses (Dorsemagen 2004). The results of this constant interaction can be seen in an alternating public preference for one or the other style, which continues to present time.

2.3.1. Reconstruction 1950-1965

2.3.1.1. Historical background
The first years after WWII were needed to clean up devastated city centres. Building activity focussed almost entirely on residential buildings. The economy needed until the early 1950s to recover. With the rise in productivity and the ‘economic miracle’ the need for office buildings grew. After the experiences of the war the public was open to new, modern concepts for architecture and urbanism. Many architects took up the concepts of the ‘New Objectivity’ and stated an antithesis to the traditionalist design of the fascist regimes. The concept of the modern city for the future, suitable for the expected increase of individual motorisation, was applied to many city centres. The urban focus lay on the separation of functions: The city centres were designed for work and shopping. Residential functions were relocated to the suburbs.

2.3.1.2. Architecture – Rationalism versus Modernism

Rationalism
It had to be built fast. Although classic modernism was the inspiration for a cost-optimised building process, for many people it was too dogmatic. Therefore, a widely accepted style turned up—‘Functionalism’ or ‘Rationalism’—that sized modernist ideas down to human scale and equipped façades with decorative elements that were accepted by the masses. Unlike the classic modernism, in which the structure defined the design, now the structure became a decorative element. Columns formed a strict grid, even if they were not structurally necessary. Façades were not left undecorated but clad in different materials, such as plaster or natural stone, preferably of natural colours (Dorsemagen 2004). The philosophy was to build simple, restrict to the bare necessities, but as beautiful as possible (Flagge 1987). Thus, the very

Figure 2.8
A rationalist style street front in Bielefeld (GER)
common form of the skeleton building was created, which can be found in many urban centres across Western Europe.

Modernism
Next to the functionalistic mass of buildings, many significant office buildings used the ‘International Style’, based on Mies van der Rohe and his wish for ‘Almost Nothing’. Famous examples for the post-war international style can be found in the works of Egon Eiermann or Paul Schneider-Esleben. His high-rise building for Mannesmann in Düsseldorf, Germany from 1956 is considered as the first post-war skyscraper in Germany. It contains a concrete core and a steel structure supporting the original post-frame façade. Another example by Paul Schneider-Esleben is the administration building for Commerzbank from 1965, also in Düsseldorf. This building’s design was inspired by the ideal of a city for private motorisation. It used to have drive-in counters for bank customers. The façade is made of pre-fabricated sandwich panels, a development from car industry (Dortmund University 2008).

2.3.1.3. Office concept
The 1950s were still characterised by a standard office layout with cellular offices (Joedike 1983). In the late 1950s, the open-plan office was first developed for very flexible rental office buildings in America. The German management consultants of ‘Quickborner Team’ became famous creating the so-called ‘office landscape’ and promoting it in Europe since 1958 (Hezik 2007). The office landscape provides open spaces and diverse interiors, which want to give the office worker interesting perspectives although he always uses the same desk. The concept underlying this design wants the physical surrounding to reflect a democratic and egalitarian management style. It became the symbol of flat hierarchy in the early 1960s.

2.3.1.4. Construction and installations
The skeleton structure helped saving building material, which was scarce after the war. Until 1945 steel-columns were commonly used as load bearing structure. After WWII the shortage of steel lead to the use of reinforced concrete. This became the most common material for skeleton structures in the 1950s. After 1960 steel-skeletons reappeared in construction, as they could be assembled easily and fast. Their deficiencies in fire protection almost always demanded a covering of the load bearing structure with plaster, concrete or plate material (Dorsemagen 2004). Prefabricated concrete skeletons are a development of the 1960s. The majority of buildings are usually only equipped with basic technical installations, such as radiators and opening windows.

The representative offices, inspired by the international style, also aimed to renew building industry. A major step in the development of transparent buildings occurred in 1959, when the company Pilkington developed the production-principle of float glass. This made it possible to create large glass panes in defined thickness and faultless quality at
very low cost (Davies 1990). Since that date, significantly more buildings were equipped with ‘curtain wall façades’. In order to improve the unpleasant conditions in buildings with non-insulated glass façades, technical building services and air-condition technology took a large step forward too.

2.3.2. Economic Prosperity 1965 - 1980

2.3.2.1. Historical background
By the end of the 1950s the inner city locations were almost fully reconstructed. Building activity turned towards the outskirts of towns. The increasing level of motorisation made it easy to reach work locations in the periphery. But then, in the early 1960s, the Western European countries experienced the first recession after WWII. In succession the economic development and social society was questioned, which led to the social rebellion of the late 1960s that culminated in the student riots of 1968. In 1973 the first oil crisis took place, energy prices rose, goods became more expensive, unemployment rates went up, and the economic boom slowed down.

2.3.2.2. Architecture – New Brutalism versus Structuralism
It did not take long until alternative proposals occurred that turned away from the strict functional separation of the city. The forerunner of this dispute was the so-called ‘Team Ten’, a group of younger architects who met during the organisation for the 10th CIAM congress in 1953. They opposed both the fundamental functionalists around Le Corbusier and the ‘folkloristic tendencies’ of the re-construction architecture. Two different movements emerged from Team Ten: The ‘New Brutalism’ and the ‘Structuralism’ (Frampton 2001).

New Brutalism
The expression ‘Brutalism’ was already coined around 1950 by the Swedish architect Hans Asplund. It refers to the French expression ‘béton brut’, which means raw concrete. It describes an architectural style characterised by the visible concrete material with all traces of its moulding. The expression ‘New Brutalism’ is based on the architects Alison and Peter Smithson. New Brutalism buildings do not necessarily have to be made from concrete. They are more generally characterised by a rough appearance and visible structural materials. Buildings are often designed with strong 3-dimensional shapes and volumes. Specific rooms are created for definite uses, and often these uses shall be visible from the outside (Joedicke 1983).

In the United Kingdom and in the Netherlands many examples of New Brutalism can be found. The town hall of the city of Terneuzen (1973), for example, was designed by Jacob Bakema and Hans van den Broek. The construction material is made visible and the outer shape of volumes quite obviously indicates the functions inside.
Structuralism
On the contrary to the Brutalist concept, that every room should be
designed for its purpose, ‘Structuralism’ takes a different path. In
this theory the general structure of the building is most important. It
provides the framework for a variety of uses and connects different
functions. No impersonal or sterile forms should be used like in
classic modernism, but rather should the architecture and urbanism
be inspired by pre-industrial village structures. The users should be
able to interfere with the building and adjust their environment to
their personal needs. This often resulted in irregular shapes, differing
volumes and a variety of material use (Joedick 1983).

Among the first promoters of structuralism were Aaldo van Eyck and
Herman Herzberger. Herzberger realised many projects following this
principle. The building for Centraal Beheer in Apeldoorn (1968-1972)
is the most typical example. It is designed as a city within a city. The
structure of the building is based on a rectangular grid, which is filled
with an irregular set of platforms and work-spaces of different heights
and often without a defined use. According to Herzberger, not all
surfaces of the building were finished on purpose. This gave the users
the opportunity to take in their own environment spontaneously by
individual decoration (Pevsner et al. 1994).

2.3.2.3. Office concept
One would expect that the rebellion of the late 1960s with its socialist
ideals was in favour of the open-plan offices, but the practical
experience outweighed these ideals. The offices were too noisy and
offered no privacy. Consequently, new office buildings turned away
from the concept of very big open-plan offices towards a smaller scale,
in which work spaces were preferably organised in smaller groups.
The huge indoor spaces, which needed artificial lighting, were not
accepted any more. Every work space was desired to be located close
to the façade.
2.3.2.4. Construction and installations
The availability of cheap energy and construction material led to buildings of a higher construction quality than before, which show a wide variety of architectural styles and materials used. The technical building services also took advantage of cheap energy prices. It was often desired to provide the highest technical standard. Thus, many office buildings were equipped with mechanical ventilation and air conditioning, which had to compensate the poor insulation and glass qualities. This has resulted in very high energy consumption of buildings of this era. Unfortunately, the economic prosperity also led to the use of unknown materials. Buildings of the late 1960s until the mid 1970s hold the most problematic toxins. (Giebeler et al. 2008)

The Netherlands saw a special development in building construction. On the one hand there was a strong need for office buildings all the way through to the early 1970s. On the other hand there was a lack

Figure 2.12
Centraal Beheer, architect: Herman Hertzberger (1967 - 1972), Apeldoorn (NL), photo: Willem Diepraam
of skilled labour. Consequently, the government started a campaign to improve the building productivity as early as the late 1950s. This stimulus led to three consequences. Firstly, the on-site production of concrete and formwork was improved. Secondly, the stack system was developed, which uses wall-size prefabricated concrete units as load-bearing walls and similar floor elements. On site the units are connected with bolts and concrete to form a massive construction. Thirdly, prefabricated building systems appeared, which are based on a load bearing framework, floor plates, and curtain walls (Hezik 2007). The consequences of these developments can still be seen today. In comparison to Germany or the UK, the Dutch market almost exclusively knows off-site production.

2.3.3. Post 1980 era

2.3.3.1. Historical background
The end of the 1970s saw another change in the social situation. The second oil crisis in 1977 made clear that energy was valuable. The upcoming environmental consciousness added to the sensitivity for toxic materials, but also raised the desire for spatial quality of buildings. Therefore, the building industry turned towards new office concepts and new architectural designs. Also, the tendency to locate office buildings outside the city centres has been revised. Since the late 1980s, a trend back into the city can be seen. Companies demand well communicated locations and a functional infrastructure in the proximity of their office (Eisele 2005).

2.3.3.2. Architecture - High-Tech versus Post Modernism
The oil crises had two consequences for the development of architecture. One stream of designers tried to solve the new demands by intensifying the high-tech architecture. The other stream headed back towards the roots of building and propagated a style named “Post Modernity” (Pevsner et al. 1994).

High-Tech Architecture
‘High-Tech Architecture’ tries to solve all problems with the help of industry and technological inventions. The building envelope, as the biggest building component, takes in a very important role in this. Centre Pompidou (1977) in Paris by Renzo Piano and Richard Rogers is the first example that consequently shows the structure and building services in the façade. Thus, architecture also sets visions and targets for the industry. In his article ‘A wall for all seasons’ Mike Davies criticises that traditional windows with really poor glazing functioned in history because they used additional layers such as shutters and curtains to change the technical properties of the window. Modernist buildings abandoned such constructions and, hence, demand much energy for technical installations to improve the building’s usability. In his article, which is based on a research report for Pilkington published in 1981, he therefore sets the famous task to develop a ‘polyvalent wall’. The new façade should solve the tasks of traditional shutters and
curtains on a molecular level. Glass, as the dividing element between inside and outside should be able to adjust automatically to the users’ needs and to outside circumstances. Different coatings or technical layers in the glass should control transparency, shading, and thermal performance. These features should be able to change automatically, controlled by sensors and micro-controls. Additionally, the ‘wall’ should produce energy and be as thin as possible (Davies 1990).

This sketch of a polyvalent wall has inspired many inventors ever since and can be seen as the starting point for the so-called ‘intelligent Façades’ of today. One of the first office façades constructed with an enormous technical effort is the headquarters of ‘Lloyds of London’ (1978-1986) by Richard Rogers Partnership. In this building all building services are shown in the façade and all offices are serviced from the window side of the room. The façade functions as an exhaust façade that extracts excessive heat loads before they enter the room. Another

Figure 2.13
Sketch of the ‘Polyvalent wall’ by Mike Davies (1981) (Davies 1990)

Figure 2.14
Hong Kong and Shanghai Banking Corporation, architect: Foster Associates (1979-1985), Hong Kong (CN)

Figure 2.15
technical advantage is that the building provides more usable office space when all technical ducts are placed outside the façade (Powell et al. 1994)

One of the most elaborate examples of high-tech architecture is the ‘Hong Kong and Shanghai Bank’ (1985) in Hong Kong by Foster Associates. The entire building is constructed from components that were developed in conjunction with the manufacturers around the world, produced there, and shipped to the site (Brookes et al. 1990). The exterior skeleton shows the transport of building loads.

Postmodernism
Post-modern architecture developed in the United States already in the 1960s as a reaction to the modern style. It criticises modern architecture as too technical, too impersonal and without humane quality (Jacobs 1961). Also, the lack of iconographic features is seen as the source of the lack of identification of people with Architecture (Venturi et al. 1977). Consequently, post-modern architecture deals with many decorative elements. It quotes from different historic styles and also sometime excessively combines these. In opposition to modern architecture the buildings are preferably designed to suit the location and their surrounding. Nevertheless, humour and irony can be part of post-modern architecture too. In their book ‘Learning from Las Vegas’ from 1972 Robert Venturi and Denise Scott Brown explain the concept that a building basically needs to be a functional ‘box’ that can reach any desired expression by cladding the façade (Venturi et al. 1972). Frampton (2001) puts this concept into harder words when he says that post-modern architecture is characterised by short circles of production and consumption and reduced to ‘packaging in a large scale’ (Frampton 2001).

It took the post-modern movement until the early 1980s to gain importance in Western Europe. In the Netherlands many office buildings since then have been built using a pre-fabricated construction system and a highly decorative façade. Examples can be found in many office parks. A rather extreme representative is the headquarter building of Gasunie (1994) in Groningen. The 18 floors of office space are built in a very efficient rectangular building system. However, the Atrium, the façade and the building edges received a decorative organic style.

In Germany postmodernism developed differently. After the functional re-construction of the cities after WWII and the modernist extreme concepts of the 1960s and 1970s the people longed for traditional, small scale buildings. Hence, the architecture of the 1980s quoted from pre-industrial themes. This has resulted in the excessive use of dark wood and visible beams as decoration, both in interior, as well as exterior design. Using 45-degree corners aimed to soften the sharp corners of buildings and refer to naturally grown villages. The promenade of the CentrO shopping centre in Oberhausen (1996) is an example for a long row of shop fronts with different designs inspired
by various styles. The composition aims to create the impression of a naturally grown Mediterranean harbour front in the middle of an industrial area.

2.3.3.3. Office concept
Since the 1980s the computer appeared in the office. This eliminated the need for big open plan offices with typewriter desks. Instead, office work became more individual. The group offices, in which few people working on one project share a room, prove to be best suitable for the new tasks and have been developed further.

The ‘non-territorial office’, on the contrary, is a development of the late 1990s. There are no individual desks allowed. In the most dogmatic execution, this means that you have to look for a free desk every morning. This concept originated from the idea, that a modern office employee works from home and on the train, and is only part time present in the office. Although this may occur, the non-territorial office has not been widely accepted. Especially, if you are working in different places, the office becomes a sort of ‘second home’, where personal communication takes place, and which has to provide the chance for identification (Voss et al. 2006).

Therefore, modern offices provide a variety of work surroundings and often resemble a combination of cell-offices for concentrated work, group offices for more communicative or creative tasks, and flexible work spaces. The adaptability of work space is economically very important. It is desired to quickly adapt the office space to the work needs, rather than adapting the work processes to fit the space (Hezik 2007).

2.3.3.4. Construction and installations
One major consequence of the oil crises was the implementation of energy codes. Thermal insulation of façades, which had not been considered before, moved into the technical focus. Glass industry presented insulated glass and the façade industry developed the first thermal separation of window profiles. Since then the insulation of buildings and aim to reduce energy consumption has been a topic of constant development. Figure 2.18 shows how the façade construction industry is embedded between technological inventions and legislation. It illustrates that building practise on average is five years behind the technological development. From there it usually takes another five years, until the actual practise is defined as minimum requirements by normative regulations.
Also the operating practice shifted drastically after the energy crisis. In the 1980s and 1990 it was desired to reduce energy consumption by adapting commonly known building services systems. The focus lay on mechanical ventilation and air conditioning. Ventilation rates were reduced to the minimum. Indoor temperatures were kept at the limits of the comfort range. This resulted in occupant dissatisfaction. Since the late 1970s the term “Sick Building Syndrome” has been used to describe symptoms caused by poor indoor climate. Since then users are increasingly demanding healthier buildings, which has led to a critical analysis of building materials and a revision of ventilation concepts since the 1990s.

2.4. Latest developments in office façades
Since the 1980s the people’s perception of their natural environment has changed. Legislation is making ever stricter demands on thermal insulation and energy saving. The report ‘Our Common Future’ from the ‘United Nations World Commission on Environment and Development’, also known as ‘Brundtland Report’ was published in 1987 and the “Earth summit” in Rio de Janeiro in 1992 brought the wider theme of sustainability into the public focus. Not only the saving of energy became important, but also the entire impact of today’s people on the environment for future generations. Many new concepts for office façades and technical building services have been initiated by these demands. Planners have started to understand façades and technical installations as complementary functions of a building that demand an integral planning. The following section presents the latest developments in office façade technology and building service concepts.
2.4.1. Glass Industry

Industry has constantly improved the performance of window glazing since the first oil crisis in 1973. A simple insulating glass, with dehydrated air as filling had been invented in the 1960s. But it took till 1975 until it was widely used (Giebeler et al. 2008). Such glass achieves a reduction of heat loss by 50% in comparison to single glass, which reaches a u-value of approximately 5.6 W/m²K. Since the early 1980s the glass performance is improved by applying low-E coatings on the glass. These glasses reach a u-value of 1.8 (Compagno 2002).

In order to reduce the conductivity within the glass, the cavity can be filled with different inert gases, such as argon, krypton or xenon, which have a lower specific heat capacity than air. With these gas fillings a glass can achieve u-values of 1.1 W/m²K with argon filling and to 0.8 W/m²K with krypton filling. While argon is relatively cheap to obtain – it makes out approximately 1% of the air – the other gases are rarer and therefore more expensive. Hence, insulating glass of two panes with U-values better than 1.0 W/m²K are too expensive for a broad market. Furthermore, the cavity between the glass panes has to become relatively wide to reach this u-value. In this case, the convection within the cavity becomes an important factor. When there is a big temperature difference between inside and outside the glass performs significantly worse than in the defined normative test conditions (Renckens 1997).

Therefore, the development went further to the creation of triple-pane glass in different forms. A triple pane glass with argon filling can reach a u-value of 0.7 W/m²K. The current benchmark that can be reached by triple pane glass with krypton filling and different coatings is 0.5 W/m²K. As this glass becomes very heavy, there are alternatives that use

![Figure 2.17: U-values of different types of glass](image)
low-E-coated plastic foils instead of the centre glass pane. Thus, such glass can reach a u-value of 0.4. This type of insulated glass has been used in the US and in Scandinavian countries for 30 years and proven to be functional.

The latest development in glass technology is vacuum glass. Vacuum glass can also reach a u-value around 0.5 W/m². To do so, the cavity between two panes is evacuated, which prevents convection and eliminates the cost for inert gases. However, it is necessary to seal the spacers extremely tightly. Additionally, small spacers have to be placed on the pane surface in the cavity to maintain the distance between the panes. Vacuum glass products are expected to be available in 2010 (Schneider 2008).

2.4.2. Double Façades
Double façades are characterised by one thermal façade layer and an additional layer that fulfils additional purposes. In residential buildings box windows have been used since the early industrialisation (since glass became affordable). By opening and closing one or the other layer they allowed an optimised thermal performance in different seasons.

The Steiff factory in Giengen/Brenz (GER), built in 1903 is considered as the first example for first double façade in a non-residential building. The large glass surface was designed to provide abundant daylight for the sewers, but it needed the second layer to ensure sufficient insulation because the sedentary work demanded a heating level compared to residential buildings. Although office work would set similar demands, these buildings were commonly solved with larger heating systems. Thus, it took until the 1970s for the double façade to reappear in the shape of high-tech architecture, such as the Lloyd’s building in London.

Only in the 1990s the double façade started to become fashionable. Improvements in glass technology, such as triple glazing, achieved u-values of glass blow 0.5 W/m²K. Hence, the transparent architecture, which now could comply with energy saving norms, did not suffer from heat-loss any more, but tended to overheat by solar gains. This caused severe needs for air-conditioning and fuelled the call for a reduced portion of transparent building parts. In order to still fulfil the desire for all-glazed buildings, new strategies had to be found.

The new double façades are equipped with a thermal layer on the inside position and an additional exterior layer that is not insulated. The cavity provides a buffer zone and space for sun-protection devices. The additional glass layer gives nose protection in case the windows shall be opened by users. Various ventilation concepts can be combined with this façade construction. Generally, double façades can be characterised in four types.
2.4.2.1. Box Window
The simplest solution for a double façade is a box-window. The additional glass layer is placed in front of the insulating window. The windows are separated horizontally and vertically. The cavity needs to be ventilated. An opening ratio of approximately 10% has proven to be the optimum to sufficiently extract solar heat gains and still provide a good noise protection (Voss et al. 2006). Box windows can also be integrated in unitised façade systems with floor high elements.

![Figure 2.19](image)
Figure 2.19
Principle construction of a unitised box-window façade (Knaack et al. 2007)

2.4.2.2. Multi storey façade
Placing a glass screen in front of a façade creates a so-called ‘Multi storey façade’. It is defined by a cavity that reaches over several floors and façade grids. The cavity needs ventilation openings at the bottom and the top. As it spans a greater height, the cavity tends to overheat by solar irradiation. There are very different cavity temperatures at the different floor levels, which causes problems for operable windows and air-conditioning systems. Other major problems are sound-transport within the cavity and fire protection.

![Figure 2.20](image)
Figure 2.20
Principle sketch of a multi-storey façade (Knaack et al. 2007)

![Figure 2.21](image)
Figure 2.21
2.4.2.3. Corridor Façade

To solve the problems of different cavity temperatures, a horizontal separation can be used. In this case the cavity forms corridors along the building. Ventilation openings alternate and thus create a diagonal ventilation of the cavity and prevent the intake of used air from lower floors by short-circuiting of exhaust and intake air. The horizontal separation does not necessarily need to be on floor level. Placing it at the top of a parapet optimises the use of daylight. Furthermore, the air in front of the window is cooler, as warm air rises above.

Figure 2.22
Principle sketch of a corridor façade (Knaack et al. 2007)

Figure 2.23

2.4.2.4. Shaft-Box Façade

This partitioning concept combines the advantages of natural ventilation by thermal updraft with the noise and fire-proofing qualities of box windows. The solar gain in a vertical shaft, covering up to 10 floors creates an updraft that extracts used air from adjacent box windows. The box windows get their fresh air directly from outside. The effective air-extraction allows smaller ventilation openings and hence a better noise protection.

Figure 2.24
Principle sketch of a shaft-box façade (Knaack et al. 2007)

Figure 2.25
ARAG Tower, architects: Foster + Partners with Rhode Kellermann Wawrowsky, Düsseldorf (GER), Example of a shaft-box façade
2.4.2.5. Conclusions double façades
The major advantages of double façades are a good protection against exterior noise sources, and the protection against wind loads, which allows opening windows even in high-rise buildings. For the natural night cooling by opening windows and flooding the building with fresh air, the additional glass layer provides the necessary protection against burglary. In terms of building installations, the protected cavity offers space to place a very good sun-protection system. Daylight deflecting sun blinds improve the use of daylight. Being inside the cavity, the highly reflective surfaces are well protected from staining.

Nevertheless, this construction also causes several disadvantages. While the thermal buffer function of the façade is desired in winter, it causes problems of overheating in summer. Windows opening to the cavity cause situations, which are uncontrollable for technical building services. In summer, the incoming air can be hotter than the outside temperature. In winter, the warm air from the room may condensate on the outer glass pane.

A double façade always has to be developed in combination with the installation concept and with respect to the surrounding climate conditions. Hence, it is always an individual solution for one particular situation. Naturally, this causes higher construction costs. The price for a double façade can reach up to 1.5 to 2.5 times the costs of a single façade. In latest projects the double façade is therefore not the preferred option any more and rather used in combination with single façades in one building. The additional layer is only placed in those zones where it is necessary, for example to protect operable sun blinds or on the side of a building that is exposed to noise (Knaack et al. 2007).

Double façades can be an interesting option for the refurbishment of office buildings. An existing façade can be improved by adding an exterior layer. Thus, the original façade may be allowed to stay in place. New building services can be installed in the façade cavity, which makes it possible to technically update the building without interfering with the interior.
2.4.3. Service integrated façades

In order to reach an optimal performance of a building the façade has to be planned in combination with the ventilation concept and the technical building services. Since the late 1990s concepts occur, in which most of the building services are placed in the façade zone. The major problem of such de-centralised concepts always used to be the control and maintenance of the enormous number of components. Only with progress in information technology and facility-management software these HVAC-concepts became practicable. In the following, the latest developments of service integrated façades are presented in examples.

2.4.3.1. Post Tower, Bonn - The first application

An early example of positioning building service components into the zone of the façade is the ‘Post-Tower’ in Bonn (GER). The 162.5 m high office tower was built from 1998 to 2002 and designed by Murphy Jahn Architects. The double façade is divided into 10-storey high zones. The climate installation concept is based on de-centralised induction units, placed in the top-floor zones along the façade. Fresh air is taken into the façade cavity. There it is pre-conditioned by solar irradiation. The induction units take this air and heat it to the desired temperature. Depending on the outside weather conditions the ventilation rate of the cavity is adjusted. Used air is extracted through big winter gardens in the central zone of the building (Compagno 2002).

The major development task in this building was the control and maintenance of the HVAC components. All openings in the façade, as well as the ventilation units are controlled by a facility-management-software. As the amount of components exceeded any previous project every floor is treated by the software as one building in itself. Nevertheless, the complex control allows a feasible performance and individual maintenance intervals for all components.

2.4.3.2. TEmotion by Hydro building systems – The open system

Important façade manufacturers and façade-planners have developed their own concepts for integrated façades. These aim to bring as many functional components into a unitised façade as possible, such as sun-protection, ventilation systems, air conditioning, energy generation, and artificial lighting. These façades are often composed of zones with fixed glazing, operable windows and decentralised HVAC service installations. Facility managers, climate designers, and the manufacturers of HVAC-components are integrated in the development process. The heating, cooling, and air conditioning are realised by de-centralised units that provide all necessary installations with minimised dimensions.

The name ‘TEmotion’ is combination of ‘technology and emotion’. The façades system was designed by Wicona (Hydro Building Systems) and the University of Dortmund. A prototype was first presented in 2005. The façade is a combination of a box window and an installation
element within one unitised element. The box window is permanently closed. The exterior pane protects the solar blind. All functions of ventilation and air conditioning are placed in an opaque vertical element. It is possible to open parts of this element for natural ventilation. Additionally, there is a mechanical de-centralised HVAC unit that allows ventilation with heat-recovery and air conditioning.

The combination and dimension of the transparent and the functional elements can be chosen freely, which can give the designer of the building a certain design freedom. The entire control system is integrated in the façade-unit. All functions can be monitored by a BUS-installation. Thus, it is possible to mount different components in the service unit without major changes in the building’s installation system. The product never left the prototype status as it held two disadvantages that made marketing difficult. The façade was composed of existing products, which caused rather big dimensions. Even more severe, the design possibilities with this unitised façade were limited, which led to a lack of acceptance among architects (Hövels 2007).

2.4.3.3. The ‘Capricorn Façade’ by Gatermann und Schossig – An individual product

A lack of acceptance among architects was not the problem of the Capricorn Façade. Unlike industrial product development this façade concept was initiated by the architects Gatermann and Schossig for a defined building.

For the administration building of the company Capricorn in Düsseldorf the architects developed a solution, in which all building services should be provided from the façade. In this case the unitised aluminium façade is equipped with specially designed de-centralised building service units. These units are minimised in size. With a dimension of approximately 1.20 / 1.00 / 0.20 m the climate units can be placed in the parapet level of the façade. The installation provides ventilation with heat recovery, heating and cooling. Furthermore, the façade elements are equipped with operable box-windows, Venetian blinds in the cavity and artificial lighting.

Figure 2.28
Capricorn Haus, architects: Gatermann and Schossig (2005), Düsseldorf (GER)
The highly engineered integrated façade unit characterises the outer appearance of the entire building. Gatermann Schossig Architects have used similar façade and installation concepts for other buildings, such as Stadtwerke Bochum, and thus create a certain corporate ID.

2.4.3.4. Conclusions Service integrated Facades
The integration of de-centralised service components into the façade provides many advantages in comparison to central air-conditioning systems. Air has a very low heat capacity. Thus, a central air-conditioning demands a large volume of air to be transported through a building, which consumes a lot of service energy. De-centralised systems condition the air directly at the place where it is needed. Hence, warm or chilled water is transported through the building instead of air. Thanks to the better heat capacity of water these circuits occupy less space and demand less service energy. As every façade element is equipped with HVAC installations, it is easy to provide individual comfort control for every office space.

Also, by eliminating central air conditioning installations and big air distribution channels, this concept leads to new building layouts and frees lettable office space. No air-ducts are needed to distribute air into the office. Hence, suspended ceilings can be smaller or even eliminated. This creates either higher rooms or lower floor heights. More usable floors can be fitted within the same building height. Also, if there are no suspended ceilings the structural floors can be used for innovative and ecological climate concepts such as concrete core conditioning.

The very large number of maintenance points (filters, flap, and fans) asks for a well administered facility management system. BUS-installations and adequate software help to solve these problems. An intensive facility management helps to adjust the service intervals for each unit individually. Thus, the maintenance cost for such installation is similar to that of centralised building services.

The major problem for the marketing of service-integrated façade systems still lies in the unclear responsibility of different parties. Façade manufacturers are not able to take the risk of climate installations and vice versa. This can only be solved by co-operations of specialist companies. Another challenge is the acceptance of such façades by planners, designers, and clients. The well developed products presented above have not been used often, as many stake holders found them too restrictive. A more open system and modular concept is obviously needed. Nevertheless, the idea to combine façades and building services is very promising for refurbishment. Placing new installations in the façade layer allows a building process almost fully independent from the interior.
2.5. Motivation for façade refurbishment

The question why a building comes into consideration for refurbishment has to be split up into two levels of decision-making: ‘Why do we reconsider the existing building stock?’ and ‘What are the main decisive arguments for refurbishment instead of replacement?’ This section tries to find out these motivations for two reasons. Firstly it helps to define, which buildings are most likely to be refurbished. Secondly, it delivers restrictions and potentials, which a refurbishment strategy has to deal with.

The motivations presented below result from literature studies, the evaluation of realised case studies, and the personal communication with different stake holders of office real-estate. These are real-estate developers, financial consultants, planners, and technical experts. The arguments thus encountered can be sorted into ‘Building Immanent Factors’, such as design, function, building physics, and technical performance, and external conditions, which are subdivided into the categories ‘Legal Reasons’, and ‘Economic Reasons’. In the following, these parameters are explained and brought into hierarchy.

2.5.1. Reasons to reconsider an existing building
Before starting a renovation planning, the general decision has to be taken to reconsider an existing building. The following Table gives an overview of the motivations for building owners to initiate a planning process for existing buildings.

The architectural design of a building fulfils an important purpose in the public space. A building design, which is not accepted by people living in the proximity, or an obvious vacancy, can easily lead to social problems, because people do not identify with their neighbourhood. The same applies for previous mistakes of urban planning. In such cases, the existing built environment is likely to be reconsidered. Furthermore, the building’s design is very important for the owner and the user. The owner’s demand for public perception and reputation can only be fulfilled by an appropriate architecture. Outdated styles or obvious decay can not be accepted. The same applies for the interior functionality. Inflexible floor layouts and a poor general indoor quality lead to unproductive work processes and, even more severe, unpleasant working conditions. Thus, one of the main reasons to reconsider an office building is the change of function, which asks for a different built surrounding and higher technical standard.

The technical deficiencies can be found in building physics and building service installations. Leakages, poor insulation, and inefficient building services lead to poor user comfort, high energy demands, and thus high operational costs. With the current sensibility for energy consumption and operational costs, these factors are increasingly important decisive factors for a building user. If operational costs are
high and the identification with the building is low, tenant users may consider relocation and buildings are threatened to become vacant.

The presence of hazardous materials, deficiencies in fire security, and the possible dangers for third parties are important aspects for the usability of a building, but they are also legally imposed. The major legal cause for refurbishment can be found in energy saving rules. The

Table 2.2
Reasons to reconsider an existing building

<table>
<thead>
<tr>
<th>Building imminent factors</th>
<th>Urban design</th>
<th>Desired improvement of the urban quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prevent vacancy as cause for social problems in a neighbourhood</td>
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<tr>
<td>Architectural design</td>
<td>Outdated appearance</td>
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<tr>
<td></td>
<td>Exterior impression bad for the reputation of the user / owner</td>
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<td></td>
<td>Decay of a valuable architectural heritage</td>
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<tr>
<td>Function</td>
<td>Transformation of the building</td>
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<td></td>
<td>Change / Optimising of office concept</td>
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<td>User comfort</td>
<td>Unpleasant indoor conditions - users’ complaints</td>
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<td></td>
<td>Hygienic problems</td>
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<td></td>
<td>Sick building syndrome (SBS)</td>
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<td></td>
<td>Building related illness (BRI)</td>
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<tr>
<td>Technical Installations</td>
<td>High operational energy demand</td>
<td></td>
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<tr>
<td>Hazardous material</td>
<td>Asbestos</td>
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<tr>
<td></td>
<td>PCB</td>
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<td></td>
<td>PAK</td>
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<tr>
<td></td>
<td>MMMMF</td>
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<tr>
<td>Building physics</td>
<td>Lack of insulation</td>
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<td></td>
<td>Wind leaks - draft</td>
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<td></td>
<td>Water leaks</td>
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<td></td>
<td>Fire protection deficiencies</td>
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<tr>
<td></td>
<td>Planning for climate change</td>
<td></td>
</tr>
<tr>
<td>Building owner / user</td>
<td>Tenant considers relocation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Owner user initiates renovation</td>
<td></td>
</tr>
<tr>
<td>Legal reasons</td>
<td>Fire regulation</td>
<td>Compulsory fire safety improvements</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>Danger of damage to third party</td>
</tr>
<tr>
<td></td>
<td>Energy consumption</td>
<td>Compulsory energy consumption certificate (energy passport) for resale or rental contracts</td>
</tr>
<tr>
<td>Economic reasons</td>
<td>Operational cost</td>
<td>High energy demand</td>
</tr>
<tr>
<td></td>
<td>High maintenance cost</td>
<td></td>
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<tr>
<td>Lettability</td>
<td>Bring an empty building back to the market</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tenant considers relocation</td>
<td></td>
</tr>
<tr>
<td>Marketing</td>
<td>Users’ representation need</td>
<td></td>
</tr>
<tr>
<td>Financial market</td>
<td>Institutional investors are bound to invest</td>
<td></td>
</tr>
</tbody>
</table>
European directive on the energy performance of buildings has by now been transferred to national legislation. When selling or renting a building it gives the new owner or tenant the right to ask for an energy consumption certificate (European Commission 2002). The public discussion about energy performance and the rising energy costs has made building users sensitive for this topic. Tenants demand buildings with low running costs and up-to-date installations. A higher base rent is accepted, as long as the total rent including running costs is lower than in comparable buildings (Roux Deutschland 2008). This closes the circle to the question of lettability of a property.

Buildings are re-considered when there is a danger of vacancy and financial loss, or if the improvement helps to raise the reputation of the occupier. A further motivation is often imposed by institutional developers. Real-Estate funds are equipped with large sums of money. They are bound to spend the investments and to provide a stock of high quality with best rental possibilities. Predominating for these prospects is the optimal location of a property. Thus, these funds tend to improve the building stock in the most valuable office locations, either by replacing or by refurbishing existing buildings.

2.5.2. Decisive factors for refurbishment instead of replacement

When the decision is made to start the planning process for an existing building, the next step has to be the assessment whether the building shall be demolished or refurbished. Table 2.4 shows the most important arguments, which predominate or at least indicate that a building will be refurbished.

The first arguments for refurbishment can be found in the building itself. If the user identifies with his building, he is less likely to demolish it. This especially applies to buildings of a high architectural and functional quality or those, which are occupied by an owner user. Examples are, ‘Mannesmann Tower Düsseldorf’ (see appendix A), the campus buildings of Delft Technical University, and the case studies to be presented in chapter 5. The life cycle of different building components can also be in favour of refurbishment. If technical elements have been renewed in previous building phases only a partial refurbishment is necessary. The same applies for different refurbishment periods for interior finishes and the façade.

The legal status of an existing building has a strong influence on the refurbishment decision. The most obvious reason to preserve a building is its status as a monument. The protection can be limited to certain building parts, the building as a whole, or the neighbourhood. Depending on this, different refurbishment solutions have to deal with the existing edifice. The ‘Ministry of Finance’ in The Hague is a good example for a building which has been considered as culturally valuable. During the refurbishment process only the characteristic
features of the original façade have been preserved. Many parts have been changed or added, so that the refurbished building is a modern interpretation of the original concept. Furthermore, the project has taken the opportunity to improve the urban surrounding by opening the building’s atria to the public (see Appendix A).

The building permit can also be of economic importance. For example, a new building for the ‘Stadtparkasse Düsseldorf’ (appendix A) would not have been permitted the same height and volume as the existing building. Thus, for the building owner and investor, a new building would have reduced the usable and tenable space and thus the profit (Feireiss et al. 2002).

Refurbishment is often more sustainable than new construction. By preserving construction components it reduces material flows. Keeping a company in built-up areas with functional public transport is environmentally friendlier than occupying natural land resources. Such ecological aspects are increasingly part of legislation. On the one hand, countries like the Netherlands and Germany aim to reduce the so-called ‘urban sprawl’. Thus, the redevelopment of inner city

<table>
<thead>
<tr>
<th>Table 2.3</th>
<th>Decisive factors supporting refurbishment instead of replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building imminent factors</strong></td>
<td></td>
</tr>
<tr>
<td>Architectural design</td>
<td>Identification with the building</td>
</tr>
<tr>
<td></td>
<td>Preservation of socio-cultural heritage</td>
</tr>
<tr>
<td>Technical installations</td>
<td>Technical components have not reached the end of life span - due to different replacement intervals</td>
</tr>
<tr>
<td><strong>Legal reasons</strong></td>
<td></td>
</tr>
<tr>
<td>Building permit</td>
<td>New permit would allow less building volume / height</td>
</tr>
<tr>
<td></td>
<td>Prevention of ‘urban sprawl’</td>
</tr>
<tr>
<td>Monumental protection</td>
<td>The building is listed</td>
</tr>
<tr>
<td>Life-Cycle assessment</td>
<td>The EU is aims to impose a life-cycle assessment of building projects - refurbishment would score better thanks to less material consumption</td>
</tr>
<tr>
<td><strong>Economic reasons</strong></td>
<td></td>
</tr>
<tr>
<td>Construction cost</td>
<td>Refurbishment is cheaper</td>
</tr>
<tr>
<td>Construction process</td>
<td>Local situation prohibits demolition</td>
</tr>
<tr>
<td>Operational cost</td>
<td>Interior has been refurbished before and is bound to stay in place (different renovation intervals)</td>
</tr>
<tr>
<td></td>
<td>Wish to keep IT-systems in operation</td>
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<tr>
<td>Relocation cost</td>
<td>Rent for temporary space</td>
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<tr>
<td></td>
<td>Off-time</td>
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<td></td>
<td>Reduced productivity during relocation</td>
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<tr>
<td>Marketing</td>
<td>Sustainability as sales argument</td>
</tr>
<tr>
<td></td>
<td>Users’ representation need</td>
</tr>
<tr>
<td>Financial market</td>
<td>Since 2009 financial crisis, investors are more cautious</td>
</tr>
</tbody>
</table>
locations is supported while new developments in the countryside are made scarce. On the other hand, the European Union is planning to extend the current energy labelling of buildings towards a ‘Life-Cycle-Assessment’ (LCA). It will be easier for refurbishment projects to score in this, than it would be for new constructions, simply because of the reduced material consumption. A good LCA is already today a strong rental argument, as some companies desire to use the ecologic qualities for marketing purposes.

From the financial perspective the refurbishment has to be feasible. This means, refurbishment bears the potential to be cheaper and faster than demolition and new construction. Several aspects are part of such calculation. Among others: the actual construction cost and construction time. Practically, it may be difficult to demolish a building in a built up area, which would cause an expensive or time-consuming building process. The ‘Münchener Rückversicherung’ (appendix A) is an example, in which the limited street space led to the high level of prefabrication of façade parts. Also, the expenses for building operation can not be left out of consideration. Renting intermediate space basically doubles the lease expenses during the building process. Relocating computer installations is considered difficult - and thus expensive. Even more severe, the relocation of staff during the refurbishment causes expenses, such as a loss of productivity because of the off-time for the relocation itself as well as for reduced productivity during the time needed to accustom to the new work space.

A special development can be seen in the investment market since 2007. Before that date, open real-estate funds were extremely well funded and enforced many new developments. Since market saturation for office buildings took place in 2007 and particularly since the economic crisis in 2008, the institutional investors are bound to invest more carefully (Evers et al. 2008). Currently, only prime locations are demanded, tenants request a ‘sustainable’ building, and investors are more critical about the use of their money. Thus, such funds show a bigger interest in refurbishing existing buildings in top locations (IVG 2008). Also, private investors and closed real estate funds show an increased activity in refurbishment. In the current economic crisis a fear of inflation can be noted. This leads to a preference for real estate, which grants a certain safety. Consequently, the value of existing stock rises and more money is available for refurbishment. In the end, an office building is an economical investment. It will only be refurbished, if it promises a financial benefit for the owner.
2.6. Refurbishment strategies in current practice

The previous sections of this chapter have shown the development of office façades from the beginning to the latest innovative façade solutions. Especially in the youngest developments, the importance of combined planning of façade construction and technical building services has become an important issue. In contrast to all new constructions, refurbishment of a building offers different tasks and challenges. In order to develop a systematic for façade refurbishment, it is therefore essential to analyse how present office buildings are currently treated to improve their technical and economical performance.

This chapter takes a closer look at best practise examples for façade refurbishment and introduces proven or innovative solutions. The different refurbishment strategies can be sorted into an overview matrix. Therein, they are separated by the position of the new components in relation to the position of the original façade. The matrix also gives a compact description of the form of intervention, method of construction, and the possible materials to be used. Next to the matrix, this chapter also explains the general features of each strategy with reference to the best practise examples, which can be found in appendix A. Chapter 5 will use this scheme to verify the approaches presented here and to evaluate further refurbishment strategies, which will be developed in the case-study projects. The general applicability of all of these strategies will then be validated in chapter 6.
Table 2.4
Overview of refurbishment strategies in current practice
(Part 1 of 2)

<table>
<thead>
<tr>
<th>Façade Replacement</th>
<th>Curtain wall</th>
<th>Double façade</th>
</tr>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction</th>
<th>Option 1</th>
<th>Construction</th>
<th>Post beam façade</th>
<th>Unitised façade (Box windows / corridor façade / hybrid façade)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Load bearing system</td>
<td>Suspended per floor</td>
<td>Suspended per floor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structural connection</td>
<td>Posts to floors</td>
<td>Units to floors or columns</td>
</tr>
<tr>
<td>Option 2</td>
<td>Construction</td>
<td>Unitised façade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load bearing system</td>
<td>Suspended per floor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural connection</td>
<td>Units to floors or columns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>Construction</td>
<td>Cold-Warm Façade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load bearing system</td>
<td>Stick system suspended per floor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural connection</td>
<td>Posts to floors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cladding material</td>
<td>Glass / metal</td>
<td>Glass / metal</td>
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44
<table>
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<tr>
<th>Additional Exterior Layer</th>
</tr>
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<tbody>
<tr>
<td>Wrap-up</td>
</tr>
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</table>
Table 2.5
Overview of refurbishment strategies in current practise
(Part 2 of 2)

<table>
<thead>
<tr>
<th>Exterior Upgrade</th>
<th>EIFS</th>
<th>Ventilated cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1</strong></td>
<td><strong>C2</strong></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>Construction</td>
<td>Replacement of windows, extra insulation, exterior finishing</td>
</tr>
<tr>
<td>Load bearing system</td>
<td>Planar connection to load bearing wall</td>
<td>Metal framework on existing façade</td>
</tr>
<tr>
<td>Structural connection</td>
<td>Surface-to-surface glued and screwed</td>
<td>Linear or point wise connection to load bearing wall</td>
</tr>
<tr>
<td>Option 2</td>
<td>Construction</td>
<td>Cladding on timber sub structure</td>
</tr>
<tr>
<td>Load bearing system</td>
<td>Timber framework on existing façade</td>
<td></td>
</tr>
<tr>
<td>Structural connection</td>
<td>Linear connection to load bearing wall</td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>Construction</td>
<td></td>
</tr>
<tr>
<td>Load bearing system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural connection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cladding material</td>
<td>Mineral or synthetic plaster</td>
<td>Metal / glass / natural stone / plastic / timber</td>
</tr>
<tr>
<td></td>
<td>Partial replacement</td>
<td>Interior insulation</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>Interior Upgrade</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interior façade</strong> insulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interior layer</strong> insulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-insulated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**C3**
- New filling for post-beam façade
- Interior insulation and finishing, replacement of windows

**D**
- Box windows with insulated new façade inside and original façade as exterior leaf
- Exhaust façade in combination with improved original façade

**E2**
- Existing post-beam structure
- Planar connection to load bearing wall
- Carrying floors / framework

**E1**
- Combined cold-warm façade with new windows
- Existing post-beam structure
- Carrying floors / framework

**Existing connection to floor / column**
- Surface-to-surface glued and screwed
- Units attached to floor / framework
- Units attached to floor / framework

**Metal / glass**
- Plaster / plaster board
- Interior finish
- Interior finish
2.6.1. Façade replacement
The replacement of a façade is by far the most common approach to refurbish an office building. In this case the building is deconstructed to its carcase and entirely rebuilt. Figure 2.32 shows the refurbishment of ‘Mannesmann Tower’ in Düsseldorf. The building is completely renewed with only the load bearing structure kept in place. It is usually chosen for a façade replacement if more features need to be improved than only the building envelope. With the original façade removed, all opportunities are open for a new building skin that complies with all building physical, technical, and design needs. Also the inner layout and the building services can be entirely renewed. Especially curtain wall structures are interesting for replacement, as new façade units can be prefabricated and installed relatively easily. As this method demands the office building to be empty, it is preferably applied, when the building is already vacant, either because of a long-term vacancy or during a change of tenant. Otherwise the occupant and all staff need to be relocated during the building period.

2.6.2. Additional layer outside
A complete replacement often causes a lot of interference with the interior, long construction time, and thus high costs. If technically possible, a second layer can be added to the outside of an existing structure. The dimension of such a structure can range from a few centimetres to several meters. It can cover the entire existing façade, a portion of it with different forms of divisions, or it may span tent-like over several buildings.

The ‘3x-concept’, for example, builds a glass curtain wall around an existing façade. Thus, the technical demands for the original façade are reduced. Wind and rain loads are avoided. In the same way, the sun blinds are protected. The cavity can also be used for an elaborate ventilation concept, taking advantage of the solar gains and thermal air movement. The ‘Stadsparkasse Düsseldorf’ is a good example,

Figure 2.29 Mannesmann tower, Düsseldorf (GER) – exchange of the 1950s façade with new units (above) providing the same look but up-to-date properties, Rhode Kellermann Wawrowsky (RKW 2009)

Figure 2.30 Concept sketch ‘3x’ – A secondary glass façade protects the original façade and provides the space for ventilation components (Evers 2000)

Figure 2.31 Faculty of Architecture, Delft University of Technology, architects: MVRDV and M. Eekhout (2008), Delft (NL), the glass atria cover former courtyards and provide student workspace
in which the double façade is extended over the roof-top to create a protected roof garden.

‘Covering-up’ the entire building in a climate buffer can be seen as a special case. Thanks to the large air volume, this concept creates a subtropical climate with reduced demands on the original façades. The faculty of Architecture at Delft University of Technology has been equipped with two glass atria covering former courtyards. Thus, the surface of the building is reduced and additional working space is generated.

2.6.3. Upgrade outside
If there are no restrictions for the building design, and the original façade provides sufficient structural capacity, the building envelope can be upgraded from the outside. This concept replaces windows and adds insulation and a new cladding. Three concepts are possible:
An ‘Exterior Insulation and Finishing System (EIFS)’ fixes insulation material onto the existing load-bearing wall. This insulation is then coated with mineral or synthetic plaster. A ventilated cladding demands a sub structure and insulation mounted on the original façade. Metal, stone, glass, or other material is used as cladding. A curtain wall can be refurbished by partial replacement of the façade. The carrying sub structure is reused and newly clad with insulated elements and windows.

2.6.4. Upgrade inside
If monumental protection or the structure of the building does not permit changing the exterior impression, an improvement of the interior façade surface has to be considered. The interior insulation is usually combined with new windows and applied to load bearing walls. Generally, this concept holds more technical risks than exterior solutions. The thermal bridges need to be solved and care has to be taken that no condensation occurs in the insulation layer. Particularly the edges of window frames need a sufficient insulation layer to prevent condensation and moulding. A minimal thickness of 50mm has shown to be sufficient (Häupl et al. 2007
Furthermore, humid indoor air must not enter the construction. This is usually done by applying damp proof membranes on the inside of the construction. Adaptable polyamide permit vapour transport dependent on the humidity of the interior ambient air. Thus the structure can also dry out in summer.

Alternatively, a capillary active insulation material can be used without vapour barrier. Calcium silicate plates provide a good u-value and absorb condensate, which may occur in the insulation layer. In warmer conditions the humidity is then rapidly dispersed. Furthermore, the traditional construction with clay plaster is reviving. A thick plaster layer on the room side of the façade insulation absorbs so much humidity from ambient air that it does not reach the insulation.
2.6.5. Additional layer inside
If an office façade is to be improved on the inside, the large amount of glazed parts often asks for solutions beyond an interior insulation and the replacement of windows. Two strategies can be distinguished: The former US Consulate General in Düsseldorf (GER) has been refurbished by improving the performance of the existing façade and adding a non insulated inner layer. Both layers in combination provide the desired performance and function as an exhaust façade. Alternatively, the additional inner layer can be insulated. Thus, the old façade functions as box window. A special solution is the ‘box in a box’. Here, not only the walls but also roof and floor are built in as new constructions. If the load bearing structure and room height permit, this solution thus solves all thermal bridges.

Figure 2.35
Former US Consulate General, architect: Christoph Ingenhoven (1998), Düsseldorf (GER), the original façade together with an additional interior façade pane creates an exhaust façade (photos: H. G. Esch, Hennef)
2.7. Conclusion

Currently, buildings consume 40% of all final energy in Europe. Two thirds of Europe’s non-residential buildings are older than 30 years. These buildings consume more than four times the energy of comparable new constructions. Hence, these buildings hold the potential to significantly reduce the energy consumption and greenhouse-gas emission of the contemporary society.

Furthermore, people spend most of their time inside buildings, which shows that it is very important that buildings have to provide a healthy and liveable surrounding. In the past 50 years architects many different forms of constructions have been used to provide this surrounding, which always followed the actual social, political, or economical ideals. However, as time passes by, the demands and circumstances change and the buildings themselves wear out. Especially the façade and building services reach the end of their technical lifespan after 30 years. Thus, the refurbishment of these components can bring an office building up-to-date again and help to extend its life span.

The planner has to decide, how to deal with these conditions, because in the end every office building is an economical investment. It has to provide a workspace, which facilitates optimal work efficiency, and it represents the exterior image of its user. The better a building can fulfil these tasks; the higher is its value and the rental rate an institutional owner can ask from tenants. The decision whether a building is replaced or refurbished thus depends mainly on the feasibility calculation. Even monuments of a high socio-cultural value demand functions and technical properties that permit a future use. The feasibility estimation of a building project depends on many factors, which investors or owners adjust for each project individually. In order find the optimal solution it is therefore compulsory to define the desired functionality of the building, the technical and design goals, and the acceptable level of interference.

Only if the planner is familiar with the possible refurbishment strategies, he can provide a client with the full range of options which will lead to the optimal refurbishment solution for an individual project. An office façade can be refurbished from the outside or the inside. The possibilities range from small improvements to substantial refurbishment with a replacement of the entire building skin. The analysis of best practise examples has shown that all projects demand individual solutions, which require a very high planning effort.

Currently, most projects are solved, by deconstructing the building to its carcase and rebuilding from this base. Such solution always demands the building to be empty and thus the relocation of the users. If a building is anyway empty during a change of tenant, this may be an efficient option, but owner users and institutional owners would be willing to refurbish many more buildings, if there were
solutions available, which allowed the improvement of building skin and technical installations while the users can stay in the building. Therefore, further solutions beyond a substantial refurbishment must be found.

The case studies to be presented in chapter 5 will try to elaborate some of these solutions. In the first place, the cases will be solved by technically comparable strategies, which can be represented by the scheme above. Furthermore, the case studies will look for refurbishment concepts, which cause a minimal construction time and impact on the interior; and which can be applied keeping the building in use. All of the refurbishment strategies will be evaluated in order to find synergetic effects and economic advantages. Before being able to assess case studies though, there is a need for a thorough market analysis. The following chapter will therefore check the market circumstances in Western Europe and evaluate the actual market volume, as well as the quality and quantity of different existing office façades types.
2.8 References

AGEB (2008). Energieflussbild 2007 für die Bundesrepublik Deutschland. A. Energiebilanzen. Essen, GER.


3. Western European Office Façades – Qualification and Quantification of the Building Stock

The previous chapter has explained the development of office façades in Western Europe in the past 50 years. It has shown which theoretical tendencies formed the framework of architectural development. Furthermore, it explained how office buildings are currently refurbished; and it found out that each individual project demands very much planning effort. The goal of this thesis is to find out, how office façades can be refurbished based on strategic approaches, and how the planning effort can be reduced. To do so, it is essential to elaborate, which types of office façades there are in Western Europe, and how these are distributed across the different countries and eras.

The first section of this chapter analyses the current market situation in Western Europe in general and with a stronger focus on the Netherlands, Germany, and the United Kingdom. These countries have been chosen, because they represent the biggest markets in the same oceanic climate zone. The market analysis uses literature and national statistics in order to evaluate the total stock of buildings and the share of office façades, which are in need for refurbishment. Furthermore, it points out the special market segments and current tendencies in office real-estate for the three different national markets.

The second part of this chapter presents a systematic, which brings the broad variety of possible office façades down to a usable number of 22 types. These types are sorted by the form of their load bearing structure and façade construction. Thus, they represent the qualitative range of this research. The last part of this chapter quantifies these types by local spot checks of important office locations in major cities in the three assessed countries. Thus, those façade types are encountered, which have been most common in different regions and eras. These will be the starting point for the research on case studies to be presented in chapter 5.

3.1. The market for façade refurbishment in Europe

This section analyses the market situation for office refurbishment in Europe. Based on literature studies and own calculations it gives an impression of the total building stock in Europe. It estimates the quantity of buildings and their façades for the five biggest national markets, as well as the percentage of buildings older than 30 years. Furthermore, this section highlights the national market situations in the Netherlands, Germany, and the United Kingdom. The results permit an outlook into the future development of the refurbishment market and form the basis for the following quality assessment of the existing Western European office façades.
3.1.1. The current situation of the European office market

The European office market experienced significant growth from 2005 to 2007. In 2008, the current economic crisis hit the real estate market. Figure 3.1 illustrates the steep increase in office take up in Europe until mid 2007 and the drop in demand in the past year. Consequently, the rental rates levelled out in 2007 and are decreasing since early 2008 (Figure 3.2).

![Figure 3.1](image1.png)

**Figure 3.1**
European Office take up index (PNB Paribas Real Estate 2009)

![Figure 3.2](image2.png)

**Figure 3.2**
Development of the European rent index (PNB Paribas Real Estate 2009)

While these indices give a global impression of the European market in general, a closer look at national markets shows that the situation differs between countries. Figure 3.3 shows the prime rents and vacancy rates of the most important European office locations. Dutch prime rents stayed at the same level between 200€/m²/a (The Hague) and 370€/m²/a (Amsterdam). In The Hague the vacancy rate has risen strongly. Amsterdam already suffered from a high vacancy rate before the crisis.
and has now reached the highest vacancy rate in Europe. Germany has not been hit by the crisis in the end of 2008. The situation is expected to worsen in 2010. The figure also shows impressively how the economic crisis hit the former speculative markets. Vacancy rates have reached unprecedented heights in Spain, Greece, Russia, and Ukraine. It also illustrates that British office tenants fled from central London, with Europe’s highest rents, to the new developments in Thames Valley. While in London the top rents decreased and the vacancy rate to 7.5%, the vacancy rate in Thames Valley decreased slightly.

Real-estate companies expect a revision of rental rates in the coming months. The ‘Office Clock’ by Jones-Lang-LaSalle for the first quarter of 2009 (Figure 3.4) sees all European locations in the top right quadrant, which means that rents are expected to fall in the future. The drop in demand is owed to collapses of companies and a decrease in employment. Companies renting new offices can thus demand lower rents for their desired quality of space. This will lead to higher vacancy in less popular locations and a redirection towards the best locations (Jones Lang LaSalle 2008).
3.1.2. Volume of the European office market
Research has shown that reliable data on the building stock in Europe, both on construction period and on construction type, is very scarce. The treatment of statistical data differs from country to country. Some countries, like Switzerland and Sweden, keep up-to-date statistics. Other countries (Italy, Spain) supply old statistics that have been discontinued. Again others (Germany) have only recently started to keep track on the building process in the field of non-residential buildings (Hoffmann 2006). Several different studies on the building stock in Europe have been realised. Due to methods of counting and estimations, all of these studies deliver different figures. The study by C. Hoffmann (2006) tries to unify those results and gives an overview of the estimated building stock. Based on her results, this section estimates volume of office façades in need for refurbishment.

3.1.2.1. Building stock per 2005
The most important source of data can be found in the ‘Europarc-Survey’, in which research institutes in the five biggest Western European Countries - Germany, France, Italy, Spain and Great Britain - estimate the stock of office buildings in these countries per 01.01.1998 based on matched figures. Results of this study were published by the IFO institute in 1999. According to this publication, the total building stock excluding agricultural constructions in the five countries mentioned above sums up to 16 to 17 billion m² net occupiable floor area (NOA). Figure 3.5 gives an overview of the distribution of NOA for the total building stock per country (Russig 1999). Non-residential buildings cover roughly one third of this sum. In Spain the relation residential / non-residential equals 70/30; in Germany the ratio is 62/38. In Russig’s study the term ‘non-residential building” covers all buildings of non-residential use and excludes agricultural buildings. Therefore it includes buildings for education, health-care, trade and production (Russig 1999).

![Estimated total building stock in Europe per 01.01.1998 [mio m²]](image)

Figure 3.5
Estimated total building stock (NOA) per 01.01.1998 [million m²]
(Russig 1999)
3.1.2.2. Building stock older than 1979
The Europarc-survey further divides the European building stock into two age groups: ‘Built before 01.01.1978’; and ‘Built between 01.01.1978 and 01.01.1998’. Figure 3.6, published by Russig (1999), shows that in 1998 two thirds of the office stock were older than 20 years. Italy, Germany, and the UK hold a larger share of old buildings than France and Spain, where the building boom started later than in the other countries.

![Figure 3.6 Percentage of non-residential real-estate built before 1978 (Russig 1999)](image)

3.1.2.3. The total stock of office buildings
In order to find out the actual stock of office buildings within the group of ‘non-residential buildings’ a closer look at national statistics is necessary. As Germany represents almost one third of the Europarc-survey it was recommendable to achieve more information on this market. The data for new construction in Germany is available for the time period from 1980 to 2007. In this period the relation of ‘office and administration buildings’ to ‘non-residential buildings excluding agriculture’ equalled approximately 16% (Statistisches Bundesamt 2007). For this study, this relation is used to get a rough estimation of the existing office stock.

Next to the office space, it has been particularly interesting to achieve an approximation of the existing façade surface. The market scan, to be presented later in this chapter, has analysed 600 buildings in the Netherlands, Germany, and the United Kingdom with a total GFA of 4.6*10⁶ m² and has delivered an average relation of GFA to façade surface of 55%. For the desired rough approximation of the office stock, this figure shall be used. The overview in Table 3.1 shows that per 01.01.1998 the five biggest European countries provide a stock of office buildings of roughly 916*10⁶ m² NLA. This represents a façade surface of approximately 788*10⁶m². Per 1998 it shows that around 2/3 of the existing building stock in the assessed countries was constructed before 1978. For the office market this equals 604*10⁶ m² NLA (933*10⁶ m²GFA). The façade surface of office buildings, constructed before 1978, sums up to 510*10⁶m².
Table 3.1
Stock of office and administration buildings in Wester

<table>
<thead>
<tr>
<th>Country</th>
<th>all buildings excl. Agriculture **)</th>
<th>non-residential excl. Agriculture ***</th>
<th>office- and administration *****)</th>
</tr>
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<tbody>
<tr>
<td>Italy</td>
<td>NLA [million m²]</td>
<td>NLA [million m²]</td>
<td>NLA [million m²]</td>
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<tr>
<td></td>
<td>total 1998</td>
<td>3.500</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>before 1978 70%</td>
<td>2.450</td>
<td>809</td>
</tr>
<tr>
<td>Germany</td>
<td>total 1998</td>
<td>5.000</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>before 1978 67%</td>
<td>3.350</td>
<td>1.273</td>
</tr>
<tr>
<td>Great Britain</td>
<td>total 1998</td>
<td>2.800</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>before 1978 67%</td>
<td>1.876</td>
<td>619</td>
</tr>
<tr>
<td>Spain</td>
<td>total 1998</td>
<td>1.800</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>before 1978 64%</td>
<td>1.152</td>
<td>380</td>
</tr>
<tr>
<td>France</td>
<td>total 1998</td>
<td>3.500</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>before 1978 60%</td>
<td>2.100</td>
<td>693</td>
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<tr>
<td>Total</td>
<td>total 1998</td>
<td>16.600</td>
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</tr>
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<td>before 1978</td>
<td>10.928</td>
<td>3.774</td>
</tr>
</tbody>
</table>

*) Source: (Russig 1999)  
**) includes: All building stock, excludes agricultural buildings  
*****) includes: All building stock, excludes agricultural buildings and residential buildings  
******) includes: Only office- and administration buildings  
******) Relation GFA/façade area: Estimation based on market survey by TU Delft

3.2. The office market in the Netherlands

There are no official statistics on the stock of offices in the Netherlands. The most reliable sources are the annually produced reports by realtors and real estate consultants. Of these reports 'Kantoren in cijfers' by R.L. Bak of CB Richard Ellis is the one most used and quoted (Bak 2005; Bak 2006). However, the data only takes into account offices larger than 500 m² and does not include municipalities with less than 10,000 m² of office space. Offices smaller than 500 m² are mostly located in office villas and town houses, which are not part of the scope of this research for façade refurbishment, because these inner city buildings were usually built before. Furthermore, the data only includes solitary office buildings and does not count office space within industrial buildings, hospitals and universities. University buildings are, however, an interesting option for façade refurbishment. The report by Heijer (2007) contains a detailed survey of the University building stock in the Netherlands (Heijer 2007).
3.2.1. Development of the Dutch office stock
In the period immediately after WWII the main focus lay on rebuilding residential buildings and industrial plants. Offices were increasingly built since the early 1960s. In this time also new types like the multi-tenanted business complex were introduced. Business organisations requested premises that allowed flexible use and easy relocation. For the same reasons, renting became the favourite form of ownership. The 1960s also were the period, when real-estate became an important field for investors (Voort et al. 2007). Due to the economic downturn in the late 1970’s, caused by the oil-crises, building production was reduced. In the late 1980’s the economy recovered. By 1985 the office stock consisted of approximately $21.6*10^6 \text{ m}^2$. In the following years the building economy in the Netherlands experienced two major peaks of production. Within 20 years the office stock doubled. Figure 3.7 shows the development of the building production and the rental take-up in relation to the GDP growth.

![Figure 3.7](image)

Rental take-up and new construction in relation to economic (GDP) growth (Zuidema 2006)

Building production is directly linked to the economic growth. Due to preparation and construction time the peaks in building production occur about two years after the peaks in economic growth. This makes it difficult to match the demand and the supply of office space. In periods of economic prosperity a lot of office buildings are developed, when the buildings are actually finished the economy may already be declining again, the demand decreasing. From 1989 to 1991 there has been a peak in production of office space. The building production decreased between 1991 and 1993, but the rental take-up stayed on a high level. Over the period of six years the take-up levelled out the reduced production. Offices were rented off stock.

In 2000 the building market saw a new peak of production and take-up. As the graph shows, the overall economy (GDP) did not improve as much as the building sector. In this period a lot of real estate has been developed by property developers on their own risk. Particularly in the Netherlands, new construction of office buildings was often funded by
international real-estate funds, which were bound to spend investors’ money (Willmes 2008). The effect of this ‘real-estate-bubble’ can be seen in 2000 and 2001. When the GDP declined the rental take up broke off, and successively the building production collapsed.

Until 2008, the office market improved slightly. The demand for office space grew, especially in the top segment of the market. This has increased the market dynamics and some municipalities have shown a substantial take-up. However the overall situation could not be stabilised. Relocating companies rent less space than before and leave old, vacant buildings behind. Of the $5.7*10^6 \text{ m}^2_{UA}$ of vacant office space in 2006, $5.3*10^6 \text{ m}^2$ had been vacant for more than three years. Especially buildings with lower standards, situated in less attractive locations, are difficult to let (DTZ Zadelhoff 2006). In 2008 the total office stock in the Netherlands, as defined above, summed up to $46.2*10^6 \text{ m}^2_{UA}$, which resembles $54.2*10^6 \text{ m}^2_{GFA}$. Only $40.2*10^6 \text{ m}^2_{UA}$ of this stock are in use. The national vacancy rate equals 12% (DTZ Zadelhoff 2009) and is expected to rise in 2009 in relation to the current economic crisis.

![Graph showing office stock and stock in use (1000 m$^3$LFA)](image)

3.2.2. Amount of buildings built before 1985

Bak (2006) has done an inventory of the Dutch office stock for the year 1985, which is a useful separation to define buildings that are potentially in need for refurbishment. In 1985 the office stock consisted of approximately $21.6*10^6 \text{ m}^2_{UA}$. Since then the annual deductions and newly built offices are known. Assuming that the deductions rather applied to the older buildings, one can estimate the amount of office space built before 1985, which is still present today. The deductions of the office stock since 1985 sum up to $3.2*10^6 \text{ m}^2$ (Bak 2006). The remaining stock of offices built before 1985 is then approximately $18.4*10^6 \text{ m}^2_{UA}$, or $21.6*10^6 \text{ m}^2_{GFA}$ which represents 42% of the total office stock in 2005 (van Sabben 2008). It is interesting to see that this
relation of 42% differs strongly from the other countries mentioned previously. This is due to the special situation in the Netherlands, where office stock doubled between 1985 and 2005. Other countries did not see this enormous building activity. But, this peak of production will be due for refurbishment soon too. By the year 2015, the percentage of buildings, older than 20 years, will be 59%.

3.2.3. Tasks in the Dutch office market
In order to determine the future development of the Dutch office market, several research projects have been carried out. The most important project, ‘De vraag naar kantoren tot 2015’, was published by the Economic Institute for the Construction Industry. According to this publication the demand for office space is influenced by four factors: the replacement demand, the demand for expansion, the conversion into office jobs, and the average use of office space (Zuidema 2006). Based on the development from 1990 to 2004 Zuidema predicts the demand for office space until 2015. The estimation takes into account four different economic scenarios, which have been set up by the ‘Dutch Central Planning Office’ and depend on the rate of internationalisation and the reformation of the public sector. The average use of space per person is independent of the different economic scenarios. Therefore, the scenarios mainly respond to economic development and the change of the working world towards the tertiary sector.

Zuidema forecasts that the demand for office space will grow until 2015. Depending on the economic growth, the office stock will increase by approximately $6\times10^6\text{ m}^2_{\text{GFA}}$ to $9\times10^6\text{ m}^2_{\text{GFA}}$ to $62\times10^6\text{ m}^2_{\text{GFA}}$. In 2015 the Dutch office stock will be $59\times10^6\text{ m}^2_{\text{GFA}}$ to $62\times10^6\text{ m}^2_{\text{GFA}}$. To reach this level, the demand for replacement holds the biggest share in this estimation. It is expected that till 2015 between 5.9M and 9.3*$10^6\text{ m}^2_{\text{NFA}}$ will need to be replaced. Of course, today non-one can predict if one of these scenarios will become reality, but nevertheless, it is interesting to see that even the worst estimation delivers a need for refurbishment of almost $6\times10^6\text{ m}^2_{\text{GFA}}$ in the Netherlands.

3.2.3.1. Vacancy
Vacancy of office buildings is the major problem in the current Dutch market. A vacancy rate of 5% is required for a healthy market situation, in order to allow fluctuation (Voort et al. 2007). Only if a building is vacant for more than three years, it is considered as ‘structurally vacant’. Since 2001 the vacancy rate in the Netherlands has continuously been 12-13 %, which equals $6\times10^6\text{ m}^2_{\text{GFA}}$. Deducting the positive estimation of 5% of ‘normal vacancy’ still leaves a market volume of $3.6\times10^6\text{ m}^2_{\text{NFA}}$, which are currently impossible to rent out.

Vacancy is not distributed evenly. Figure 3.9 shows that most vacancy (up to 30%) can be found in the smaller municipalities surrounding the big cities of the Randstad, e.g. Alphen aan de Rijn, Diemen and Gouda. These places were developed as satellite towns for the big cities in the 1980s and early 1990s. Dynamis has concluded that especially
the architectural image, a poor interior quality, lack of flexibility, and an unattractive urban surrounding are the main reasons for property to become untenantable (Dynamis 2008). This also explains the high vacancy rate of Amsterdam, because there are many office parks in the city’s outskirts, which were developed since the late 1970s.

Nevertheless, while the economy was prospering, investors did not consider vacancy to be an urgent problem. The return on investment of rented properties still made up for the (partially) vacant real-estate. The government did not see vacancy as a serious social problem either, since there were no unsafe situations or unwanted use (van Sabben 2008). Only since 2007, a change in public perception is taking place. The negative influence of empty office space on the surroundings is not considered acceptable any more. This has stimulated research on the transformation-potential and opens opportunities to refurbishment.

Figure 3.9
Vacancy per municipality (DTZ Zadelhoff 2009)
3.2.3.2. Fluctuation
In the future, companies are expected to sign shorter rental contracts and to relocate more often. This is also supported by the big availability of office stock in the Netherlands. This fluctuation creates a bigger demand for high-quality and easily adaptable office space. A term often used in relation to high quality office space is ‘grade A’. For the Netherlands it is expected that unless an office building is rated ‘grade-A”, it will not be lettable (Huizinga 2006).

3.2.3.3. Energy Saving
By 2020 the Dutch government aims to achieve an annual reduction of energy consumption of 20%, an increase in the amount of renewable energy of 20% and a reduction of greenhouse gasses by 30%, compared to the base year of 1990 (Government of the Netherlands 2008). Since January 2008 dwellings, which are built or rented, need to have an energy-performance coding that makes it easier to compare their energy demand. It is expected that such ‘energy passport’ will also be introduced for non-residential buildings in the near future. This legislation in combination with the rising energy prices already has an influence on users’ demands from their buildings. It is expected that they will also influence future constructions and the treatment of the existing building stock.

3.2.3.4. Transformation of office buildings to dwellings
Currently, various government programs are stimulating the transformation of office buildings to dwellings in order to overcome the problem of structural vacancy of office buildings and the severe shortage of affordable housing. However, DTZ Zadelhoff has calculated that only a very small share of the office market comes into question for transformation.

They estimated the structurally vacant office space as to be 15% of the supply or 1.2*10^6 m²Ơ. Buildings constructed in the period of 1945 to 1990 are considered the most problematic part of the supply and therefore the most interesting for transformation. These buildings make out 700,000 m²Ơ of the structural vacancy (DTZ Zadelhoff 2006). For successful transformation, an office building has to be completely empty. If a building is not empty for more than 50%, transformation is considered too expensive, as the remaining tenants need to be bought out. This division leaves only 470,000 m²Ơ of structurally vacant office space, 5% of the supply. As shown above, most of the vacant office space is located in non-functional business parks. These locations are not interesting for residential use, because they lack the necessary infrastructure for a liveable surrounding and are often located close to major highways. This definition leaves only the very small market share of old, empty offices in liveable surroundings as candidates for transformation.

The DTZ-study did not consider the building physical aspects of office buildings, which often do not allow a residential use because
the necessary sound insulation cannot not be realised. All these aspects minimise the amount of offices suitable for transformation. Therefore, the transformation of offices to dwellings or other functions is no solution for the high vacancy in the Netherlands (Huizinga 2006). Further solutions are needed to solve the current problems.

3.2.4. Special market sections

3.2.4.1. Universities
The buildings used by universities often resemble office buildings. Therefore, the real estate of universities in the Netherlands is included in this research. According to den Heijer’s publication ‘Universiteitsvestiging in Nederland’ the total amount of university buildings in the Netherlands (per 2006) sums up to 4.5*10⁶ m² GFA. The highest production of university buildings took place in the 1960s and 1970s with an average addition of 1.1*10⁶ m² GFA per decade. The universities with the biggest building portfolio from the 1960s and 1970s are Delft University of Technology (320,000 m² GFA), Amsterdam-VU University (291,000 m² GFA) and the University of Utrecht (267,000 m² GFA). Today 62% of all Dutch university buildings originate from the time before 1980 and 76% were constructed before 1990 (Heijer 2007). Table 2.6.1 gives an overview of the construction periods of Dutch universities.

3.2.4.2. Governmental property
The Dutch government occupies approximately 11% of the entire national office stock. In 2009 it has decided that from 2010 only those buildings shall be rented, which score ‘C’ or better in the national energy labelling system. Currently two thirds of the stock in use does not fulfil
this demand. These buildings shall be brought to the same level as soon as possible. The municipalities agreed to follow this example and improve their stock to the same level by 2015. Consequently, the real estate developers are going to refurbish the buildings they let to the government, because it is improbable that they risk losing such reliable tenant (Senter Novem 2009).

3.2.5. Conclusion for the Dutch market and potential for refurbishment

In 2009 the Netherlands provide an office stock of $46.2 \times 10^6 \text{ m}^2_{\text{GFA}}$ which equals $54.2 \times 10^6 \text{ m}^2_{\text{GFA}}$. More than 40% of this stock is currently older than 20 years, which equals more than $20 \times 10^6 \text{ m}^2_{\text{GFA}}$. Additionally the Netherlands hold a stock of roughly $4.5 \times 10^6 \text{ m}^2_{\text{GFA}}$ of university buildings. 62% $(2.8 \times 10^6 \text{ m}^2_{\text{GFA}})$ of these were built before 1980. According to the Economic Institute for the Construction Industry the office stock is expected to grow by $6M - 9 \times 10^6 \text{ m}^2$ and will sum up to approximately $60 \times 10^6 \text{ m}^2_{\text{GFA}}$ in 2015. As the biggest peak in office production took place in the 1980s, the amount of buildings older than 20 years will grow from 42% to 59% within the next five years. Until 2015 there will also be a replacement demand of approximately $8.5 \times 10^6 \text{ m}^2_{\text{GFA}}$.

The biggest problem of the Dutch real-estate market is vacancy. If the building industry continues with new construction as in the previous decade, the vacancy rate will remain at the current level of 12%. But, if many tenants move to new premises, the amount of structurally vacant office space in the older buildings will grow and the relative quality of the office stock will decrease. With a high demand for ‘Grade-A’ office space it will become more difficult to rent out older office buildings.

Due to the introduction of stricter European legislation and rising energy prices the energy saving performance of building envelopes will have to improve. This means that the existing stock of old office buildings will have to be upgraded to stay useful and lettable. The Dutch government wants to be the best example. Two thirds of their buildings, 7.5% of the total national stock, will therefore be renovated in the near future.

In the Dutch market situation the refurbishment of offices can solve many of the current problems, such as oversupply, vacancy, and the social problems of redundant office parks. However, refurbishment has to focus on three special tasks: The planning will have to provide grade-A office space in retrofitted existing buildings in order to reduce the vacancy in valuable locations. The refurbishment will have to create energy-efficient buildings in the built up environment, which are attractive for users and investors. And refurbishment planning should aim to prevent excessive development of new buildings in unattractive locations, as there already is an enormously high rate of structural vacancy in office parks with many buildings that have no future, neither as offices nor by transformation.
3.3. The office market in Germany

The German market provides a historical specialty. Due to the separation of Western Germany and the former German Democratic Republic (GDR), the two building markets developed in totally different ways. This resulted in different statistical data as well as different building types and market situations. In 1950 the last count on building stock took place in Western Germany. This survey only counted the number of buildings and made a rough separation into residential and non-residential buildings. It did not deliver any information on size or use of buildings. (Russig 1999) The German Federal Statistical Office began collection of data on new construction and demolition for Western Germany in 1970. For the territory of the former German Democratic Republic (GDR) it provides data for the time since 1993. Figures can be taken as reliable for these periods. Further information on the development of office space has therefore been gathered from research reports and market surveys published by real-estate companies.

3.3.1. Development of the German office stock

3.3.1.1. Historic development
From 1945 to 1948 the main focus in Germany, as in many other countries, lay on ‘cleaning out’ of city centres from debris, and on fulfilling the urgent need of temporary housing. Parallel first ideas and visions of different ideals for the new City centres were developed. In 1957 US Secretary of state Marshall proposed an intensive program for reconstruction in Europe (Marshall Plan), which aimed to reactivate the German economy, industry and administration. This led to the first peak of economic growth: In 1955 the increase of GNP reached 12%. By the end of the 1950s, 2/3 of the inner city centres had been rebuilt and cities expanded into their outskirts (Dorsemagen 2004). In the 1970s most offices were constructed in the outskirts. Since the 1990s we experience a return of offices to the city centres.

Figure 3.11 shows new construction of office- and administration buildings in Germany from 1970 to 2006 in relation to the annual growth of the gross domestic product (GDP). It clearly shows how building production follows the economic development with a delay of approximately two years. This is obviously due to the long planning and construction time of buildings. The graph clearly shows the effect of the first oil crisis in 1973 on building production by the downturn of production in 1975. The effect of rising prices after the second oil crisis in 1979 is also visible by stagnation in building productivity throughout the 1980s. The German reunification in 1990 gave the building economy an enormous push. Since 1992 statistics count Berlin to Eastern Germany. Hence, it is obvious that the territory of former Eastern Germany received the biggest attention. The post reunification development activity proceeded till the early 2000s when the market was (over-) saturated. The German building industry slightly recovered.
from 2004 to 2006. Since 2007 there is no data on building production available yet. But, the decrease in GDP already indicated the upcoming economic crisis.

3.3.1.2. Office stock per 2006
Russig (1999) mentions a total building stock, excluding agricultural buildings, in Germany of $5.0 \times 10^9 \text{ m}^2_{\text{NOA}}$. According to the same study roughly 38% of these buildings are non residential buildings, which delivers a building stock of $1.9 \times 10^9 \text{ m}^2_{\text{NOA}}$ for Germany (Western Germany and former GDR) per 01.01.1998. A different estimation of the building stock can be found in report WB 72/1992 by Fraunhofer Institute. This estimates for 1992 a building stock of $1.15 \times 10^9 \text{ m}^2_{\text{NOA}}$ of non residential buildings (excluding agriculture) for the territory of former Western Germany (Erhorn et al. 1992). Figures of the two studies differ due to two reasons: Erhorn (1992) only refers to the territory of former Western Germany. And, the main building activity between 1992 and 1999 took place in the territory of the former GDR. Hoffmann (2006) agrees to take the total figure of $1.9bn \text{ m}^2_{\text{NOA}}$ for non residential buildings per 01.01.1998 in Germany as plausible.

The German Federal Statistical Office separates non-residential buildings into different groups, one of which is ‘office and administration buildings’. There is detailed data available for the building activity (new construction and demolition) since 1980. Based on this data Erhorn (1992) calculates a building stock of office and administration buildings of $205.3 \times 10^9 \text{ m}^2_{\text{NOA}}$ per 1992 for Western Germany. This sum is composed of $79.3 \times 10^9 \text{ m}^2$ of pure office buildings and $126 \times 10^9 \text{ m}^2$ of office space in buildings with mixed uses (Erhorn et al. 1992). Using the
latest data provided by the German Statistical Office, the total stock of office and administration buildings in Western Germany and West Berlin can be estimated to be $250\times10^6\ m^2_{\text{NOA}}$, which equals $380\times10^6\ m^2_{\text{GFA}}$. The total stock of these buildings in Germany including the territory of the former GDR sums up to approximately $304\times10^6\ m^2_{\text{NOA}}$ ($461\times10^6\ m^2_{\text{GFA}}$)

3.3.2. Amount of buildings built before 1978

The two available studies of the German office stock deliver slightly different estimations for the distribution of buildings into age groups. Erhorn (1992) divides the stock of office buildings in Former Western Germany and West Berlin per ultimo 1992 into three age groups:

- older than 1951: 55%
- 1952 to 1977: 35%
- 1977 till 1992: 10%

Presuming that demolition rather applies to older buildings and taking the actual building production and demolition into account we can conclude that per 2006 71% of the stock of office and administration buildings in Western Germany and West Berlin were constructed before 1977 and 79% were built before 1993.

Russig (1999) estimates for 1998 a relation of 67% of non-residential buildings that were built before 1978 (Russig 1999). Carrying this figure further with actual data, we find that in 2006 60% of the buildings were constructed before 1978, and 30% were built between 1978 and 1998. There are three main reasons for differences between the two studies:

- Russig (1999) covers both Western Germany and the former GDR
- There was a major peak in building production in Eastern Germany after the German reunification, between 1992 and 1998. In this period many buildings were demolished and replaced particularly in Eastern Germany.

It can be concluded that in 2006 between 60% and 70% of the German office building stock was constructed before 1978. In Western Germany the relation is higher than in Eastern Germany. For Germany this figure equals a stock between $180\times10^6$ and $200\times10^6\ m^2_{\text{NOA}}$ ($275-305\times10^6\ m^2_{\text{GFA}}$) that was erected before 1978.

3.3.3. Tasks in the German office market

In the German market, a very large building stock has accumulated, which is in need for refurbishment. Looking at the building activity in the past 38 years (Figure 3.11) we can see that between 1978 and 1990 the production of office buildings levelled around $2.5\times10^6\ m^2_{\text{NOA}}/a$. In the time after the German reunification, the building economy reached a peak production of $7\times10^6\ m^2_{\text{NOA}}/a$. Since 2006 it has returned to the
level of 1990. This reduction frees a working capacity of approximately $5 \times 10^6$ m$^2_{NOA}$ per year. Seeing, that $180 \times 10^6$ m$^2_{NOA}$ are in need of refurbishment today, the building industry would be occupied for 36 years to improve these buildings. The situation will worsen in the future. From 2020 onwards, all post-reunification buildings will reach the end of their technical lifespan. This means that between 2020 and 2036 approximately $85 \times 10^6$ m$^2_{NOA}$ ($130 \times 10^6$ m$^2_{GFA}$) will add onto the stock of buildings that demand to be refurbished.

3.3.3.1. Economic and market situation
The German office market is very volatile. After the German reunification an enormous boom in building production and demand took place. This consequently led to market saturation in the early 2000s and a decrease in rental activity and rental rates till 2004. In 2005 the situation started to improve. The market survey by DTZ Zadelhoff from 2005 showed that an oversupply of office space was expected for non-central areas of most cities. The most severe oversupply in central locations was expected in Berlin, Frankfurt, Leipzig, and Dresden. This was mainly owed to the enormous building activity in Eastern Germany after the reunification. For locations like Stuttgart, Essen, Hamburg, and Düsseldorf DTZ saw no risk of oversupply (DTZ Research 2005).

Since 2006 the turnover is increasing. 2006 saw an increase of 17% and a decrease of total available stock by 2%. In early 2008 Atisreal still considers the office market to be improving. For prime locations they expect a decrease of vacancy and even a shortage of modern office space in some locations. The rental rates for modern units were expected to rise in 2008 (Atisreal 2008). However, since 2008 the German office market struggles with the consequences of the international financial crisis. Mainly financial institutions have to set free staff. This effect consequently mainly hits the financial capitals (Haimann 2008). It is expected that particularly the city of Frankfurt will see an increase in vacancy and a decrease in rental rates.

3.3.3.2. Vacancy
While the total stock of vacant office space decreased in 2006 and 2007, the vacant stock of un-refurbished space increased in 2006 by 11% and in 2007 by another 10%. This shows that only up-to-date space is possible to be rented, while un-refurbished space is threatened to become structurally vacant (Schnittler 2007). In the major cities Berlin, Düsseldorf, Essen, Frankfurt, Hamburg, Cologne, Leipzig, Munich, and Stuttgart the vacancy sums up to roughly 9 billion m$^2_{GFA}$ (2008). Of this figure, 1 billion m$^2_{GFA}$ is located in un-refurbished office buildings and considered to be difficult to let (Atisreal 2008).
3.3.4. Special market sections

3.3.4.1. The former German Democratic Republic

The refurbishment market for office buildings on the territory of the former German Democratic Republic is totally different than in the other countries treated in this research project. The entire building process in the former GDR was characterised by centrally controlled industry and design. The ‘Deutsche Bauakademie’ in Berlin was responsible for the development of building systems and standardisation. In this process, the main point of focus lay in the development of building systems with a minimised use of material.

Basically all office and administration buildings in the former GDR were constructed with a very limited number of pre-fabricated systems. On the contrary to residential buildings, which were built of pre-cast concrete slabs, the so-called ‘industrial buildings’ were commonly made of skeleton structures. Until the 1960s there had been different building systems available that were mainly based on Russian post-war constructions. In the early 1970s two standardised systems were presented:

- ‘SK Berlin 72’ by ‘Bau- und Montagekombinat Ingenieurbau Berlin’ was a concrete skeleton structure-system with pre-fabricated load bearing columns and beams, and non-load bearing wall and floor slabs.
- ‘Universalschalsystem US 72’ was a standardised ‘Universal Sheeting System’ for on-site construction.

Shortly after this, a forced development towards an even more standardised and economical pre-fabrication was initiated, aiming for one system to be used for all industrial building tasks. This led to so-called ‘VGB - Vereinheitlichter Geschossbau’ (Uniformed Construction) by ‘VEB Betonleichtbaukombinat’. This system related to SK72 but reduced the number of components further and provided standardised connections. Different grids and heights were only possible within this system.

The next step of development took place in the late 1970s and early 1980s. The VGB was developed further towards the so-called ‘Skelettbau system SKBS 75’ (skeleton building system 75). By further reduction of the number of components one could minimise the use of material and create a better compatibility with the standard wall elements of the residential building systems. Components of the metal skeleton building system ‘MLK - Modern Leicht Komplett’ by ‘VEB Metallleichtbaukombinat’ could be integrated too.

In the first place, the buildings of the GDR were supposed to be functional. The building systems and the scarceness of material and funds limited design possibilities. This was also rectified with the socialistic philosophy that every person should be given a building of the same quality and design. For the façades of office buildings this
meant that the design freedom was basically limited to the dimension of windows in prefabricated concrete façade units. Figure 3.12 shows three façade examples as they were propagated in the standard design handbook.

All these building systems have in common, that the structural grid, and most importantly, the floor height restrict the flexibility of refurbishment. The consequent reduction of material use results in a doubtful quality of construction, which leads to structural and functional restrictions, namely the load bearing capacity and the sound insulation properties. Furthermore, only little is known about the use of toxic materials in these constructions. For example, PCB and asbestos have been widely used in pre-fabricated buildings all across Europe until the 1970s, but only in the GDR they have been kept in use until the end of the 1980s. This situation often results in unexpected additional costs during the refurbishment process, which many investors are not willing risk.
The user’s point of view provides another major restriction for the future use of these buildings. The experience has shown that prefabricated concrete buildings are not accepted in Germany and are not considered valuable, because people associate these with the poor quality and state of maintenance in a socialist regime. After the German reunification an oversupply of office buildings has been built in Eastern Germany. As long as many newer buildings are vacant, there is no need to bother about the former GDR buildings. There have been a few proposals of how to deal with the existing office building stock of the former GDR. But, these have only been very special solutions such as the transformation into hotels or the reuse of building elements for new constructions. The office-buildings themselves are currently not marketable. This situation is very unlikely to change, as the population, particularly in the eastern parts of Germany is decreasing. There will be hardly any need for refurbishment of these buildings.

Figure 3.13
Examples of façade design taken from a construction handbook (Schmidt, Kraft et al. 1961)

Figure 3.14
Universities in Germany - the necessary investment estimated by the scientific council (black) in comparison to the funds provided by the federal or state-governments (BWI-Bau 2005)
3.3.4.2. Universities
University education became increasingly attractive to all social classes after WWII. Particularly the structural changes in the 1960s, when the mining industry declined and the economy decided to shift to the tertiary sector, led to an enormous development of new university campuses. The peak production of university buildings took place in the late 1960s and 1970s. University compounds such as Bochum and Bielefeld are major examples. Today many of these university campuses are in need for refurbishment. Statistics by BWI Bau (Betriebswirtschaftliches Institut der Bauindustrie) compare the estimated need for investment in university buildings to the actual investment. Figure 3.13 shows clearly that for the past 13 years the investment did not reach the estimated need. The German Rectors’ Conference amounts the total demand for refurbishment of Universities to at least 25*10^9 € (German Rectors’ Conference 2009). Consequently, there is an enormous need for economic refurbishment strategies. (I-Bau 2005)

3.3.4.3. Municipal properties
BWI Bau also estimated the need for investment in other public buildings such as schools, administration buildings and infrastructure. For the period 2000-2009 they estimated an investment-need for new construction and/or refurbishment of 60*10^9 € for school buildings and 21*10^9 € for administration buildings. These figures give an impression of the volume of existing buildings and, more important, their urgent need for refurbishment (BWI-Bau 2005).

Figure 3.15
The investment demand for German municipal property between 2000 and 2009 (BWI-Bau 2005)
3.3.5. Conclusion for the German market and potential for refurbishment

Germany provides a stock of office buildings of roughly 304 million m² NOA (461*10⁶ m² GFA). Approximately 2/3 of this stock, or almost 200 million m² NOA (300*10⁶ m² GFA), are older than 30 years. The peak production of the period 1990-2006 will reach the end of their technical lifespan between 2020 and 2035. In this time, another 85*10⁶ m² NOA (130*10⁶ m² GFA) will enter the market for refurbishment.

Currently the German office market still sees an increase in demand in the major economic locations in Western Germany. In prime locations there is a shortage of modern office space. On the other hand, there is much vacancy of non-refurbished office buildings in the same spots. For these prime locations the market demands refurbishment strategies that can provide the desired high-standard office space in a short time-span. The second refurbishment task is to prevent occupied buildings from becoming vacant. Hence, these offices must be upgraded while they are in use.

Currently, the political situation in Germany is supporting refurbishment planning. Owners are requested to invest in the building stock and refurbishment projects are subsidised. For example, landlords have to provide an energy-consumption certificate for their building to allow potential tenants to compare alternatives. The state-owned German bank KfW offers loans at very good conditions, if the building owner can validate the energetic improvement of a building by refurbishment.

The office stock in Eastern Germany provides special tasks. There is an overall stock of 60*10⁶ m² NOA (90*10⁶ m² GFA) with a very different quality and age structure. On the one hand there was an enormous activity of demolition of old stock and construction of modern office space in the city centres after the reunification in 1990. On the other hand, there still is a very big stock of office buildings from the former GDR. Almost all of these building are constructed of an industrialised building system that is based on 1960s technology and standards. For these buildings, no economic future is visible, as all the profitable office locations have been oversupplied in the 1990s.

3.4. The Office Market in the United Kingdom

Just as in the other countries there is only few official data kept on the existing office buildings in the United Kingdom. The studies on the European building stock by Russig and further institutional research have been important sources to estimate the volume of the office stock. Research publications by real-estate developers show that the British office market can be divided into three sections. London and its surrounding area is by far the most important and prospering locations. The other major cites only slowly move into the focus of developers. For small cities and rural areas there is no official information available.
3.4.1. Historical development in the UK

The UK office for National Statistics does not provide data on the annual volume of office-building construction. Instead, Figure 3.15 shows the output of private commercial buildings in relation to the annual growth of GDP. The output represents the building activity. It contains the values of:

- building, civil engineering and associated work done by the contractor’s directly employed staff which is chargeable to customers
- materials used, labour costs, overheads and profits
- work done on the contractors’ own initiative on buildings such as dwellings for eventual sale or lease
- work done on demolition and site preparation
- work done by the contractor on the construction or maintenance of its own premises
- articles made by the contractor and used in construction work
- any materials supplied by the contractor free of charge to subcontractors

![Diagram of output of private commercial buildings and GDP growth](image)

Figure 3.16
Annual output of private commercial buildings in the United Kingdom (£million) and GDP growth [%]

The graph shows clearly, how the building output follows the economic development with a delay of a few years. In the 1950s and 1960s the economy and construction output started to develop well. The first oil crisis in 1973 causes a negative GDP-growth and a depression in the building output. It takes the building economy till the mid 1980s to recover. This is not only owed to the second oil crisis in 1977, but even more to the general economic crisis that occurred in the United
Kingdom from 1980 to mid 1982. This crisis was mainly caused by a poor productivity of the industrial sector – due to an outdated machine park – and a lack of capital in the British market.

In the late 1980s the economy and building sector recovered. But, as can be seen in the graph, the building market grew too fast for the rest of the economy. This caused a so-called ‘real-estate-bubble’. As the GDP started to decrease in 1988, the bubble burst and thus led to a severe depression in 1991. With a delay of two years this depression is visible in the building activity too. Since 1993 the economy has been recovering, but the building output grew far above average. Consequently, the British economy was severely hit by the global real-estate crises in 2008. Currently, it is experiencing worse a depression than in 1991.

3.4.1.1. Total office stock per 2005
Russig (1999) estimates a total building stock, excluding agricultural buildings, in the United Kingdom of $2.80 \times 10^9 \text{ m}^2_{\text{NOA}}$. According to the same study roughly 33% of these are non-residential buildings. This equals a stock of non-residential buildings of $924 \times 10^6 \text{ m}^2_{\text{NOA}}$. Estimating that the average proportion of office and administration buildings to non-residential buildings is similar to Germany (16%) leaves us with roughly $148 \times 10^6 \text{ m}^2_{\text{NOA}}$ of office buildings in the UK in 1999.

Other sources of data on the office market are publications by the research departments of real-estate companies. The ‘Office Barometer UK & Ireland” by Jones Lang LaSalle quotes the building stock and population for a further six other important locations in the UK (Jones Lang LaSalle 2008). Table 3.2 shows the office stock for these locations and the City of London. The NOA for these seven major city locations sums up to $38.5 \times 10^8 \text{ m}^2$ in 2008.

<table>
<thead>
<tr>
<th>Location</th>
<th>Office stock [NOA]</th>
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<tbody>
<tr>
<td>Western Corridor (West London and Thames Valley)</td>
<td>$7.72 \times 10^8 \text{ m}^2$</td>
</tr>
<tr>
<td>Birmingham</td>
<td>$1.74 \times 10^8 \text{ m}^2$</td>
</tr>
<tr>
<td>Leeds</td>
<td>$1.06 \times 10^8 \text{ m}^2$</td>
</tr>
<tr>
<td>Manchester</td>
<td>$1.86 \times 10^8 \text{ m}^2$</td>
</tr>
<tr>
<td>Edinburgh</td>
<td>$2.18 \times 10^8 \text{ m}^2$</td>
</tr>
<tr>
<td>Glasgow</td>
<td>$1.42 \times 10^8 \text{ m}^2$</td>
</tr>
<tr>
<td>Central London</td>
<td>$22.6 \times 10^8 \text{ m}^2$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$38.5 \times 10^8 \text{ m}^2$</td>
</tr>
</tbody>
</table>

3.4.2. Amount of buildings built before 1978
In 1999 the relation of non-residential buildings constructed before 1978 equalled 67% of the total stock. As there was a very high building activity between 1999 and 2008, we can estimate that the relation decreased slightly and today equals around 60% of the office stock. This means that in 2008 roughly $90 \times 10^8 \text{ m}^2_{\text{NOA}}$ or $145 \times 10^6 \text{ m}^2_{\text{GFA}}$ of office buildings in the UK must have been 30 years or older.
3.4.3. Tasks in the British office market
The British building industry saw two major peaks of production in the past three decades. One major production peak occurred from 1988 to 1992. These buildings will reach the end of their technical life span in approximately ten years. The even larger amount of buildings will be in need for refurbishment in 20 years from now, when the production of the 2000s becomes outdated. Nevertheless, there is already a huge stock of buildings, mainly in important inner city locations, which has to be improved before.

3.4.3.1. Economic and market situation
London is – next to Paris – the biggest office market in Europe. With top rental rates reaching 80€/m² in the City and up to 159 €/m² per month in the West End it is also the most expensive office market in the world (Cheshire et al. 2007). The office market experienced an enormous boom until the first half of 2007. Since the end of that year the crisis of the bank sector is hitting London, which is the financial capital of Europe, particularly hard. In the end of 2007 the vacancy rate in Central London was at only 4.25%. Within one year it doubled to 8.5% (PNB Paribas Real Estate 2009). Because of the current financial crisis, the rental rates are decreasing and the market activity is slowing down. However, real estate companies still do not expect a severe oversupply of office space in London (Atisreal 2008).

In other cities, the vacancy rate is higher than in London. But here this is often owed to the fact that the structure of the office supply does not meet the occupiers’ demands. King Sturge finds out that in 50% of the British city centres there is a severe shortage of so-called ‘grade-A’ properties. They provide statistical data on the major office rental transactions. In 2007 grade-A space (new or high-quality refurbishment) accounted for 70% of the 119 deals recorded. 29% of the transactions were grade B-buildings and only two deals were of grade-C. They still expect a big need for refurbishment of offices (King Sturge 2008).

3.4.3.2. Green building
Another major driving force for the British office market can be found in the discussion about ‘green buildings’. With the implication of the ‘Code for Sustainable Homes’, politics in the UK enforce owners to construct environmentally friendly buildings (BREEAM 2008). Even more, King Sturge sees a rising sensibility for this topic among building users. This will bring pressure to landlords to provide such buildings. They expect ‘green offices’ to become the market norm in the future and therefore recommend to all investors to keep this fact in mind in order to maintain the lettability of their property (King Sturge 2008).
3.4.4. Conclusions for the British market and potential for refurbishment

The British market provides an enormous amount of office buildings that are older than 30 years. Nevertheless, the refurbishment and maintenance status of these buildings differs strongly between locations. London is the main office location in the UK with a low vacancy rate and a relatively well maintained building stock. Other cities such as Manchester or Liverpool provide a much higher vacancy rate. Vacancy applies mainly to buildings of low standard or poor quality. All real-estate research organisations see a shortage of high-quality office space throughout the country.

Both British legislation and building users enforce the construction of ecologically efficient, ‘green’ buildings. The pressure on landlords and institutional investors to provide such buildings is rising, particularly as eco-friendly buildings with low energy consumption are expected to be much better lettable in the future.

All these arguments support the need for refurbishment of office buildings in British city centres. Even the current financial crisis could fuel the refurbishment market. There will be less money available for new constructions. It will reduce the enormous building activity of new offices in London’s outskirts. Furthermore, the extremely high rents are expected to decline. Institutional investors will have to invest more carefully than in the past decade. If users still ask for high quality office space in good locations, refurbishment could prove to be the faster and cheaper way to provide ‘green grade-A’ buildings.

3.5. Systemising existing office façades - Five types

The post-war architecture has delivered a very wide variety of office façade types. In order to get an insight into their function and to elaborate sensible refurbishment strategies, it is essential to sort the possible façade constructions into a systematic. The systematic presented in this chapter is based on the load-bearing structure of the building envelope and on the refurbishment capacity of different façade types. Table 3.3 shows the overview of typical constructions and their properties. Based on this division all existing façade constructions can be defined, sorted into 22 main types, and coded with a three-digit systematic.

3.5.1. Façade systematic

The façade systematic uses three levels of division in order to bring the different façades into a usable order. In the following theses levels are briefly described.

3.5.1.1. First division – Position of the thermal barrier

The main level of determination is defined by the spatial relation between load bearing components and the thermal barrier. The
position of the thermal barrier in relation to the load bearing elements determines the dominance of the structure as a design element and the thermal performance of a building envelope (Herzog et al. 2004). Five different positions can be distinguished.

- 1. Thermal barrier detached inside the load-bearing structure
- 2. Thermal barrier along the inside of the load-bearing structure
- 3. Thermal barrier in line with the load-bearing structure
- 4. Thermal barrier along the outside of the load-bearing structure
- 5. Thermal barrier detached outside the load-bearing structure (curtain walls).

3.5.1.2. Second division – Structural form
The form and composition of open and closed parts of the façade predominates the possibilities of refurbishment. This separation illustrates which kind of load bearing structure is present behind the visible cladding. For the types 1 to 4 the structure can be divided into:

- X.1: Load bearing planar elements (walls and parapets)
- X.2: Skeleton structures

Planar structures mean that the façade structure provides a surface on the edge of the building to which a new façade can be possibly connected. This surface can be a load bearing wall or a structural parapet. A skeleton structure, on the contrary, only allows the connection of components to columns or the floor slab. In this case, the structural grid is so dense that the floor alone can span between two columns without the need for load-bearing beams in the façade.

The main category of curtain walls (5) is subdivided in the same manner. However, in this case, the structural form of the non-load bearing façade and its connections to the primary structure predominate the possible refurbishment solutions. Four different structural forms of curtain walls, which will be explained later in this chapter, can be found.

- 5.1: Parapets plus windows
- 5.2: Heavy unitised façades
- 5.3: Light-weight unitised façades
- 5.4: Stick systems

3.5.1.3. Third division – Layers
Façades often consist of more than one structural layer. The presence of different façade layers or additional exterior elements is important for refurbishment possibilities. Generally one can distinguish between ‘double façades’ with two closed façade layers and open structures. In double façades the outer layer provides weather-protection and creates the outer appearance of a building, while the inner layer takes over the tasks of thermal separation and - where required - load-bearing. Open structures can be formed by service platforms
<table>
<thead>
<tr>
<th>Structure</th>
<th>Form</th>
<th>Layers</th>
<th>Code</th>
<th>Constr. Material</th>
<th>Facing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Thermal expansion inside structure</td>
<td>1.1</td>
<td>1.1.2</td>
<td>concrete + old dean villa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>1.2.2</td>
<td>concrete + old dean villa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Masonry wall</td>
<td>2.1</td>
<td>2.1.1</td>
<td>masonry plaster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>2.2.2</td>
<td>concrete plaster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. In-line wall structure</td>
<td>3.1</td>
<td>3.1.1</td>
<td>concrete plaster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>3.2.2</td>
<td>concrete plaster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Masonry wall</td>
<td>4.1</td>
<td>4.1.1</td>
<td>masonry plaster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>4.2.2</td>
<td>concrete plaster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Cavity structure</td>
<td>5.1</td>
<td>5.1.1</td>
<td>concrete plaster</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>5.2.2</td>
<td>concrete plaster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>5.3.1</td>
<td>aluminum sandwich glass sandwich panel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4</td>
<td>5.4.1</td>
<td>aluminum sandwich glass sandwich panel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overview of the common post war façade types.
that allow access for window cleaning and provide sun-protection. Furthermore, expressive sun-protection elements, such as ‘brise-soleil’, can be found. All of these constructions have in common that there is a structure with a certain load-bearing capacity clearly set off in front of the actual building envelope.

There are also façade constructions that consist of a load bearing wall and an outer cladding that is mounted with only a small ventilation cavity. This cladding can be made of light-weight panels suspended from the façade behind. Alternatively, there are masonry walls of two shells, one of which carrying structural loads, the other only supporting its own dead weight. These façades with claddings are not counted as two-layered structures but can – if they provide insulation in the cavity – be sorted into type 4.

3.5.1.4. Material properties

Additionally to the three divisions mentioned above, the different façades can be described further by their material properties. The material used to create the main structure of the façade has both consequences for the load bearing structure and the renovation potential. The facing of a façade creates its outer appearance. Many different kinds of materials are possible to fulfil this task and have their own optical and technical consequences. For the separation into the main types, the material properties are not taken into account, as this would result in a too detailed systematic. For the development of refurbishment strategies, the facing is less important than the quality and layout of the main structure.

3.5.2. Typology

3.5.2.1. Type 1 – Thermal barrier detached inside the load bearing structure

In order to make the load bearing structure a part of the design concepts different types of façades have been created in which the thermal barrier is set back from the load-bearing structure. The load bearing structure is expressively visible on the outside of the building. The façade itself, providing thermal separation, is non-load bearing and placed between the floor slabs.

The number of perforating components may differ, but all façades have in common that beams or floor slabs perforate the thermal layer. Vertical load bearing components are located outside the thermal layer. Buildings with cantilevering balconies and without vertical structural elements outside the thermal layer are counted as type 2.1.2 or 2.2.2. As the load bearing elements are placed outside the façade layer, this type of façades always forms a multi-layered structure. The transition between planar and skeleton structures is smooth. The height of structural parapets within the load bearing structure depends on the span between two columns. Thus, only façades with clearly defined structural beams are counted as planar structures.
This type of façade became very common in the 1960s Brutalist era. Therefore, concrete is the most common construction material for the load bearing structure. Nevertheless, there are a few examples inspired by the classic modernism of the 1920s which use steel-skeleton structures. The filling façade elements are either windows or unitised façades and usually made of aluminium or steel profiles, rarely made of wooden frames.

3.5.2.2. Type 2 – Thermal barrier along the inside of a load-bearing structure

In contrast to the first type with unitised façade elements clearly set off behind the load bearing structure, this type is formed by a load bearing façade that carries windows, attached to the inside of load-bearing structure. The interior insulation is placed in the same level as the windows.

Most commonly these façades are formed by planar wall elements such as parapets and columns (Type 2.1). In some cases the building
design aims to emphasise the horizontality of parapets. Hence, vertical load bearing columns are set back from the outer walls and placed inside or in the thermal layer. Nevertheless, this structure falls into the same category, as it provides planar, structural wall surfaces. On the contrary, skeleton structures with interior insulation (Type 2.2) are defined by floor slabs and columns visible from the outside, and non-load-bearing fillings attached to their inner edge. Usually, the load bearing structure of such office façade is made of concrete. Steel columns with additional cladding are very rare. Window units are made of aluminium or steel profiles. Also wooden window frames are possible.

While most of the façades are single layered constructions as described above, there is one possible type of double layered structures in which the floor slabs perforate the façade and thus create service balconies. On the contrary to Type 1 these balconies cantilever from the main structure. Load bearing columns are placed along or inside the thermal barrier.

**Figure 3.19**
Façade type 2.1.2 – Blackfriars Station, London (UK), architect unknown

**Figure 3.20**
Façade type 2.1.1 – Tomato House, Rotterdam (NL), architect: Maaskant Architects 1958-1962, (Hoffmann 1973)

3.5.2.3. Type 3 – Thermal barrier in line with the load-bearing structure

The most traditional forms of constructions are massive buildings with load-bearing façades. They are identified by a more or less massive wall with windows of varying size built into the same layer. In terms of form, a clear historical development from massive walls towards more dissolved structures can be noticed. Massive constructions (Type 3.1) are characterised by load-bearing walls with window openings. Since the 1950s a reduction of the load bearing walls to the dimension of pillars took place in order to maximise the dimension of windows and reduce the demand of construction material. Thus, the common skeleton structure (Type 3.2) was created. The grid of the load bearing columns is limited to a distance in which no or only minimal structural
beams are necessary within the façade to transfer loads from floor to columns. Structural columns in the façade mainly carry vertical loads. Wind loads are transferred via floor slabs to load bearing elements inside the building. (Dorsemagen 2004)

The traditional construction material for load bearing walls is masonry. In-situ concrete became more and more favourable in the 1960s, as it creates homogenous building elements and deserves less manpower to construct. Also in the 1960s, construction with pre-fabricated concrete elements became fashionable. As these are structurally connected and carrying, they are counted as load bearing walls.

Before WWII, the load-bearing columns of skeleton structures were usually made of cast iron or steel. In the 1950s in-situ concrete was preferred, as steel was scarce. Later steel structures reoccurred, as they are faster and easier to assemble. Their limitations in fire safety asked for a cladding with plaster, concrete or plate material. Pre-fabricated concrete elements combine the advantages of both structures and thus were used for later buildings. (Dorsemagen 2004)

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**Figure 3.22**
Façade type 3.2.1 – Concrete skeleton structure from 1952, Former Stadtwerke Building, Bochum (GER), architect: Ferdinand Keilmann

**Figure 3.23**
Façade type 3.2.2 – Two-layered skeleton façade, Free University, Amsterdam (NL), architect: Architectengroep 69

**Figure 3.24**
Façade type 3.2.1 – YMCA Building, Portsmouth (UK), architect: F.J. Guy (Mills 1961)
Structural double layered constructions can be found in form of service balconies and expressive cantilevering fixed sun protections that potentially provide a certain structural capacity. Columns and the edges of floor slabs in skeleton structures are often decorated with natural stone or other plate elements. As these claddings have no structural function they are not counted as a multi-layered façade.

3.5.2.4. Type 4 – Thermal separation along the outside of the load-bearing structure

Higher demands for thermal insulation, imposed after the oil crisis in the late 1970s, led to better insulation of façades. An easy way to achieve this goal is to position the thermal layer onto the outside of the load bearing structure. This creates an uninterrupted thermal barrier. An additional façade cladding is applied, which protects the insulation providing a ventilated cavity between insulation and cladding - a so-called ‘cold façade’, in which humidity that possibly penetrates the cladding is kept away from the insulation (Knaack et al. 2007).

Window elements are attached to the outer edge of this load bearing structure. The outside of massive façade parts is equipped with insulation material and clad with an exterior shell. Alternatively, prefabricated insulating elements can be found. The exterior façade cladding allows many different designs. Nevertheless, the load bearing structure of the building is still recognisable from the outside and thus defines the grid of the façade. The form of window openings ranges from the impression of a massive building via buildings with massive parapets and slim columns (both Type 4.1) to skeleton structures with additional cladding (Type 4.2).

The façade cladding can be of almost any material, such as natural stone or metal plates. Also double-layered masonry walls with a ventilated cavity can be counted among these façade types. The façade structure in itself only provides a one-layered structure. The ventilated cladding is suspended from the actual load bearing structure and has no structural function. However, there are also buildings, which are equipped with additional service platforms that are used for window cleaning and carry the sun-screens. These structures are counted as ‘double layered’.

The addition of exterior insulation and a ventilated cladding has also been a common solution for refurbishment. Hence, a large number of buildings can be found that have been refurbished in this way since the 1980s and that are now in a state for re-refurbishment.
Figure 3.28
Facade type 4.1.1 – Head office IBM, Berlin (GER), architect: Gutbrod and Binder (Hoffmann 1973)

Figure 3.29
Facade type 4.2.2 – University of Augsburg (GER) from 1977, architect: Universitätsbauamt Augsburg (Meyer-Bohe 1980)
3.5.2.5. Type 5: Thermal separation detached outside the load-bearing structure (curtain wall)

The desire to create as much transparency as possible and to liberate the façade design from the load bearing elements has led from windows in massive façades or window elements in skeleton structures to the full glazing of buildings. This could only be achieved by clearly dividing the functions for load bearing and thermal separation into two different building components. So called curtain walls were developed (Dorsemagen 2004). The main structural difference between curtain walls and the other façade types is that dead loads and wind loads are brought into the main structure not with linear fixings but only at defined points. The layout of the façade itself is relatively independent from the load-bearing structure.

Four different types of curtain walls are distinguished in this research: The ‘Parapet plus Windows’ (Type 5.1) is characterised by non load-bearing, pre-fabricated massive parapets suspended from the load bearing structure in a few defined points. These parapet-elements carry rows of windows built in on-site. Unitised façades, on the other hand, are characterised by floor-high pre-fabricated elements, which are attached directly to the load bearing structure (floor or column). Generally two different constructions of these façades can be distinguished. The pre-fabricated units can either be made of light weight concrete, equipped with window openings (Type 5.2); or the

![Diagram of facade units](image)

**Figure 3.30**

Façade types 5.1.1 and 5.2.1 – Systematic of possible fittings
Unitised elements are based on aluminium or steel frames with fillings and cladding (Type 5.3). The unitised façades have in common that pre-fabricated elements usually are delivered and mounted with their final fillings, glazing, and cladding.

On the contrary, stick systems (Type 5.4) are composed of linear components. Vertical posts are attached to the primary load-bearing structure. Transoms are mounted between the posts. The so-created framework is filled on-site with transparent or opaque elements, such as glass or insulated sandwich panels. The filling elements are fixed by pressure plates. These again can be decorated by aluminium cover caps in many different shapes and colours. Stick-systems (Type 5.4) are usually made of aluminium or steel profiles. Wooden posts and beams are very rare. The filling elements can either be glass for the transparent parts or opaque panels, which provide the thermal insulation in one element. Curtain walls are a classic example for ‘warm façades’, in which the façade structure provides the rain screen and thermal insulation in one element (Knaack et al. 2007).
Figure 3.32
Façade type 5.1.1 – Parapet plus Window, University of Bielefeld (GER) built 1971-1976, architect: Köpke, Külka et al.

Figure 3.33
Façade type 5.2.1 – Heavy unitised façade, Law Court, Bochum (GER), built 1978, architect: Willy Schwartz

Figure 3.34
Façade type 5.3.1 – Light weight unitised façade, administration building, Amsterdam (NL), architect unknown
Two forms of multiple layered façades can be distinguished among the curtain walls. Some façades consist of two closed façade layers, which form an elaborated ventilation system. Depending on the ventilation concept, these so-called double façades can either place the thermal insulation on the inner or the outer shell. First examples of these façades appeared in the 1960s. But, only since the late 1990s these double façades experience a boost, which is based on the increasing consciousness for sustainability. Another concept was common in the 1970s and early 1980s: In this time, buildings were equipped with cantilevered service balconies, which provide the support for window cleaning and sun-shading.

Figure 3.35
Façade type 5.4.1 – Post-and-beam stick system, former Shell administration building, Rotterdam (NL), architect unknown

Figure 3.36
Façade type 5.4.2 – Post-and-beam façade with service platforms, EnBW administration building, Stuttgart (GER), built 1978, architects: Kammerer + Belz
3.6. Distribution of different façade types – City spot checks

The definition of façade types presented above has shown that a broad variety of façades is technically possible. The systematic reduces the variety of façades to a total number of 22 types which makes it possible to search for strategic refurbishment solutions. However, there is no statistical data available explaining which types of façades were commonly built in different locations and in certain periods of time. In order to fill this gap of knowledge, this chapter assesses several locations of office buildings in the Netherlands, Germany and the United Kingdom. The findings give an impression of the spatial and chronological distribution of the different façade types. They show significant differences between the three countries and indicate which façade types are most commonly realised in practise. Thus it delivers those types, which are most suitable for a strategic development of refurbishment concepts.

3.6.1. Selection of locations

The market research has shown that mainly those buildings are interesting for refurbishment, which are either occupied by owner-users, or those that have the potential to become so-called ‘Grade-A’ buildings. The major aspect of Grade-A offices, which can not be improved by refurbishment, is the location. Therefore, the spot check focuses on the most favourable locations in different cities, which were developed before 1980. In most cities these locations can predominantly be found in the city centres. Also, the proportion of owner-users is traditionally higher there. Other locations holding office buildings, which can have a future after refurbishment, are university campuses and those office parks, which are in close proximity to economic centres, and which provide very good traffic connections, infrastructure, high quality architecture and urban design.

Different regions provide diverse building types according to local traditions, architectural styles, or climate conditions. Also, the economic prosperity of a city can influence the state of maintenance. This research project focuses on the façade structures of Western Europe. In order to cover the variety of qualities and local differences in this market, it has been chosen to analyse different cities in different regions of the Netherlands, Germany and the United Kingdom. Within these cities, those locations have been visited that provide a big number of buildings with a general potential for refurbishment. These locations mainly are the city centres that are characterised by a big stock of office buildings from the 1950s to the 1970s and high rental rates.

Additionally, three office parks in the Netherlands have been assessed, which were developed in the 1970s. These office parks represent the first extension of office locations from the city centres.
to the outskirts. As described previously, they have a higher potential for future lettability than the younger developments. Particularly those office parks are interesting for refurbishment planning that provide a very good infrastructure and a higher quality of urban and architectural design than others. Here also, the rental rates have been a good indicator.

The third type of visited locations, are university zones in city centres or in the close proximity. These buildings are occupied by an owner user, and typically universities are often short of usable floor space. Therefore, their buildings are less likely to be vacated. Table 6.1.1 shows the overview of the assessed locations.

<table>
<thead>
<tr>
<th>Country</th>
<th>Location</th>
<th>No. of buildings</th>
<th>GFA [m²]</th>
<th>Facade Area [m²]</th>
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</table>
3.6.2. Form of assessment

In the defined locations, a total amount of 571 buildings have been assessed. These buildings equal a total gross floor area of roughly 5.6 * 10^6 m^2, and 2.6 * 10^6 m^2 facade. For each building those features have been collected, which are important for a potential refurbishment planning.

This data contains:

- Location of the building
- Potential maximum rental rate for the location
- Year of construction
- Year of refurbishment (if applicable)
- Dimension of the building
- Number of floors above ground
- Gross floor area
- Façade surface
- Type of façade construction
- Form of sun-shading
- Presence of operable windows

The location of the building and the potential rental rates have been generated from publications by real estate companies such as IVG, DTZ Zadelhoff and Atisreal. The building dimension was measured on site and verified in satellite pictures by Google Earth. The construction phases of the building could be found out by interviewing personnel and checking for information plates on the building. The specification plates in lifts have been easily accessible sources of information. Furthermore, especially high-rise buildings are well documented in online databases, such as ‘archinform’ (archINFORM 1994-2007), ‘greatbuildingsonline’ (Artifice 1997-2008), and the ‘NRW Architekturdatenbank’ (Dortmund University 2008). The type of the façade construction, the form of operable windows, and the system of sun-shading have been evaluated by assessment of the outside and – where possible – the inside of the building.

3.6.3. Results of the spot-checks

The spot checks have delivered interesting results for different building types, construction periods, and for the different national markets. They show great differences of construction types in the different countries as well as in different construction phases. Due to the relatively small dimension of the sample, the results can not be extrapolated to the total national building stock. Nevertheless, they allow a reasonable insight into the quality and quantity of office buildings, which are suitable for refurbishment. The strong overrepresentation of certain constructions indicates the biggest market shares for system-based façade refurbishment. All tables in this chapter show summaries of the results.
Table 3.5
Results of the building spot checks in the Netherlands, sorted by type and construction time.
3.6.3.1. Distribution of office façades in the Netherlands

The spot check of the Dutch office market covers 115 buildings with a total area of roughly 1.00×10⁶ m², and a little over 500,000 m² façade. Table 3.5 shows the relative distribution of GFA of the different building types. The horizontal lines represent the different building types as defined in the previous chapter. The horizontal extension resembles a time line, which starts in 1950, the beginning of office building activity, and terminates in 1990, thus covering the buildings that are in need for refurbishment now and within the next 5 years. For each period of five years the buildings of one type are accumulated. The area of each circle represents the GFA of one façade type of this period of time.

The results show clearly the development of building construction. The first peak of building production took place in the 1950s and 1960s. At that time the most important building task was to re-build the city centres and provide much space at low cost. At first, the most common façade constructions were traditional load-bearing walls (Type 3.1). Soon skeleton structures (Type 3.2) became increasingly important, as they were capable of reducing the amount of building material.

Façade construction changed with the development of technical possibilities and political influence. The effect of the oil crises and regulations on energy saving can be seen in the late 1970s. Types 1 and 2, which are characterised by load bearing elements penetrating the thermal layer, are not built anymore. Instead, Type 4 with exterior insulation appears and continues to be built till today. Pre-fabricated curtain wall structure (Types 5) experience an upturn in this time.

With the non-load bearing façades (Types 5), it is interesting to see, that unitised façades (5.1, 5.2, 5.3) take in a far bigger share than the stick system (5.4). Of those unitised systems, the heavy constructions such as concrete wall-elements and the ‘parapet-plus-window’ façade (5.1) make out the biggest part. Particularly in the early 1970s this was the most fashionable design. This fact can be explained with the architectural preference for a massive, traditional appearance of a building in combination with highly industrialised production methods.

In order to indicate the most common façade types in the national market of the Netherlands, Figure 3.39 shows the accumulated GFA of each façade type for the time from the 1950s to the 1980s. It shows that many different construction types have been applied in the Netherlands. Although not all types became very common, the Dutch office building stock shows a great variety of façade structures. The most important façade types are skeleton structures (Type 3.2) with 20% market share of the spot check. They are very common in inner city locations and were predominantly constructed in the 1950s and 1960s. The second most common construction, with a share of 16%, is the pre-fabricated suspended parapet combined with windows (Type 5.1). Together with the other curtain wall systems (Types 5.2 – 5.4) these buildings were mainly constructed from the late 1960s to today.
Figure 3.37
Spot check in the Netherlands: Façade types accumulated from the 1950s to the 1980s (total volume of the spot check: $1.0 \times 10^6 \text{ m}^2$)
3.6.3.2. Distribution of office façades in Germany

The spot check of the German market covers 190 buildings with a total volume of roughly $1.4 \times 10^8 \text{ m}^2$ $GFA$ and approximately $750,000 \text{ m}^2$ $Facade$. Table 3.6 shows the overview of the results of the spot check in German Cities. Most of the buildings from the 1950s and 1960s have load-bearing façades. The skeleton structures (Type 3.2) make up the largest share. With the introduction of exterior insulation and additional ventilated claddings (Types 4) the simple one-layered structure of Type 3 is almost discontinued. The influence of the oil crisis is clearly visible by the sudden increase of Type-4 façades in the late 1970s. The ventilated cladding on skeleton structures (Type 4.2) occurs increasingly in the 1980s. These buildings mainly are refurbishments of skeleton structures from the 1950s and 1960s.

It is interesting to see that the façade types 1 and 2 with exterior structures, which are relatively common in the Netherlands, are hard to find in Germany. Also, there are far less façades of the types 5.1 or 5.2. These façade constructions of prefabricated unitised concrete elements are less accepted in Germany than in other countries. Unitised aluminium façades (Type 5.3) can be found in the late 1950s and early 1960s. In that period these were mainly post-frame façades. Since the 1980s type 5.3 reoccurs as unitised façade. Nevertheless, the most common means to clad buildings, which aim for much transparency, has always been the post-and-beam façade.
Table 3.6
Results of the building spot checks in Germany, sorted by type and construction time

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Specialties of the German market are façade constructions with two layers. While these almost do not occur in the Netherlands or in the UK, they make out one quarter of the German spot check. Most of those buildings are equipped with service platforms, aiming to allow window cleaning without the need for cleaning cradles. Such structures were common among buildings of the 1970s, when closed curtain walls and mechanical ventilation was common. Since the early 1980s operable windows reoccurred, which facilitated window cleaning from the inside, also the thermal bridges formed by the cantilevering service platforms did not comply with later energy saving codes.

The accumulation of the different façade types for the time from the 1950s to the 1980s, presented in Figure 3.39, shows that although almost all constructions have been used at some point in history, but only very few types became really common. Load-bearing skeleton structures (Type 3.2) make out 17% of the survey. Together with planar façades (Type 3.1) the load-bearing façades sum up to 30% of the spot check. The biggest market share is incorporated by the façade structures with additional cladding (Type 4.1 and 4.2). This may be due to the flexibility of the construction in terms of design and functionality. Also, this structure provides a very high reliability and adaptability to different weather conditions. The market section of ventilated claddings is expected to grow in the future, as many poorly insulated Type-3 façades are being refurbished with ventilated claddings. Together, the types 3 and 4 thus make out half of the case study. Such high ratio of on-site-constructions shows that, unlike the Netherlands, prefabricated façades, such as the types 5.1 and 5.2, have not been common in Germany. This can also be seen in the fact that post-and-beam façades (stick systems) are by far the most common solution for curtain-wall systems.
### Office Facade Spot Check - Germany accumulated 1950-1990

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**Figure 3.42**
Spot check in Germany: Building types accumulated from the 1950s to 1980s (total volume of the spot check: $1.4 \times 10^8 \text{ m}^3$).
3.6.3.3. Distribution of office façades in the United Kingdom

The spot check of the British market covers 265 buildings with a total area of roughly $2.9 \times 10^6 \text{m}^2_{\text{façade}}$ and $1.3 \times 10^6 \text{m}^2_{\text{façade}}$. Table 3.7 shows the overview of the spot-check results of different cities in the UK. The biggest market share in the UK spot check is formed by load bearing façades. As in the other assessed countries, skeleton structures (Type 3.2) have been the most common form of façades in the 1950s and 1960s. Especially in the UK spot check, they make out the biggest share of inner-city office buildings with 19%. It is also interesting to see that the planar load-bearing façade (Type 3.1) does not cease to be built in the 1970s, as in the other countries, but is common through to the 1980s.

Exterior insulation and ventilated claddings (Types 4) are also very common. It is probable that façades constructed before 1975 do not contain much insulation. Nevertheless, façades with an additional cladding have been traditionally common in sea climates, as they provide a very effective protection against high wind and rain loads. The distribution of curtain-wall façades is similar to Germany. There are only few heavy unitised façades (Type 5.2) or parapet-plus-window buildings (Type 5.1). These structures disappear at the end of the 1970s. On the other hand, unitised metal-glass curtain-walls (Type 5.3) and post-and-beam façades are very common.

The table also shows that British inner-city office buildings are on average older than those in other countries. In the UK spot check 50% of the stock was constructed before the end of the 1960s. In the Netherlands this age group only resembles 30%. Furthermore, the overall quality of those office buildings in the UK seems to be lower than in the other countries. Particularly in the less expensive locations Liverpool and Manchester the level of maintenance appears to be very low. It is also worth mentioning that only a very small portion of buildings in the UK is equipped with sun-protection means. Two thirds
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Results of the building spot checks in the UK, sorted by type and construction time.
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**Figure 3.46**
Spot check in the United Kingdom: Façade types accumulated from the 1950s to the 1980s (total volume of the spot check: \(2.9 \times 10^6\) m\(^2\) GFA).
of the buildings of the spot check do not provide any means of sun-shading. Another quarter is only equipped with solar glazing. This is the lowest ratio of sun shadings in the three assessed countries.

The accumulated floor area, shown in Figure 3.45, reveals that there are basically three types of façades that are very common in the UK spot check. The post-war skeleton façades (Type 3.2) make out the biggest share with 19%. However, the planar walls (Type 3.1) are almost just as common. Together with the construction types 4.1 and 4.2, with different levels of additional insulation and ventilated claddings, the load bearing façades make out half of the spot-check. Of the non load-bearing façades (Types 5) the post-and-beam façade (Type 5.4.1 and 5.4.2) is by far the most common choice. It sums up to 18% of the spot check.

3.6.4. Comparison of the Dutch, German, and British façade typologies

Comparing the spot check of Dutch, German, and British office buildings one can identify the characteristics of the national building constructions and architectural preferences. Figure 3.49 compares the accumulated percentages of the different façade typologies in the three assessed countries over the period 1950-1990.

The most common façade structure in the spot checks of all three countries is Type 3.2, the skeleton façade, with market shares of 19% in the UK, 21% in the Netherlands, and 30% in Germany. In the United Kingdom, the second most common façade is Type 3.1, the load-bearing wall, with a share of 17% of the spot check. This type also occurs in the other countries, with 8% in the Netherlands and 10% in Germany. Naturally, these load-bearing façades are very common in the survey, as they are the most traditional forms of construction for low-rise buildings. Load bearing façades with additional insulation and cladding, Type 4.1 and Type 4.2 are structurally very similar to the previous ones. When the exterior cladding of these façades is removed, the same structure as in type 3.1 or Type 3.2 remains as starting basis for refurbishment. In Germany the load-bearing façade with additional insulation and cladding (Type 4.1) is the second most common structure, with a share of 19%. This type is also common in the other countries, with 9% share of the spot check in the Netherlands and 10% in the UK.

All three national markets provide a relatively big share of post-and-beam façades (Type 5.4). In the Netherlands, this type takes in 7% of the market, in Germany 17% and in the UK 18%. The Dutch market is far more open for pre-fabricated constructions than the others. This can be seen by the inverse relation of unitised façades (Types 5.1, 5.2 and 5.3) to post-and-beam façades (Type 5.4). While post-and-beam façades, which require more on-site labour, make out the smallest

Figure 3.47 (opposite page) Relative distribution of façade types in the Netherlands, Germany, and the UK

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### Office Facade Spot Check - Comparison NL, GER, UK accumulated 1950-1990

<table>
<thead>
<tr>
<th>Structure</th>
<th>Code</th>
<th>The Netherlands</th>
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<th>United Kingdom</th>
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<tr>
<td>5.4.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
share in the Netherlands, they take in the biggest part among the curtain wall façades in the other countries.

In terms of structural variety, the UK and the Netherlands are quite similar. Both countries clearly have their most common façade constructions, but also provide reasonable shares of other types. The German office buildings, on the contrary, focus on three common façade structures and only show a very small tendency to ‘experiment’. German office buildings are mainly built on-site in the form of load-bearing façade structures with all additional components, such as insulation, windows, and cladding mounted in a later stage of the building process.

3.6.5. Quantification of the most common façade types
The local sampling of the office stock has revealed the relative presence of different façade types in the most valuable office locations in the Netherlands, Germany, and the United Kingdom. The spot check is based on a relatively small percentage of buildings. It is therefore not possible to extrapolate the percentages of all façade types to the total national stock of buildings. Nevertheless, in order to define those façade types most suitable for systematic refurbishment, it is important to achieve a rough estimation of the market volume and quantity of the different façade types.

For the most profitable building locations the spot checks have delivered only two to three façade types per country, which are significantly more common than the others. Being so strongly overrepresented, it can be estimated that particularly these façade types can also be found in other locations with a similar probability. Based on this estimation, only the volume of these very common façades types is extrapolated in order to achieve an impression of the approximate dimension of market volume for refurbishment. These types are, as described before:

- Type 3.1 – load bearing planar façades
- Type 3.2 – load bearing skeleton structures
- Type 4.1 – exterior insulation and cladding on planar structures
- Type 5.1 – parapet plus windows
- Type 5.4 – post and beam façades

<table>
<thead>
<tr>
<th></th>
<th>National office stock [1000 m²]</th>
<th>Coverage of the local spot check [1000 m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GFA Facade area</td>
<td>Facade area Percentage</td>
</tr>
<tr>
<td>The Netherlands before 1985</td>
<td>21,600 12,096</td>
<td>529 4.37%</td>
</tr>
<tr>
<td>Germany before 1978</td>
<td>309,000 173,040</td>
<td>669 0.39%</td>
</tr>
<tr>
<td>United Kingdom before 1978</td>
<td>150,000 84,000</td>
<td>1,347 1.60%</td>
</tr>
</tbody>
</table>

Table 3.8
The office stock suitable for refurbishment
The previous section of this chapter has presented an estimation of the existing stock of office buildings. Table 3.8 shows the approximate GFA and façade area of office buildings in the Netherlands, Germany and the United Kingdom, which are older than 20 years, as derived from this research. Furthermore, it shows the façade area covered by the local spot checks and its relation to the national stock.

Figure 3.50 shows the extrapolation of the five most common façade types, built before 1985/1978, for the Dutch, German and British market. Although these figures can only provide a very rough approximation, they give an impression of the market volume of office façades that are potentially in need for refurbishment. Load bearing planar façades (Type 3.1) may sum up to 30M to 40×10^6 m². Skeleton structures (Type 3.2) with windows even exceed this amount by 10×10^6 m². Façades with additional exterior insulation (Type 4.1) may also sum up to 40M to 50×10^6 m².

The façade types 3.1, 3.2, 4.1, and 4.2 provide a very similar construction of a load bearing structure with window units. They can potentially be refurbished in a similar manner. Thus, it is interesting to sum up the quantity of these façades. For the three assessed countries one can expect a market volume between 100M and 150×10^6 m². The other very common façade type in all three countries is the post and beam façade (Type 5.4). Summing up the national office stock, one can expect between 40M and 50×10^6 m² of post-and-beam façades in the three assessed countries that, which are older than 25 years.

The façade construction-type 5.1 – parapet plus window – provides a big market share in the Netherlands. But, as the Dutch market is relatively small, it only accounts to a small quantity of façade area in this country. In the other countries, this type only resembles a minimal percentage of the spot check. Extrapolating this to the national market leads to extremely fuzzy results. Therefore, the figures for the other countries are very unreliable. For the Dutch market only, an approximation of roughly 2×10^6 m² can be estimated.
3.7. Conclusion

The market survey has shown that Europe provides an enormous variety of office buildings. Dependent on the national or local situation the age-structure of these buildings differs. Nevertheless, the study shows that all countries have a stock of 60% to 70% of old office buildings that ask for improvement now or in the near future.

The building market in the Netherlands, Germany and the United Kingdom provides two major forms of façade constructions that together make up 2/3 of the total market. The biggest share of almost 50% is taken in by load-bearing walls with different shapes of structure and different forms of additional cladding. All these façades have in common that they are composed of load-bearing elements and window frames, carried by these. With the introduction of energy codes after the oil crises of the late 1970s, the single layered load bearing structures (Types 3) were reduced. Instead, the exterior insulation and ventilated claddings (Types 4) have become increasingly important.

The second most common form of façades is the post-and-beam façade, which sums up to 10%-15% of the façade market. This type is particularly characterised by a high level of conformity. Although there is a constant development in the quality of the structure, the general set-up of the stick systems is comparable. The different unitised curtain wall systems are present in all countries and hold market shares of approximately 5% each. Only in the Netherlands, the parapet-window structures were used to greater extent. Due to the small size of the Dutch market, this local overrepresentation does not influence the total market volume of the three analyzed countries significantly.

Furthermore, the façade types with exterior load bearing structures, which occur in all countries, tend to be niche solutions. Especially with the introduction of energy codes, these structures were discontinued, due to their large amount of thermal bridges. Other constructions, which are possible in theory, could not be found in the local spot checks at all. Particularly, double layered unitised curtain walls did not occur.

For the development of strategic refurbishment approaches, the focus shall further lie on those façade types that have a reasonable market share. Table 3.9 presents the overview of all possible façade types. In this case, those combinations of façade type and construction period are marked grey, which have been found to provide reasonable market shares in the local spot checks. These façade structures will be the targets to be solved by the case studies, which are presented in chapter 5.
Table 3.9
Façade types and construction periods: The grey fields highlight those combinations, which have been very common in the spot checks and should be solved by strategic refurbishment planning.
3.8. References

archINFORM (1994-2007). archINFORM, archINFORM.
German Rectors’ Conference (2009). Zum Konjunktur- und Investitionsprogramm II. German Rectors’ Conference, Bonn (GER).
4. Evaluation of refurbishment projects

Planning a refurbishment project demands different points of focus from a new construction. This chapter gives an overview of the different important aspects of façade refurbishment, sorted by the main focal points: architectural design, building construction, technical installations, and economic aspects. The first part gives a short impression of the different requirements and common restrictions in façade refurbishment planning. The second part of this chapter explains how an existing building can be assessed in order to identify its refurbishment potential. The last part presents how the case studies, which will be described in the following chapter, are assessed.

4.1. Aspects and requirements of façade refurbishment

4.1.1. Aspects overview

In order to be able to deal with current and future demands for a building envelope one has to take many different aspects into account during the design process. Figure 4.1 presents an overview of the requirements for office façades today and in the future. The different aspects are sorted into the categories ‘Architectural design’, ‘Building construction’, ‘Technical installations’, ‘Economics’ and ‘Life Cycle Performance’. The first two categories are commonly accepted as demands in façade planning. However, during the course of this research project, the other three turned out to be of equal importance. The following text in this chapter will explain the major features of this scheme.

The façade of a building is the connecting element between inside and outside. To the outside, refurbishment planning has to deal with the urban surrounding and the initial architectural design. To the inside, the façade has to provide the desired quality of use. The façade is also responsible for the physical performance of the building and has to cope with its structural capacity. The building envelope has to have a strong relation with the technical infrastructure of an office building. An optimal energy and comfort performance can only be achieved, if façade and installations are planned as a unity.

Every office building is an economic investment, which has to prove its feasibility. The construction cost and the building process are only one part of this feasibility calculation. During the life cycle of a building, the operational costs often exceed the initial costs (Evers et al. 2006). Therefore, a refurbishment process does not only cover the planning and construction. It has to deliver a solution suitable for the future, based on a building with a history. The refurbished building has to be functional, even if the requirements change. The life cycle costs are the strongest argument when comparing different refurbishment solutions.
Figure 4.1
Overview of the aspects for façade construction and the requirements in façade refurbishment.
4.1.2. Architectural design
The building envelope is not only a technical device that prevents energy loss and provides comfort. It also has a social importance. The architectural quality is a cultural value, which even the most technically advanced façade has to live up to. Furthermore, renovation projects always have to deal with a given architectural design. Every existing building has its own history and is a document of its development. On the other hand, the building owner and the user demand that their building provides a representative and individual design which facilitates the identification with the company and has a positive connotation. These two demands do not always coincide. Even if no monumental protection applies, refurbishment planning requires making a decision about how to deal with this situation. Three general concepts can be distinguished: ‘Preservation’, ‘Dialogue’, and ‘Desire for Change’.

4.1.2.1. Preservation
A building can be listed as a monument for different reasons: historic importance, artistic quality, technical quality, urbanism, or social importance. In any of these cases different rules and limitations apply. These must be elaborated before the start of a refurbishment planning by contacting the municipality and responsible institutions. If the outer appearance is protected, the façade refurbishment has to focus on the interior, which often leads to technical problems with thermal insulation, structural connections, and the interior organisation of the office. If the building performance can not be sufficiently improved this way, it is sometimes chosen to reconstruct the entire façade with the same appearance but modern standards.

4.1.2.2. Dialogue
Following the concept that a building represents a historical development, any renovation design and addition should be authentic and should deal with the given situation. Therefore, it is essential to analyse the original design concept of the buildings and discover the
different construction phases. Based on these results the refurbishment planning can make a design statement. The new design can emphasise an original concept, transfer traditional ideas to a modern language, or contrast with the given situation. This approach demands an intensive occupation with the existing structure, façade quality and building use. If properly planned, it holds the potential to improve the building performance and façade appearance with minimal nuisance to the interior and ongoing work.

4.1.2.3. Desire for change
Today, not all designs for office buildings from the 1960s and 1970s are commonly considered valuable or fashionable. Hence, often the façade refurbishment is welcomed as a reason to change the building’s appearance completely. It is also a marketing argument that, once the building is refurbished, the effect must also be visible to passers by. A complete redesign of the building envelope often necessitates an entire replacement of the façade. This causes major interference

Figure 4.4
Sparkasse Duisburg (GER), 1976, architect: W. Moraw, (Hampl 2007)

Figure 4.5
Sparkasse Duisburg (GER) - Redesign proposal 2008, architect: Rhode Kellermann Wawrowsky (Hampl 2007)
with the interior and the load bearing structure. Often this means that the building has to be vacated, which leads to relocation costs and unproductive time for office staff. Therefore, the refurbishment concepts should keep in mind that the architectonic/architectural preferences may change in the future and they should provide a solution that facilitates future adaptability.

4.1.3. Work environment
The interior concept of an office is subject to constant change. In the 1960s big office landscapes were fashionable. Later, companies preferred individual rooms for concentrated work. Since the 1990s new concepts are occurring that combine rooms of different qualities for individual work, group work, or informal gatherings.

4.1.3.1. Social and functional concept
A lot of research has been done on the amount and quality of office space needed in the future. Zuidema (2006) expects that the amount of office space per person will decrease because more people will work part time from home or take more advantage of computer technologies (Zuidema 2006). This tendency in office work has led to the development of flexible office concepts, in which people have no fixed workstation but share their desks. However, these concepts are critically discussed and not widely accepted by the users. Office workers want to be able to define their own work environment even if they only use the desk part time (Voss et al. 2006). Nevertheless, a tendency is visible that individual workstations become smaller, but then common working areas for informal meetings, short conversations, or different types of work become increasingly important. Office staff is thus given the opportunity to choose a quiet space for concentrated work or a more public zone for group work or creative jobs. The variety of environments improves the commitment with the work environment, the creativity, and (Voss et al. 2006). Thus, it is not expected that the total office space per employee decreases, but the office building will need to provide a larger variety of indoor qualities. The refurbishment of façade and technical installations has to deal with this demand today, but also provide possibilities for future adaptations (Giebeler et al. 2008).

4.1.3.2. Office grid
When refurbishing an office façade the planner usually has to deal with the existing building grid, as the load bearing structure and interior finishes are based on it. An office grid is always created according to the functional needs of the very time. In the Netherlands, a very common office grid is 1.80m. This delivers useful 2-grid rooms with a width of 3.60m for two people. 3 grids create a 5.40 wide office for up to four people or a meeting room. In Germany, the office grid commonly ranges between 1.25m and 1.50m. The smaller grid allows creating individual rooms with the width of only two grids.
The technical development of office equipment has led to an interesting coincidence. For office buildings in Germany, the grid of 1.25 was often used in the 1960s and 1970s, also because the position of load bearing columns facilitated the most efficient underground car parks. A 3.75m room was perfectly suitable for two desks with typewriter, chairs, and bookshelves. In the 1990s computers were introduced to office work. The need to place a CRT computer screen on a desk demanded

Figure 4.6
Mass office layout in the 1960s, 1990s and after refurbishment of a 1960s building
bigger rooms. Hence, the common grid for new constructions was changed to 1.35m. Fortunately for refurbishment planning, computer technology developed faster than building production. Today’s offices are equipped with TFT monitors or notebook PCs which occupy less space. Thus, the grid of 1.25m is sufficient again. If desks face the walls, the movement area between the desks can be shared by two users.

4.1.4. Interior finishings
Interior finishings are renovated in different intervals from the rest of the building, usually every five to ten years, or when the tenant or building function changes. Dividing walls, suspended ceilings and top floors have many connection points with the façade. Therefore, during refurbishment it has to be considered, if and how the interior should be renovated or adjusted. The case studies presented in the following chapter point out some façade refurbishment strategies that try to limit the interference with interior finishes. This approach reduces the days off work and prevents the relocation of staff, which would otherwise be necessary.

4.1.5. Load bearing structure
Refurbishment-planning has to deal with the existing load bearing structure and detailing. The quality of the structure, material and connections set the limits for the refurbishment possibilities. The given structure is always a result of the economic situation of the time of construction. Thus, its capacity differs dependent on the construction period and the material used. Generally, steel structures and concrete constructions show different points of attention.

4.1.5.1. Steel main structure
Steel structures are very common for office buildings, particularly high rise buildings and pre-fabricated constructions are constructed in steel. The big advantage lies in the reduced dead load of steel profiles in comparison to concrete structures. Steel beams are dimensioned exactly to the desired need. Hence, these structures tend to provide very little tolerances and very little extra structural capacity. Furthermore, the fire safety of steel structures is difficult to achieve. Until the 1979 trusses, beams, and columns were often coated with asbestos, which today is required to be removed under special safety conditions.

4.1.5.2. Concrete main structure
Concrete structures usually provide more tolerances and additional capacity than steel constructions. However, the material quality is not always free of doubt. In the early post-war period dimensions of the structural framework were minimised to save material, and the concrete mixtures were not always realised in the optimal way, particularly, as most concrete was mixed on-site. There is also a normative regulation that leads to many problems with existing concrete structures. According to the early DIN Norm 1045 (in Germany) a concrete cover on the reinforcement steel of 20mm was sufficient. In the 1970s the
environmental impact on early concrete structures became visible. This led to an update of the norm in 1988 which since then demands covers of 35 mm.

Another problem, often occurring with concrete elements exposed to weather conditions is carbonisation. Concrete is a basic material, but in contact with air and high humidity a chemical reaction takes place. The carbon dioxide (CO₂) of the air reacts with the concrete. The basic calcium hydroxide (Ca(OH)₂) turns into calcium carbonate (CaCO₃). Thus, the pH value decreases. At a level below pH<9 the concrete loses its capacity to prevent corrosion of the reinforcement steel. When corroding, the volume of the reinforcement increases, which causes the concrete to spall. Carbonated concrete also looses its load bearing capacity, which becomes particularly important, if the anchors of prefabricated façade units become unreliable or when new components are to be attached to affected concrete structures.

4.1.6. Building physics and comfort
An office employee spends his entire working day inside a building, often in the same room. The building has to provide the necessary comfort for a healthy environment. Especially the building envelope is responsible for this comfort. It forms the separation between the conditioned indoor climate and the outside atmosphere with changing weather impacts. Thus, it has to provide many different technical features to cope with these conditions. While today’s constructions meet current needs, the global climate change will cause higher temperatures, greater wind loads and stronger rainstorms in the near future (Stock 2005)ff. A building that is to be in use for at least 20 years has to account for these aspects. In the following, the building physical demands for a façade are briefly explained.

4.1.6.1. Thermal insulation and vapour tightness
Façades separate inside and outside. In this function they need to provide thermal insulation and vapour tightness. Approximately 75% of the end energy consumed in European buildings of the tertiary sector is used for heating and cooling (Schlomann and Gruber 2004). Many buildings of the 1950s and 1960s are still equipped with single glass. First insulation standards were only introduced in succession of the oil crises of the 1970s. Since then the legal demands have been constantly increased. Today the saving of energy is demanded for ecological and also economical reasons. For the future, very low energy consumption will be demanded. Norms will be geared towards the ideal of a ‘passive house’, which aims to operate a house only by solar irradiation and internal heat gains. At this stage it is visible that buildings with low energy consumption are better marketable than others. Table 4.1 shows, which insulation values for different building parts are possible to achieve with currently available means, and which are considered to be cost effective.
Proper thermal insulation also prevents humidity problems if it pays attention to structural and geometrical thermal bridges, as these can cause severe problems with condensation. DIN 4108, part 2, defines that the inner surface temperature always has to be higher than 12.6°C in order to prevent condensation and moulding. Especially building parts from concrete that penetrate the wall and the connection to the ground tend to be difficult to insulate. If an interior thermal insulation is preferred, all connecting building elements cause thermal bridges that need to be solved. Here it is also most important to provide a proper vapour seal in order to prevent warm humid air to reach the cold inner wall surface behind the insulation layer. Condensation in this position is often difficult to recognise and can cause severe problems.

### Table 4.1
**Technical possibility and economical feasibility of different thermal insulation means**
(Giebeler et al. 2008)

<table>
<thead>
<tr>
<th>Building element</th>
<th>Solution</th>
<th>Currently cost effective u-value</th>
<th>Forward looking u-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steep roof</td>
<td>Insulation under and between rafters</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Insulation on top of rafters</td>
<td>0.16</td>
<td>0.11</td>
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<tr>
<td></td>
<td>Insulation on top and between rafters</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>Flat roof</td>
<td>Insulation in roof construction</td>
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<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Inverted roof</td>
<td>0.22</td>
<td>0.16</td>
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<tr>
<td>Top floor</td>
<td>Insulation on top floor</td>
<td>0.14</td>
<td>0.12</td>
</tr>
<tr>
<td>Facade</td>
<td>Exterior insulation finishing system (EIFS)</td>
<td>0.17</td>
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<tr>
<td></td>
<td>Ventilated cladding</td>
<td>0.18</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Interior insulation and vapour barrier</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>Basement</td>
<td>Interior insulation and vapour barrier</td>
<td>0.27</td>
<td>0.27</td>
</tr>
<tr>
<td>Piping</td>
<td>Insulation of hot and chilled water pipes</td>
<td>1x diameter</td>
<td>2x diameter</td>
</tr>
</tbody>
</table>

Source:

### 4.1.6.2. Summer heat insulation and sun protection
While thermal gains have a positive effect on the energy balance of a building in winter, they cause higher heat loads in summer. Therefore, effective solar protection is essential. Adjustable exterior solar blinds can reduce the cooling load up to 50% (Eisele 2005), but they often have to be opened in windy weather. Permanent cantilevering louvers are very robust and function independently of the weather. However, in less sunny conditions they also block natural daylight, which increases the demand for artificial light and thus the internal heat load. Interior blinds can only achieve a reduction of cooling load by 10% (Eisele 2005) because the irradiation is absorbed by the material of the sun
blinds. Placing sun blinds inside the cavity of a box window or double façade combines the advantage of exterior and interior blinds. This is also the place for daylight deflecting blinds, because here they are less subject to staining.

Furthermore, the ventilation concept and technical building services can reduce the cooling load. For example, a controlled night-time ventilation can help to cool thermal masses inside the building, which then again absorb excess heat during the day. The application of Phase Change Materials (PCM) can increase the thermal absorption capacity.

4.1.6.3. Glare protection
While sun protection is installed to prevent overheating in summer, and thus functions as a means of technical building management, the protection against glare contributes to the individual visual comfort. Therefore it is recommendable to separate these two means. The sun screens are controlled according to heat gains. The glare protection is an individual tool, handled personally by the employee.

4.1.6.4. Acoustical comfort
The acoustical comfort is influenced by noise immissions and the acoustical quality of the room. There are two sources of noise against which an office façade has to insulate. On the one hand, noise from outside has to be blocked; on the other hand, it has to prevent sound transfer from room to room. Sound insulating (triple) glass can block noise from exterior sources such as traffic or wind. A double façade or box window is often realised if it is desired to open a window, while the building finds itself in a noisy surrounding. For sound protection between rooms, mainly the detailing between façade and connecting elements is essential. DIN 4109 asks for a noise reduction of 37 dB(A) between office rooms. NEN 1070 demands a reduction between 30 and 40 dB(A) dependant on the functions of the rooms.

Next to the need for sound insulation, the acoustical comfort is also influenced by the reverberation time. Many surfaces increase the risk of a poor acoustical quality in a room. This demand often collides with modern climate concepts. For example, while a suspended ceiling improves the reverberation time significantly, at the same time it shields the thermal mass of the load bearing structure from the room. Thus this mass can not be used to absorb heat by night-time cooling or concrete core activation. The refurbishment design thus has to find right balance between acoustical and thermal comfort.

4.1.6.5. Fire protection
Many existing buildings demonstrate an insufficient fire safety. This is caused by different standards at the time of construction and by changes made during the time of use. Usually an existing building has the ‘right of continuance’, which means that it may be used even it does not comply with current legislation, provided it was legal and built according to the building permit at the time of construction.
Fire protection is an exception of this rule. Because of its importance for the safety of people, municipalities can ask for an improvement (Koch 2008). After refurbishment, the building usually has to comply with current standards. Therefore, in the planning phase, one has to assess the given situation and develop a fire protection concept in collaboration with the responsible institutions.

Major problems of older office buildings are fire compartments that do not comply with current standards, openings in walls or floors that were made either originally or later to bring in installations, and the use of inflammable material in walls and façades. To close floor openings, if possible, installation ducts should be placed in the floor that is serviced. Otherwise, fire shutters, insulation, and special coatings need to be applied. Especially the connections between façade and floors or fire walls demand attention. Figure 4.8 shows which rules apply to the façade connection according to Dutch legislation.

Double façades are particularly difficult to treat in terms of fire safety. During a fire, they facilitate flashover due to hot gases rising in the cavity. After a fire, the secondary façade layer makes it difficult to discharge smoke from the building. Therefore, horizontal separations are requested for double façades, which prevent hot gases and flames from rising. Alternatively a sprinkler installation may be required.

![Fire resistance requirements for façade connections in the Netherlands](image)

**Figure 4.7**
Overview of the fire resistance requirements according to Dutch norms (Truijens 2009)

Source: Truijens, K., Brandveiligheid qevel vloer ansluitingen (2009), NEN 6064
4.1.7. **Hazardous materials**

In building history many different materials have been used, natural or artificial, that later have been found to be unhealthy for the people inside the building. This section describes the most common pollutants that were used in office buildings between 1950 and 1980. Every building can provide different combinations of toxic materials. It can only be estimated, which material one has to expect, by the building age, the form of construction, and possible users’ complaints. In any case of suspicion an authorised expert must be consulted. Official limits only exist for asbestos, PCP, and PCBs. For other materials there are only recommendations available (Giebeler et al. 2008). Special rules apply for the treatment of almost all toxic materials. The treatment of PCBs, PCP, and asbestos is even regulated by legal guidelines.

4.1.7.1. **DDT**

Dichloro-Diphenyl-Trichloroethane is a synthetic pesticide. It was invented in 1874 and widely used as pesticide against insects in agriculture and health care since the 1940s. In buildings DDT was used as wood preservative. The toxic effect on the ecosystem is proven. The substance damages almost all viscera and the nervous system. For human beings exposed to DDT in their living surrounding it is also suspected to enlarge the risk of cancer (Stockholm Convention on Persistent Organic Pollutants 2008). The publication of Rachel Carson’s book the ‘Silent Spring’ in the mid 1950 started a first discussion about the effect of pesticides on other life forms. However, it took until 1972 for DDT to be banned in most industrialised countries. Window frames and structural timber built in before that date is suspect of contamination. The topic reappeared in the public eye after the German reunification. In the former GDR DDT was used in buildings until 1989. Still today a higher concentration of DDT can be found in inhabitants of this region than in other Western European countries (Giebeler et al. 2008).

4.1.7.2. **Lindane**

Lindane (Gamma-Hexachlorocyclohexane) is a neurotoxin that was developed as an insects’ pesticide. It was widely used as wood preservative in buildings. It is suspected to cause cancer, neurological problems and damages to the viscera. Lindane is absorbed by aspiration of contaminated indoor air. In Germany it was banned in 1984. The European commission did not ban Lindane until 1997. For Lindane applies the same as for DDT and PCP, in the former GDR it was commonly used till 1989 (Giebeler et al. 2008).

4.1.7.3. **PCP**

Pentachlorophenol was one of the most common wood preservatives. It was widely used as fungicide until the 1980s. Since then its use is banned in most developed countries, with some exceptions (telegraph posts and railroad ties in the USA). In other countries it is still in use, mainly in leather and textile industries. In Germany and most European countries, PCP was forbidden for interior use in 1978. In the
former GDR, it was used until the German reunification. The German Government developed a PCP-regulation that defines the treatment of contaminated buildings and components (EPA 2006).

4.1.7.4. PAHs
Polycyclic aromatic hydrocarbons are a group of chemical compounds that occur in oil, coal, and tar deposits, and are produced as by-products of fuel burning. They are not produced on purpose but by-products of refinery processes. PAHs are proven to be cancerous, mutagenous, and skin irritant. In buildings PAHs can mainly be found in products made of oil or coal-products, such as asphaltic felt, waterproofing, and as softening agent in plastic products. As these products are very common, one can expect PAHs in any building (Giebel et al. 2008). A special situation occurs if PAHs are found in glues for parquet flooring. Until mid 1970s certain tar-based glues were used, which can be identified by their dark colour. If these are present, their influence on the ambient air has to be tested. The German State Ministries for Building developed a directive on how to treat these floors (Schubert, Dommaschek et al. 2000).

4.1.7.5. PCB
Polychlorinated biphenyls (PCBs) are a class of organic compounds with chlorine atoms attached to biphenyl, which is a molecule composed of two benzene rings each containing six carbon atoms. PCBs have been produced since 1930 and used for many purposes thanks to their wide range of technical capacities. They are very stable, hardly inflammable, and resistant against many acids and bases. In buildings, PCBs can be found as flexibilisers in plastics and sealants (open use). A good indicator is this: If a sealant material after 30 years of exposure to daylight is still elastic, it should be analysed for PCBs. They were also used as isolators in electric capacitors and transformers (enclosed use). PCBs are known to be highly carcinogenic and teratogenic. The longer a human is exposed to the substance, the more severe the accumulation of PCB in the body. PCBs were banned for open use in the EU in 1978. Since 2000 also the enclosed use is prohibited (Giebel et al. 2008). PCBs attract a big public interest, because many public buildings and schools, which were built before 1978, are contaminated. This has led and still leads to many judicial proceedings aiming to find the responsibility for cases of cancer.

The treatment of contaminated buildings is very complicated, as PCBs tend to evaporate from their primary source and attach to any porous material. This means that not only the primary source (sealant, paint, rubber flooring, or leaking electric component) has to be removed, but also other surfaces have to be treated. For prefabricated concrete façade units this means that the sealant itself has to be removed and the shoulders of the joints have to be grinded. Also all other surfaces in the building and inventory must be cleaned, replaced, or sealed off against indoor air. The German state governments have therefore published a directive on the treatment of PCB. This defines a certain
amount of PCBs in ambient air. Rooms with more than 3,000 ng/m³ air have to be refurbished entirely and immediately. In rooms with more than 300 ng/m³ the primary source should be removed (Ministerium für Bauen und Wohnen NRW 1996).

4.1.7.6. Asbestos
Asbestos is a collective name for naturally occurring silicate mineral fibres. The fibres have been used since ancient times for flame retardant clothes and table cloths, which could be cleaned by throwing them into the fire. But also their unhealthy features were already encountered 2000 years ago. Already Pliny the Elder noted in the first century that the material damaged the lungs of slaves who wove it into cloth (Barbalace 2004).

Asbestos became popular in the building industry in the late 19th century due to its resistance to heat, electricity and chemical damage, and for its tensile strength. When asbestos is used for its fire resistance, the fibres are often mixed with cement or woven into fabric or mats. Today we find asbestos in fire resistant plates, fibre cement panels for cladding and roofing, and as reinforcement in sealants. Furthermore, asbestos was used as a spray coating for fire protection of steel structures until 1979 when it was banned in most developed countries. The general ban of asbestos products was issued around 1990. Nevertheless, some developing countries, such as India and China, have continued widespread use of asbestos, mainly in sheets for roofing and wall cladding until today.

Because of their crystalline structure asbestos fibres tend to split up longitudinally, which leads to long thin respirable fibres of 3.0-500 μm in length that can be as thin as 0.01 μm. These fibres are invisible to the human eye. They are not biodegradable and once respired stay in the lung, where they cause asbestosis and lung cancer. For refurbishment it has to be distinguished between strongly bound asbestos (fibre cement plates) and lightly bound asbestos (spray coating, some fire boards). While the strongly bound panels do not cause an immediate threat, they can often stay in place and are marked with stickers to

Figure 4.9
Left: strongly bound asbestos reinforced façade panel (grey); right: lightly bound asbestos reinforced fire board (white)

Figure 4.10
Removal of asbestos contaminated window sealant
prevent their damage. Lightly bound material tends to erode and give fibres to the ambient air. It therefore has to be removed. The removal of asbestos requires special safety means, such as can be seen in. Especially the removal of spray asbestos is extremely complicated and expensive (Deutsches Institut für Bautechnik 1996).

4.1.7.7. Man made mineral fibres (MMMF)
While asbestos are natural mineral fibres, there are also many forms of synthetic mineral fibres. These are made of molten mineral material such as stone or glass. Hence, they are commonly known as rock wool or glass wool. They are used for thermal insulation, fire protection, and sound insulation. Just like asbestos, these synthetic fibres form respirable particles that accumulate in the lung, are not biodegradable and tend to cause cancer. Nevertheless, while asbestos fibres split longitudinally and thus create long, volatile fibres, MMMFs break perpendicular to the fibre direction which leaves smaller and heavier particles, which are less likely to float in the air.

In the late 1990s a technological improvement took place. According to EU directive 67/548 any MMMF that was produced until 1996 has to be considered as carcinogenic. The period from 1996 to 2000 saw the improvement of material properties. Fibres from this period demand a special analysis before treatment. Only fibres produced after the year 2000 can be considered as safe, because the production process has been altered in a way that new MMMF are less bioreistant. Furthermore, the fibres are coated, which reduces the amount of dust created. Nevertheless, caution has to be taken with any MMMF found in a building (Bayerisches Landesamt für Umwelt 2008).

4.1.8. Technical installations
In the past, the general idea for an office façade was to completely shield off the interior from the outside conditions and provide a defined conditioned indoor climate. After seeing that fully air conditioned buildings cause higher rates of sick and dissatisfied occupants, just as high costs for operational energy and maintenance, currently a tendency is visible that new office façades permit natural ventilation. Thus, a connection to the outside world is created which lets the person inside a building experience weather changes and sounds. Figure 4.12 shows that the user accepts a wider range of temperature and humidity when a building can be naturally ventilated.

One big chance in façade refurbishment lies in the possibility to renew the façade and the technical building services in one process. On average, the technical life span of building services is similar to that of the façade, 20-30 years. Furthermore, in the past 30 years major improvements took place in this field. Today, building users have much higher demands on ventilation, heating, cooling, and individual control than during the construction phase of the building.
4.1.8.1. Heat and cold generation
The refurbishment of the façade and building services leads to a major reduction of heating and cooling demand. Thus, the systems for heat and cold generation can become significantly smaller. Old components can be replaced or partly turned off. It should also be assessed to which extend renewable sources of energy generation, such as solar collectors, can be integrated into the refurbishment planning.

4.1.8.2. Distribution in building and room
There are two general concepts to distribute heating and cooling energy inside the building: In a central air conditioning, the induction air is heated or chilled centrally and blown through ducts to the individual offices. Alternatively, hot and/or chilled water is distributed to every room, where induction units, radiators, chill ceilings, or other devices

Figure 4.11
Psychometric chart with standard comfort zones. The zone of comfortable indoor climate is bigger in buildings with natural ventilation than with complete air conditioning (Transsolar 2009)

Figure 4.12
Corroded pipes and outdated installations in an office building from 1960
condition the room temperature. The latter system is more efficient than a central air conditioning system as it demands less operating power, because water, with its higher density, is a better medium to distribute energy than air.

Existing distribution ducts are usually considered in need for replacement. Air ducts often are difficult to maintain and - after 30 years of use - tend to be less hygienic. After such long period of use, water circuits are also considered unreliable. Often, the building owner is therefore not willing to take responsibility for the future functionality of these installations and asks to replace all components, which are not easily assessable. During façade refurbishment it can be easy to mount new distribution ducts in the façade without interfering with the interior of the building.

4.1.8.3. Ventilation

Offices of the 1950s to 1980s are either centrally mechanically ventilated or equipped with operable windows. The central ventilation systems are characterised by big machines and a low efficiency. Heat recovery for central ventilation machines is a development that started in the 1990s. Natural ventilation by opening windows, on the contrary, is a very common way to provide fresh air. Currently a discussion is going on, if buildings need controlled ventilation with heat recovery to fulfil the latest energy standards. On the other hand, field research by many institutions has also shown that operable windows can achieve the same results, provided the occupant consequently practises intermittent instead of permanent ventilation.

The latest developments in ventilation technology are decentralised units with integrated heat recovery. These are placed in the façade layer and take in fresh air directly from outside. Powered by small fans, the incoming air is led past a cross-flow heat recovery and directly brought into the adjacent room. Exhaust air is extracted from the same room and is let past the heat recovery and outside. There are also units available, which can be combined with air-water heat exchangers and thus provide the heating and cooling. Such elements are very interesting for refurbishment because they integrate all technical services in the façade and make central ventilation systems redundant.

4.1.8.4. Electric installations

Electricity ducts are often placed along the façade to supply the workspaces with electric power and IT installations. Computerisation during the past two decades has brought more electric installations to the office than any planner previously expected. These cables and components had to be integrated in a given situation. The commonly used cable ducts tend to collide with dividing walls and interior finishes. Some façade constructions, such as the University of Bielefeld try to integrate the ducts into the façade design.
4.1.9. Economic aspects
In addition to the social and technical aspects mentioned above, the renovation-proposal has to prove its economical feasibility. This does not only contain the construction cost, but also the operational cost and possible financial benefits. In the following, these aspects are explained.

4.1.9.1. Energy-demand
The energy demand is the predominating aspect for the operational costs. The buildings to be refurbished almost always provide a low insulation level and outdated installations. In Europe, approximately 75% of the end energy consumed in buildings of the tertiary sector is used for heating and cooling (Schloemann et al. 2004). Improvements in this aspect can thus lead to big savings both on financial as on ecologic level. Although in 2009, we experience a drop in energy prices, it is undoubted that these will continue rising in the future. The second most important factor of energy consumption in office buildings is the electric lighting. Intelligent presence controls and energy saving

![Crude Oil Price Chart](image1)

**Figure 4.15**
Development of crude oil price (Tecson 2009)

![Energy Index Chart](image2)

**Figure 4.16**
Primary energy index for an example office building with different energetic qualities (Knissel 1999)
fluorescent lamps can reduce this demand significantly. The ‘Institut für Wohnen und Umwelt’ in Darmstadt has assessed the energy savings potential in representative office buildings. Figure 4.17 shows the effect of different technical standards for office buildings. It shows that the primary energy consumption of an office building following the design principle of a passive house can be almost 4 times lower than that of an old building.

4.1.9.2. Energy generation in buildings
In addition to the potential of energy saving by improved insulation, the building envelope also provides possibilities for energy generation. The solar gains in a façade cavity can be used to precondition incoming air in winter. Solar collectors, producing hot water for room heating or absorption chiller plants, can be mounted on the roof or in the façade. Also the integration of photovoltaic cells into the façade is widely researched. Lately, the integration of wind turbines into buildings is being realised in some new projects. Here, the application of a Darrieus-rotor appears to be the better solution, as this one can better cope with changing wind directions and speeds in built-up areas than a rotor with horizontal axis. The applicability for refurbishment projects is limited by the load bearing structure and urban surrounding.

4.1.9.3. Functional sustainability
In order to keep a building functional for the future, it is essential that the building layout can be adjusted to changing needs. The dividing walls have to be adjustable to changing office concepts. The electrical installations should be easy to adapt. The refurbished façade has to cope with these needs and allow the connection of dividing walls in different positions. The ventilation concept has to be pre-set for different possible room sizes. Furthermore, the heating and air conditioning system has to be easy to adapt in order to control each room climate in the optimal way.

4.1.9.4. Building process
Building in inner city locations always restricts building logistics. It has to be dealt with limited space for storing goods and a more complicated construction schedule. For example, the delivery of goods and a
possible occupation of public space have to be planned thoroughly. Also, the building process has a strong influence on the construction cost, as well as on the acceptance of the refurbishment among the building users.

In the first place it has to be decided, if the building has to be vacated or if the façade refurbishment shall take place while the building is in use. Vacating a building causes relocation costs, extra rental expenses for the interim location, and a loss of productivity, as people always need to adjust to a new work surrounding. If the refurbishment takes place while the building is occupied, special measures have to be taken to prevent nuisance. The building process should for example limit the drilling and chasing work, as well as the production of dirt. The occupants must be integrated in the planning process. Only if they are well informed about the upcoming works, they can arrange with the situation.

4.1.9.5. Productivity of staff
Measuring the exact financial impact of healthier, more comfortable buildings is difficult. These costs are hidden in sick days, lower productivity and medical costs. However, the four main aspects of a good indoor environment are ventilation control, temperature control, lighting control, and natural daylight. As long as the indoor climate is healthy without doubt, the individual control is of significant importance. Research has shown that being able to influence these parameters leads to an increased productivity between 1% and 7% (thermal control: 1.2%, ventilation control: 1.8%, lighting control: 7.1%). Taking into account that a productivity gain of 1% equals an average of approximately 600€ per employee per year, these aspects should be considered in refurbishment planning (Kats 2003).

4.1.9.6. Further financial concepts
A comprehensive feasibility study can also integrate further economic potentials of a building project into the calculation. In the different phases of the existence of the building, there are opportunities to save or earn money. For example, during the construction phase, a refurbishment project provides the chance to reuse building components. Old building materials, which are not reused, may still have a material value and can be sold. If the new façade or technical installations occupy less useable space than the old solution, additional rental space is made available.

A façade refurbishment also holds different marketing possibilities. On the one hand, the façade itself can function as a marketing tool for the company. This does not only cover the use as bill-board or the integration of technical advertisement media. The building itself presents the user to his customers. On the other hand the application of ‘green solutions’ is increasingly becoming a marketing argument. Energy saving buildings are easier marketable and companies use the green image for publicity (ING-Real-Estate 2008).
Furthermore, the national governments provide a wide range of grants aiming to achieve national energy saving goals. These grants sponsor the renovation of buildings, improvement of insulation, or the generation of renewable energy.

4.1.10. Life Cycle Targets
A building project does not only cover the planning and construction phase. In order to achieve satisfying results for all project partners, the operational period must be considered too. The ‘traditional magic triangle’ of project management knows the goals that are set for the delivery time of a building: time, quality, construction cost. With delivery of the building, usually the responsibility of designers and planners ends. However, during the operational time of a building, new goals occur, on which the building has to react. Thus, the magic triangle has an even bigger counterpart in the future.

Operational costs add onto the construction costs. Together these expenses make out the ‘life-cycle-costs’. During the operational phase, not only the quality of delivery is important. The building has to provide long term qualities, such as reliability, safety, and adaptability. Also time-targets arise in the future; these are, among others, availability, down times, and reaction times in case of failure or functional changes. Figure 4.20 shows the relation of these goals. It demonstrates that already in the initial phase the planner has to anticipate the future adaptability of the building in terms of redesign and flexibility of use. During the operational phase the quality management and monitoring of performance is important.

Especially, the expected life cycle costs are fundamental for the success of a building project. A study by Roux Germany has investigated that more than two thirds of all interviewed office tenants would accept a 10% higher rental rate if the operational costs pay back for this expense. (Roux Deutschland 2008) In the light of rising energy prices and constant inflation, the relevance of operational costs will increase in the future. Hence, the life cycle costs should be calculated already during the planning phase.

Figure 4.18
‘The magic triangle’ - Targets during the life-cycle of a building (Balck 2004)
4.1.11. Technical life span of building components

In order to judge the ecological and economic quality of a construction it is important to know the technical life span of building elements. Also for the analysis of an existing building it is helpful to know, which components can be trusted to last longer and which are more likely to fail sooner. The following table shows the expected technical life span of different building components:

<table>
<thead>
<tr>
<th>Load bearing structure</th>
<th>min.</th>
<th>max.</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical structures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation</td>
<td>80</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>Natural stone weathered</td>
<td>60</td>
<td>250</td>
<td>80</td>
</tr>
<tr>
<td>Brickwork</td>
<td>80</td>
<td>150</td>
<td>90</td>
</tr>
<tr>
<td>Concrete weathered</td>
<td>60</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>Concrete / bricks covered</td>
<td>100</td>
<td>150</td>
<td>120</td>
</tr>
<tr>
<td>Steel structure</td>
<td>60</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td><strong>Horizontal structures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete balcony</td>
<td>60</td>
<td>180</td>
<td>70</td>
</tr>
<tr>
<td>Concrete floors</td>
<td>100</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>Steel structure weathered</td>
<td>50</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>Steel structure covered</td>
<td>80</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td><strong>Facade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facade components</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete units</td>
<td>40</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Brickwork facing</td>
<td>70</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Mortar joints</td>
<td>20</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Tie (steel)</td>
<td>30</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>Tie (stainless steel)</td>
<td>80</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td><strong>Plaster and paint</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement plaster / lime cement plaster</td>
<td>20</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Synthetic plaster</td>
<td>25</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>EIFS</td>
<td>25</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>Latex paint</td>
<td>10</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Synthetic coating on concrete</td>
<td>15</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td><strong>Facade cladding</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural stone / slate</td>
<td>60</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Fibre cement</td>
<td>50</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>Copper</td>
<td>40</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>Zinc plate</td>
<td>30</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Aluminium</td>
<td>30</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>Glass</td>
<td>80</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>Supporting structure (wood)</td>
<td>25</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Supporting structure (steel)</td>
<td>30</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>Supporting structure (stainless steel)</td>
<td>30</td>
<td>60</td>
<td>45</td>
</tr>
</tbody>
</table>

| Windows and doors              |      |      |         |
| Frame material                 |      |      |         |
| Hardwood                       | 40   | 60   | 50      |
| Softwood                       | 30   | 50   | 40      |
| Aluminium                      | 40   | 60   | 50      |
| Steel (galvanised)             | 40   | 50   | 45      |
| uPVC                           | 40   | 60   | 50      |
| **Glazing**                    |      |      |         |
| Single glass                   | 60   | 100  | 80      |
| Luting                         | 8    | 15   | 10      |
| Insulated glass                | 20   | 30   | 25      |
| Gaskets                        | 15   | 25   | 20      |
| Movable sun blinds             | 20   | 30   | 25      |
| Canvas screens                 | 10   | 20   | 15      |
to fail. The real life span of any element depends on many different factors, such as original quality, operational strain, and maintenance. Therefore, the life expectancy can only be stated as a time span. Based on an extensive literature study and interviews, the German Federal Office for Building and Regional Planning collects the available data. It also estimates the average life span as an orientation. The following table is based on this source and further literature research. It presents the life expectancy of those building components that have a direct relation to the topic of façade refurbishment.

<table>
<thead>
<tr>
<th>Roofs</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat roof with protection layer</td>
<td>15</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Flat roof without protection layer</td>
<td>20</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Steep roof zinc plate</td>
<td>25</td>
<td>40</td>
<td>35</td>
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</tr>
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<td>Wood paint</td>
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<tr>
<td>Floating floor</td>
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<tr>
<td>Floor tiles (natural stone / concrete)</td>
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<td>Ceramic tiles / hardwood floor</td>
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<tr>
<td>Hot water pipes</td>
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<tr>
<td>Sanitary objects</td>
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<td>25</td>
</tr>
<tr>
<td>Heating and cooling</td>
<td></td>
<td></td>
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<td>installations</td>
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<td>Low temperature boiler</td>
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<tr>
<td>Calorific value boiler</td>
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<td>Geothermal heat exchanger</td>
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<td>60</td>
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<tr>
<td>Circulation pump</td>
<td>10</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Solar collector</td>
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<td>25</td>
<td></td>
</tr>
<tr>
<td>Heating pipes</td>
<td>30</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Radiator</td>
<td>25</td>
<td>35</td>
<td></td>
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<tr>
<td>Floor heating</td>
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<table>
<thead>
<tr>
<th>Mechanical ventilation</th>
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</thead>
<tbody>
<tr>
<td>Air ducts</td>
<td>30</td>
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<tr>
<td>Air outlets</td>
<td>20</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Machines</td>
<td>10</td>
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<td>15</td>
</tr>
<tr>
<td>Chiller</td>
<td>10</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Heat recovery (air/air)</td>
<td>15</td>
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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>40</td>
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</tr>
</tbody>
</table>

Sources:
4.2. Assessment tools

There are two steps in refurbishment planning that demand the help of checklists and tools. Before the actual planning process, the existing building needs to be thoroughly assessed. At a later stage, different building concepts have to be evaluated and compared. In the following, three existing tools for these purposes are presented. These tools are the inspiration for the assessment checklist and evaluation tools used for the case studies to be presented in the following chapter.

4.2.1. IFO Institute: Electronic Inventory Checklist for Existing Buildings

The German IFO Institute has developed an electronic checklist for the inventory of existing buildings. This tool wants to assist a planner during the building inspection. It collects the necessary data for an energetic assessment of the building according to DIN V 18599, which is the current German assessment means for the energy consumption of non-residential buildings. It is based on the European directive on the energy performance of buildings (2002/91/EC) and provides the basis for issuing an ‘Energy Passport’. As this calculation demands much input, the checklist assists the planner not to leave out any important features.

The electronic tool is installed on a mobile computer and used during the building inspection. It guides the planner through the building, starting with the overall building layout, assessing different room configurations and the construction of important building elements. It also analyses the existing building services and technical infrastructure. All necessary information is filled into input masks. Photos and comments can be added to each page. The tool provides precise explanations, which information, measurements, photos, and data must be collected for each item. The program provides an interface that makes it easy to transfer data to energy calculation programs, which are based on the German Norm DIN V 18599.

![IFO building inventory, screenshot](image)
The database provides a very useful system for gathering data on the building structure and technical installations. The work instructions provided for every building component and room guarantee that no important features are forgotten, which later are needed to create drawings and technical concepts. The interface to common tools for energy demand calculations makes it relatively easy to elaborate the building performance. For the task of façade refurbishment, this tool does not put enough emphasis on the façade related aspects as described above. It does not cover the function of the building, the owners’ and users’ wishes, or the economic demands on the project.

4.2.2. ABT Quickscan
The ‘Quickscan’ is a tool developed by the Dutch consultancy company ABT that can indicate if and how a building is suitable for transformation. It aims to answer the main questions: ‘Which future functions are possible in the given structures; and which expenses have to be expected to refurbish the building to those needs?’

The assessment is set up in three steps: Analysis, control, and evaluation. The assessment phase covers the six aspects: load bearing structure, building envelope, accessibility, interior finishing, technical installations, and location. The focus lies on the quality of these aspects and the normative requirements for possible future functions. All findings are fed into the computer tool. The program compares the given conditions with benchmarks for different functions and thus delivers a rating for transformation options between ‘very suitable and not suitable’. The user can then select the necessary refurbishment means for the different functions. Embedded financial data immediately presents rough cost estimations for the necessary interference.

Figure 4.20
ABT Quickscan Overview of the qualities of different features in a given building, screenshot (ABT adviesbureau 2009)
Just as the digital checklist by IFO, this tool provides the planner with a checklist for fast assessment of a given building. It also collects data on the users’ demands and the surrounding of the building. In the background the scan creates a relatively complete database of the initial situation. The graphic layout is very consumer orientated. Summing the results up to only six aspects and five levels of quality creates an overview, which is easy to understand for all stakeholders. The connection to financial data is useful to estimate the feasibility at a very early stage of the project. The tool takes a step further than providing a simple assessment by focusing on the topic of transformation. The decision, which solution may be suitable also depends on the creativity of the program operator. The direct connection to financial data meets the clients’ wishes but can also be seen as daring.

4.2.3. Arup SPeAR
The consultancy company Arup developed a tool to demonstrate the sustainability of a project. The ‘Sustainable Project Appraisal Routine’ (SPeAR) arranges the different quality aspects of a project into a framework, which allows judging the sustainability of each matter. Thus, the potential for improvement becomes visible for each aspect. The topic of sustainability is divided into four main sectors: Environmental protection, social sustainability, economic viability, and efficient use of natural resources. Each sector is subdivided into certain aspects. These aspects can be judged for each proposal according to standards defined in the program. The results of this judgement are presented in a wheel scheme. The aim is to reach minimal amplitude

Figure 4.21
Arup SPeAR: Indicators for the environmental, social, and economic sustainability of a project, as well as the consumption of natural resources (Arup 2008)
for each sector of the wheel. Thus, the environmental quality of each aspect is made visible. The wheel shows in which sector an improvement would be reasonable.

SPeAR is able to present very detailed information on the sustainability measure of a project. The wheel format creates an easily legible presentation. It indicates clearly the problems and potentials of each sector for a particular project and thus facilitates discussion with different stakeholders. For the topic of façade refurbishment, this tool focuses too much on the topic of sustainability. It leaves out further aspects, such as structural quality and building physics.

4.3. Assessment and evaluation tools used in the research project

The three tools presented above provide a widespread base for the assessment of building and very useful means to present the results. Based on these sources, the inventory checklist for building assessment and the evaluation tools have been developed, which are applied to the case studies presented in the next chapter.

An appropriate refurbishment solution for a case study can only be found, if different alternative refurbishment proposals are elaborated for each case. These solutions have to be compared in different aspects. The evaluation of the refurbishment proposals is separated into two levels. On the one hand, calculable aspects such as energy consumption and costs are simulated and quantified. On the other hand, further features of the refurbishment projects are qualitatively compared. These results are presented in a circular chart that gives an impression of the potentials of each proposal.

4.3.1. Assessment of a building to be refurbished

The thorough analysis of a given building is essential for refurbishment planning. In a first step all available material, drawings, energy bills, and expertise (structure, toxic material, and fire safety) have to be collected and evaluated. As older drawings often do not coincide with the actual situation, these need to be compared with the real situation and adjusted. In a first design phase of a façade refurbishment, at least the load bearing structure and the standard façades have to be measured. A complete photographic documentation of the building is very helpful for further planning work.

With the measurements clarified, the existing construction has to be determined. Therefore, the construction principle, building materials, overall quality, and state of maintenance are assessed. Thus, possible damages and technical problems can be found. In interviews with the building owner, users, and technical experts, the known technical problems, but also the potential of the building can be evaluated. Also the planning goals and restrictions can thus be clarified.
A comprehensive checklist, which indicates the points of interest and makes sure that no important aspects are left out, is useful for the building inventory on site. The checklist for the assessment of the case studies presented in this thesis is inspired by the methods explained above and practical experience. The logical order is based on the IFO checklist, starting with the overall building and then focusing on different zones. In addition to the technical factors necessary for the energetic calculation, the ABT Quickscan contributes the aspects of architectural design, functionality, future use, and users’ wishes.

During the course of the research project this inventory has been used for six different projects. In this process, the list has been constantly improved. Together with provided material on the building, the photo documentation and measurements, it permits to assess a given situation thoroughly and find the problems and potentials of the existing building. The detailed list can be found in appendix C.

4.3.2. Estimation of the energy demand
The energy consumption of a building is influenced by many factors, of which not all are predictable. For example the behaviour of the user, the ventilation rate and the management of technical installations are impossible to predict in simulations. Therefore, all norms for the performance of buildings can only mention the energy demand. This demand can be calculated based on normative rules. Different computer tools simplify and standardise the data input for such normative calculations. They deliver estimations of the annual energy demand for the office space in [kWh/m² GFA *a].

For the case studies it is important to compare different façade solutions with each other. To do so, a standard part of the building, usually one floor or several rooms in different locations, is analysed according to the German EnEV 2004. The programs ‘Enno-EnEV’ by Ennovatis and ‘CASA nova’ by the University of Siegen were used for this calculation. For more complex façade constructions, these thermo-static calculations could not represent the energetic interrelations. For example, the solar heat collection in an atrium or double façade can not be valued. Therefore, the proposals for the projects ‘CITG Delft University’, ‘University Bielefeld’ and ‘EnBW Stuttgart’ were also simulated using the program ‘Capsol’ by Physibel. This tool defines different zones of a building, simulates the annual thermal performance, and calculates the temperatures in these zones. Thus it determines an annual energy demand to achieve acceptable room temperatures.

All these simulations of energy demands can only be rough estimations, as they take place in a pre-design phase of the projects. The results are only supposed to indicate the potentials of the different proposals and compare these with each other. If a concept is considered interesting for further planning, more precise simulations have to be carried out to
make predictions on the building performance. The project ‘Sparkasse Vorderpfalz’ has been realised. Therefore, the different proposals were analysed thoroughly with the thermo-dynamic simulation program ‘DK-INTEGRAL’ by Delzer Kybernetik. The results of this simulation influenced the dimension of HVAC components, as well as the form of solar blinds and the colour of the façade panels.

4.3.3. Estimation of the construction cost
In the case studies, the construction costs for the different refurbishment proposals are estimated. In this pre-design phase only a very rough estimation is possible, but it serves to compare the different proposals. The cost finding is based on common literature, such as Plümecke (2008) (Plümecke 2008), and enquiries with manufacturers. Furthermore, the databases of the experienced planners, BLB Bielefeld, Evers Ingenieurgesellschaft, and Balck and Partner were helpful sources. The construction cost of the façade is calculated per \( m^2_{façade} \). The cost for HVAC installations is estimated per \( m^2_{GFA} \). All construction costs are presented excluding safety factors for unexpected incidents, and without taxes. Preliminary work, if it contains the same effort for all proposals, such as the removal of toxic material or the relocation of staff, is not taken into account. In case the relocation cost for office staff only applies to some of the proposals it is estimated with 350.00 € per person per day.

Usually the cost estimation was realised for a representative section of the building. Only, in case the refurbishment proposal contains a solution that covers a larger part of the building, such as atria, double façades, or central technical installations, the costs for these elements are allocated on the building parts covered by this solution. For example, the cost for an atrium roof is divided by the square meters of façades facing the atrium.

4.3.4. Operational cost
Operational costs cover not only the costs for heating, cooling, electric lighting, and operation of building services, but also the costs for maintaining the façade and building services, as well as window-cleaning. The energy costs result from a multiplication of the previously calculated energy demand with the price for electricity and natural gas. These prices are taken from the 2008 data by the Statistical Office of the European Communities (Goerten et al. 2008).

The operational cost of electric lighting is calculated by multiplying the installed power \( [W/m^2_{GFA}] \) with the estimated operational hours per year \( [h/\text{a}] \). Window cleaning costs of 3.00 €/m² for weathered façades and 2.00 €/m² for the insides are taken from the database of life-cycle-costs by Balck and Partner. The maintenance cost for technical installations are taken from the directive VDI 2067 by the Association of German Engineers (VDI 2000).
4.3.5. Life Cycle Cost

During the life span of 30 years the life cycle costs of a building can exceed the costs for the initial construction. This means that a solution, which is more expensive in the beginning, can pay back on operational costs in a relatively short time. For the comparison of different refurbishment proposals, the life cycle costs have been calculated for the major cost drivers. These include the construction cost, energy cost, and the operational costs as explained above. Further costs or gains, such as increase in rental rates and marketing potential, have not been calculated in this early design phase, as the focus lies on the technical improvement of the façade.

To evaluate the future development or operational costs, an annual increase of energy costs and inflation rate is applied. According to the Statistical Office of the European Communities, electricity costs have risen by approximately 5% in the past ten years (1998-2008). In the same period the oil prices quintupled (Tecson 2009). Based on this data, an annual increase of energy prices of 7% has been chosen. All other costs are expected to rise by 2% per year, which equals the average inflation rate in Germany and the Netherlands of the past 15 years (Centraal Bureau voor de Statistiek 2009; Statistisches Bundesamt 2009)

The comparison of life-cycle costing delivers graphs like Figure 4.24. The construction costs of the different proposals mark the starting point of the graphs. The unchanged initial situation starts with zero construction costs. In the course of time, the operational costs are added onto the initial costs. Due to the inflation rate and rise of energy costs, all graphs follow a parabolic gradient. At certain points in time the different curves intersect. The point, in which a proposal cuts the curve of the initial situation, symbolises the economic break-even point when the refurbishment has paid back on the savings on operational costs. The graph can thus show the performance of each concept in the long term and in relation to the other proposals.

![Life Cycle Cost Graph](image.png)

*Figure 4.22 Example of life cycle cost comparison for different refurbishment concepts taken from the case study ‘Bielefeld University’*
4.3.6. Wheel of Potentials

The results of the simulations and estimations explained above already provide a basis for the selection of a refurbishment strategy. Nevertheless, there are further features that cannot be quantified easily, but which should not be left out of the comparison, as they show further and often unexpected potentials of a design. In order to compare these potentials, a tool is needed that sums up the hard facts and also visualises the different ‘soft skills’ of a project. This overview wants to prepare the decision making process for one or the other refurbishment strategy by providing a rough overview at a very early stage of the planning process. Thus, every proposal shows its strengths and potentials for improvement in different aspects. The ‘wheel of potentials’ is an addition to the calculations and performance simulations explained before.

The means of assessment has been inspired by the common management tool called ‘competence wheel’, the same graphic principle underlying the ‘Arup SPEAR’. In this case, the different aspects of façade refurbishment are subdivided into four main categories. These are formed by the sustainability criteria defined by the World Commission on Environment and Development in 1987. Sustainability contains the three aspects of economic, ecologic, and social sustainability (World Commission on Environment and Development 1987). Transferred to the topic of façade refurbishment, these aspects are subdivided into four categories: The economic performance of a project, the ecological performance, which covers material consumption and energy demand, and the social sustainability, which can be divided into ‘Comfort’ as the quality of individual perception, and ‘Architecture and Function’ as the means to achieve the desired comfort and the socio-cultural perception of the building.

These four main categories are subdivided into the actual aspects of refurbishment which cover both quantitative and qualitative aspects. Figure 4.26 shows the assessed aspects with further sub-questions. While the hard facts can be simulated and quantified, the other aspects often depend on individual circumstances or even personal perception. The tool can therefore neither answer the question if a goal was achieved, nor to which extend. However, it can be used to say, how difficult it will be to achieve the desired goal.

When assessing the proposals, each aspect is therefore questioned: ‘Can the proposal manage to achieve the goal of/to (..)?’ The response options then are: ‘not at all’, ‘with big effort’, ‘with some effort’, or ‘easily’. It has been chosen for a graded scale of four ranks to eliminate the answer ‘average’. Additionally, a factor is provided for each aspect, which allows valuing its importance for the design task. For example, if the building is a cultural monument, the architectural design has to rather focus on ‘dealing with the existing design’ than on the creation of a new ‘architectural identity’. For presentation, the results are drawn into a circular scheme. The best answer scores full segments. If
a quality is impossible to achieve, the segment is left blank. Thus, the refurbishment proposal, which is the most likely to achieve all pre-set goals, is presented as the biggest wheel.

For the assessment of the case studies presented in the following chapter, the chosen selection covers the width of aspects in façade refurbishment. It will show that some proposal scores better in one aspect, while the other achieves a higher ranking in another sector. For example, a very good score in the comfort sector may have to be repaid by a poorer score in the field of construction cost or material consumption. Comparing these scores of different concepts, the planner can see immediately, in which aspects a concept needs improvement, or in which field the preferred solution can be inspired by the other proposals.

The wheel of competences is an individual tool that allows the rating of pre-defined features. The estimation of the necessary effort to achieve a goal depends on the individual valuation of the person to fill in the database. Therefore, it is necessary to assess the different proposals in direct comparison. Also, the selection of features depends on the point of focus and the overall planning target. Different stakeholders can adjust the tool to their needs and put a stronger emphasis on the sector of their choice. A project developer would ask more questions on the economic feasibility, while a building user would probably put more weight on the interior comfort.

<table>
<thead>
<tr>
<th>Economic aspects</th>
<th>Main aspect</th>
<th>Sub aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Construction cost</td>
<td>Construction cost</td>
<td></td>
</tr>
<tr>
<td>2 Interference with use</td>
<td>Disturbance time</td>
<td>Interference with ongoing work</td>
</tr>
<tr>
<td>3 Operational cost</td>
<td>Energy cost</td>
<td>Maintenance HVAC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintenance Façade</td>
</tr>
<tr>
<td>4 Additional benefits</td>
<td>Gain of space</td>
<td>Façade use for marketing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improvement of the building's and users' image</td>
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Figure 4.23
Example of a 'Wheel of Potentials'

<table>
<thead>
<tr>
<th>Can the proposal achieve the goal of/ (Yes)</th>
<th>Factor</th>
<th>no</th>
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<th>2</th>
<th>3</th>
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<td>1</td>
<td>1</td>
<td>4</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>short time disturbance of building users</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td></td>
<td>2</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>minimal interference with interior finish</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
<td>0</td>
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<td>2</td>
</tr>
<tr>
<td>minimal nuisance and disturbance of staff noise / dirt</td>
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<td>0</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td></td>
<td>6</td>
</tr>
<tr>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>low maintenance costs (façade) in relation to the other proposals</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td></td>
<td>6</td>
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<tr>
<td>gaining extra rental space</td>
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<td>0</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
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<tr>
<td>using the façade for commercial representation of the company</td>
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<td>0</td>
<td></td>
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<td>improving the public perception of the user / owner</td>
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<td>0</td>
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<td></td>
<td>0</td>
<td></td>
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<td>6</td>
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<td>Sub aspects</td>
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<td></td>
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</tr>
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<td>--------------------------------------------</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
| 1 Production        | Amount of material needed  
                        | Sustainable material                     |
|                     |                      |                                            |
| 2 Building process  | Reuse of components  
                        | Recycling of removed components            
                        | Influence on structure                    |
|                     |                      |                                            |
| 3 Period of use     | Energy consumption   |
|                     | Use of renewable energy |
|                     |                      |                                            |
| 4 End of life       | Recyclability of the components |

<table>
<thead>
<tr>
<th>Comfort</th>
<th>Main aspect</th>
<th>Sub aspects</th>
</tr>
</thead>
</table>
| 1 Visual comfort | Daylight  
                        | View                                      
                        | Sun protection                          
                        | Glare protection                        |
|           |                        |                                            |
| 2 Acoustic comfort | Acoustic quality in room  
                        | Sound insulation indoor-outdoor            
                        | Sound insulation room-room               |
|           |                        |                                            |
| 3 Thermal comfort | Summer condition  
                        | Winter condition                          |
|           |                        |                                            |
| 4 Individual control | Opening windows  
                        | Mechanical ventilation                    
                        | Heating                                   
<pre><code>                    | Cooling                                  |
</code></pre>
<table>
<thead>
<tr>
<th>Can the proposal achieve the goal of/ to (...)</th>
<th>Factor</th>
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<th>2</th>
<th>3</th>
<th>Sum</th>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>use sustainable material</td>
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<td>0</td>
<td>1</td>
<td>2</td>
<td></td>
<td>4</td>
</tr>
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<td>3 Design for future use</td>
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<td>Change of HVAC</td>
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<td>Change of façade design</td>
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<td>4 Health and safety</td>
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<td>improve the identification of the user with the building</td>
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<td>provide a high quality interior</td>
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<td>provide the desired functionality</td>
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<td>create functionalities beyond the original demand</td>
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<td>provide capacity for a future change of function</td>
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<td>easily relocate dividing walls</td>
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<td>maximize floor height</td>
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<td>an adaptable HVAC installation</td>
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<tr>
<td>provide sufficient space for HVAC ducts and units</td>
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<tr>
<td>use products of different manufacturers</td>
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<tr>
<td>easily change the outer looks of the building</td>
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<td>easily upgrade the façade properties in the future</td>
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<td>comply with daylighting standards</td>
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<td>keep workspace free of toxic material</td>
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<tr>
<td>provide good air quality (immissions / easy maintenance of air ducts)</td>
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<tr>
<td>provide adequate fire protection</td>
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4.4. Conclusion

The planning of a façade refurbishment has to cover a large span of aspects. Next to the usual design tasks of a new building project, such as architectural design, load bearing system, and technical installations, the refurbishment has to deal with a given situation. Here the original design, the structural and technical properties, and the – potentially hazardous- original materials have to be considered. None the less, the refurbished building has to fulfil today’s demands on user comfort and energy performance, just as the need to express the users’ identity to the outside. Thus, the refurbishment has to cover more than just the façade. As this research focuses on the technical properties of a building envelope, it takes a close look at possible combinations of technical building services with different refurbishment strategies for the façade.

This chapter has evaluated different forms of assessment for existing buildings. Each of these assessment tools has its individual focus, either on the evaluation of energy performance, on the transformation potential, the sustainability rating, or the economic feasibility of a project. For the following case studies, a checklist has been developed for the inventory of existing buildings. This list is presented in Appendix B. The collected data supports the calculations of energy demand and life-cycle costs, which are the base of comparison of different refurbishment proposals. These hard facts, however, can not cover the entire width of aspects in a project. For example, the user comfort, the correlation with the urban environment, the future adaptability of a design, or the construction process can only be estimated by individual experience. Therefore, a rating system has been developed, which indicates the necessary effort to reach a certain goal among the ‘soft skills’. The ‘Wheel of Potentials’ generates visuals for direct comparison of different proposals. Its application will be shown in the following chapter.
4.5. References


5. Case Studies

The previous chapters described methods for the assessment of existing buildings and refurbishment proposals, as well as different refurbishment concepts in common practise. However, it has not yet been evaluated to which extend a certain refurbishment concept is generally applicable to different façade types. Chapter 3 elaborated the distribution of façade types in different decades. It found out that certain façade types are strongly overrepresented in the Western European building market. Therefore, the further research aims to find the best applicable strategies for these façade types. This chapter develops technical solutions for five case studies, which can stand representative for a larger portion of the market. Furthermore, it presents product developments, which focus on solving the typical problems of the two most common façade types in the Netherlands, the UK, and in Germany.

Table 5.1 shows the distribution of the most common office façades. The table is divided horizontally into the different façade types. The columns represent the three construction periods as described in chapter 2: ‘post war reconstruction’ from 1950 to 1965, ‘the phase of economic prosperity’ from 1965 to 1980, and the later development since 1980. The grey cells of the table mark those façade types that have proven to be very common in the spot checks. For each of these common types a representative building has been chosen and assessed in an intensive feasibility study. The grey frames cover those façade types that may be interesting to be solved with the help of the two product developments ‘Refurbishment Window’ and the ‘Post-Beam Adapter’.

The five case studies to be presented follow the principle of ‘research by design’. The given building is thoroughly analysed using the means and checklists presented above. For each given building three to four different refurbishment concepts are developed. These are inspired by the currently available concepts, explained in chapter 2. Furthermore, individual solutions are developed, which take advantage of the possible synergetic effects of each special situation. These possible solutions are then evaluated on technical practicability, energy consumption and the further qualities according to the ‘wheel of potentials’. Three of the case studies are furthermore assessed on construction cost and life cycle cost.
Table 5.1
Distribution of case studies according to their façade type and decade of construction
The following projects are assessed:

- Façade type 2.1.2  
  Faculty of Civil Engineering & Geosciences (CiTG),  
  Technical University of Delft, The Netherlands
- Façade type 4.1.2  
  Office of EnBW, Esslingen am Neckar, Germany
- Façade type 5.1.1  
  University of Bielefeld, Bielefeld, Germany
- Façade type 5.4.2  
  Sparkasse Vorderpfalz, Ludwigshafen, Germany
- Façade type 5.4.2  
  Head office of EnBW, Stuttgart, Germany

The product developments presented in this chapter approach the task of façade refurbishment from a different direction. The market analysis and the case studies showed that there is a large request to refurbish an office building while it is in use. Therefore, these developments focus on those two façade constructions, which together resemble almost two thirds of the Western European building stock. For each of these, a solution has been developed together with the façade manufacturer ‘Kawneer’, which improves the performance of the building envelope and the technical building services without interfering with the office interior. The ‘Refurbishment Window’ is a special window system that can be combined with different climate concepts. This approach uses the advantages of pre-fabrication and applies both, the new façade and the building services from the outside of a building. For post-and-beam façades an adapter-profile is presented, which makes it possible to mount a new façade onto different existing structures. Thus the building envelope is improved while the connections to dividing walls and interior finishes are unchanged. The principle is registered with the European Patent Office under Patent-no.: 09159513.2-2303.

The results of the case studies presented in this chapter deliver a deep insight into the problems of refurbishment, the variety of possible solutions, and the consequences of their application to real projects. All designs presented in this chapter serve as examples and not as definite solutions. The focus lies on the technical potential of the refurbished façade. With this focus it is possible to put the findings on a wider base and apply the general strategies to further façades with similar features. Thus, the following chapter will elaborate these general recommendations.
5.1. Faculty of Civil Engineering and Geosciences (CITG), Delft University of Technology

The faculty of civil engineering at Delft University of Technology was designed in the 1960s by the Dutch architects Van den Broek and Bakema. The building is a prominent example of Dutch Brutalism. Although it is not (yet) listed as a monument, the university and municipality of Delft desire to preserve its original appearance as a so-called ‘Young Monument’. The University is planning to refurbish the building in 2010. In this respect, the author tutored the graduation research by Hilde Roodvoets, which assesses the building, develops promising refurbishment concepts and evaluates these.

5.1.1. Building characteristics

Name: Faculty of Civil Engineering and Geosciences, Delft University of Technology
Location: Delft, the Netherlands
Owner: Delft University of Technology
Occupant: Delft University of Technology, Faculty of Civil Engineering and Geosciences
Year of construction: 1969
Architects: Van den Broek & Bakema
Use: Administration, Education
Gross floor area: Approximately 70,000 m²
Facade area: Approximately 30,000 m²
Facade type: 2.1.2 Cantilevering structural platforms, Steel window units
Main structure: Concrete framework, cantilevering 6.50m towards the facade
Challenges: No thermal insulation of facade
Building considered a ‘Young Monument’
Ambitions: Improvement of facade insulation
considers the architectural design

5.1.2. Initial situation

Figure 5.1
Elevation with service balconies and cladding of pre-fabricated concrete
5.1.2.1. Architecture
The building was designed by Van den Broek en Bakema Architects, who became famous for their brutalism style, the use of visible concrete, and strong geometric gestures. In this building the service-balconies along the façade are a typical manifestation of such design concepts. The building is designed to resemble a semi-trailer truck. In this respect, the overall appearance and the horizontal gesture of the service platforms is under consideration for a monumental status.

The ground floor of the building is kept free of work functions and provides large passages underneath the building. The upper six storeys appear to rest on the prominent lecture halls. The first floor functions as the main hall, in which the entrances to lecture halls, the secretariats, and students’ meeting places are situated. The upper floors are occupied by office and study rooms.

Figure 5.2
Original design idea, the building resembles a semi-trailer truck (Bouw 1976)

5.1.2.2. Structure
In the initial plan, the building consisted of only four floors. Due to the increase in student numbers an extra storey was already added during the planning process. It was decided during the construction phase to add another floor to the building. Thus, the first five floors of the building are constructed in concrete. Only the top floor has been built as a steel framework in order to reduce structural loads. The load bearing structure consists of a concrete framework cast on site and prefabricated concrete floor plates. The façade cantilevers 6.5m from the main structural columns. Ring beams take in the loads on the far edges of each floor. These ring beams are interconnected by steel columns, which function as tension cables preventing a dangerous deflection by transferring load to other floors.

5.1.2.3. Façade construction
The façade is articulated by the concrete Ring beams, which are made visible as service platforms. Prefabricated concrete panels rest on this structure and form the outer cladding. The filling façade structure is made of steel frames, which are horizontally separated into four zones. The lower part is filled in with an enamelled single glass pane, 20mm of insulation and an inner asbestos-reinforced panel. The second part contains opening windows. The third part is filled with a fixed single glass pane; and the top zone is formed by small pivot-hung windows. All glass panes are luted into the steel framework from the outside.

Figure 5.3
Cross section of the load bearing system
On the bottom, the façade rests on the prefabricated concrete unit. The top edge is directly attached to the structural ring beam. Horizontal loads are transferred to the structural steel columns. The façade is equipped with Venetian blinds, placed on the outer edge of the service platforms. Additional interior Venetian blinds offer individual glare protection.

5.1.2.4. Interior finishing
The building does not provide a floating top-floor. The linoleum or carpet floor cover is glued directly onto the concrete floor. Dividing walls are made of wooden boards and painted. The dividing walls between corridor and office rooms are formed by cupboards, which open onto the offices. A suspended ceiling inside the office rooms covers installation ducts and improves the acoustical performance.

5.1.2.5. Technical installations
The main part of the building with office rooms and corridors is naturally ventilated by opening windows and small flaps for permanent
ventilation in the top zone of the façade. Radiators in front of the façade are used for heating and provide sufficient capacity to reduce cold air draughts at the non-insulated façade. There is no cooling installed in the regular offices. The lecture halls are mechanically ventilated and air conditioned. Furthermore, some offices on the top floor have recently been renovated and equipped with centralised mechanical ventilation and chiller baffles.

5.1.3 Refurbishment tasks
The Technical University of Delft has set up an energy efficiency plan which is part of the ‘Multi-Year-Agreement’ that the University has signed with several Dutch companies and the national government to reduce the University’s energy consumption. Each year energy use is to be reduced by at least 2%, which will result in a total improvement of energy efficiency by 30% by the year 2020. Currently, the CITG faculty building consumes 7,327 MWh per year, which resembles 18% of the University’s total energy consumption. According to the TU Delft energy monitoring, 88% of the transmission heat loss in this building is currently due to the non-insulated glass façade (Winkels 2009). Hence, its refurbishment will significantly reduce the total energy consumption of TU Delft.

The Design of the façade is not yet listed heritage, but new proposals have to deal carefully with this building. It is an important work by famous architects, which became even more important since the neighbouring building (Faculty of Architecture) by the same architects burnt down in 2008.

5.1.4 Refurbishment proposals
Four Redesign proposals have been developed for this project. Each proposal is evaluated with the thermo-dynamic simulation tool ‘Capsol’ and tested on thermal bridges. The further features of each concept are evaluated using the tool ‘Wheel of Potentials’.

Proposal 1 – Climate façade: Addition of an insulated layer
- Additional insulated façade layer on the outside of the service balconies
- Adaptation of the initial façade to an exhaust façade
- Mechanical ventilation

Proposal 2 – Upgrade: Glass replacement in the existing façade
- Reuse of the original steel frames
- Double glazing of the original profiles
- Option: Corridor façade formed by an additional non-insulated exterior glass layer

Proposal 3 – Hidden insulation: Retrofitting and partial replacement
- Removal of concrete units, adding of insulation, re-mounting of the original units
- New window units
Proposal 4 – Façade replacement (Makeover)
- New window units
- Ventilated cladding on the ring beams
- Supported natural ventilation

5.1.4.1. Proposal 1 – Climate façade
This proposal aims to provide an improved technical standard with minimal interference to the interior. It uses the existing service platforms to apply an additional insulated curtain wall façade to the outside. The initial façade is only marginally adapted.

5.1.4.1.1. Construction
A new insulated post-beam curtain wall is mounted on the outer edge of the existing balcony structure. The supporting connectors punctuate the existing concrete panels and are fixed to the load bearing ring beams. In front of the floors, the façade is filled with an opaque panel.

Figure 5.6
Standard section of the ‘Climate façade’
and additional insulation. The original façade now functions as an inner non-insulated layer of an exhaust façade. In each office room one opaque panel is removed from the balustrade and replaced with a ventilation grid that permits exhaust air to flow to the cavity.

5.1.4.1.2. Climate concept
The two façade layers function as an exhaust façade, in which the outer shell provides the insulation and the inner façade works as a screen between the buffer zone and the inside climate. The climate control is mechanically regulated. Fresh air is taken in centrally and led past a cross flow heat recovery. The ventilation air is brought into the rooms from the ceiling. Used air is extracted from the façade cavity. New openings at the bottom of the inner façade layer allow used air to pass from the room to the cavity. The used air is transported horizontally through the cavity and mechanically extracted. Thus, excessive solar gains are removed from the cavity before reaching the office space. The central exhaust duct passes through a heat recovery system. The ventilation system can bypass the heat recovery to cool down the building at night. The existing radiator heating is preserved and equipped with individual thermostats. No further cooling is installed.

5.1.4.1.3. Results
This concept provides a fast and simple solution to reduce energy consumption and raise the indoor comfort. The additional façade improves the insulation of the building without the need to adjust the initial façade construction. The new façade can be mounted from the outside, independently from interior work. The zone next to the window will become much more comfortable. The inner façade layer always has the same surface temperature as the other walls, because the used air from the room passes between this layer and the exterior façade. However, the comfort advantage of natural ventilation will be gone because this type of façade requires a mechanical system. The energy efficiency can be improved by using a central heat exchanger and by applying sun blinds in the cavity, which work independently of the weather.

Figure 5.8
Potentials of the solution Climate façade
The load bearing connection of the new façade is difficult, as it needs to punctuate the existing concrete panels. Also, the additional weight at the far end of the ring beam causes structural problems, which may have to be solved by strengthening the existing structure. Alternatively, removing the concrete units should be considered. This can free up structural capacity, but also leads to the removal of the inner façade layer, which rests on the prefabricated façade unit.

5.1.4.2. Proposal 2 – Upgrade
This proposal reuses the original façade structure and aims to improve the thermal comfort by replacing the single glass with insulated glazing.

Figure 5.9
Detail sketch of the opening windows: The insulated glass is fitted into the original frames with structural silicone; the hollow profiles are filled with insulation material and covered with an insulated cover-cap.

Figure 5.10
Standard section, Option 2 – upgrade
5.1.4.2.1. Construction
The original steel framework is constructed of T-shaped profiles, into which the glass is luted. These original glass panes are removed and the profiles cleaned. New insulated stepped-edge glass panes are placed in the original profiles using structural glazing silicone. Thus, a weather proof sealing is achieved, and the stepped edges cover the thermal bridges of the steel framework. The prefabricated concrete elements of the façade cannot be removed, as the façade structure rests on these. Therefore, the ring beams are insulated on the inside. To do so, the suspended ceiling has to be opened along the façade. The exterior Venetian blinds are renewed in the original position.

5.1.4.2.2. Climate concept
The climate concept is not changed. The offices are naturally ventilated by opening windows. The upper pivot-hung windows, originally intended for permanent ventilation, are replaced by fixed glazing. Thus, only deliberate and conscious ventilation is possible. The existing radiator heating can stay in place. However, it is recommendable to replace the radiators with smaller and faster units, as the improved façade demands less heating capacity.

5.1.4.2.3. Results
The concept provides a simple way of reusing the existing façade without the need to change any connections to interior finishings, floor, ceiling, or dividing walls. While the appearance from the inside is unchanged, the exterior impression changes slightly. The structural glazing in the original profiles creates a homogeneous surface, which can be seen as a modern interpretation of the original design. During the refurbishment process, it has to be checked carefully that the steel structure is still reliable. Broken or corroded members have to be replaced. Initially, the façade structure has been engineered to carry wind loads, much higher than the structural loads. Therefore, it is also capable of carrying the weight of insulated glass.

![Figure 5.11](image1)
Thermal analysis of the existing façade profile with new insulated stepped edge glass

![Figure 5.12](image2)
Potentials of the solution “upgrade”
The concept leaves thermal bridges in the construction, mainly in the floor connections, which are responsible for some loss of heating energy, but the simulation has shown that no condensation occurs in these. However, the window frames still hold a risk of condensation in very cold weather conditions, even if they are equipped with double glass. Using triple glass can prevent these thermal bridges. Alternatively, an additional second glass layer can improve the performance of the façade significantly. This glass layer is installed between the service balconies and forms a non insulated corridor façade, which serves as thermal buffer. In winter, the temperature is higher in this cavity, which eliminates the risk of thermal bridges. In summer the cavity needs to be sufficiently ventilated to prevent heat accumulation. This can for example be achieved by partially opening the outer glass layer.
5.1.4.3. Proposal 3- Hidden insulation

This refurbishment concept was originally sketched by Paul Coenen and Wouter Hendrikson in a student workshop and developed further in this case study research. It takes advantage of the prefabricated construction of the building and improves the thermal insulation without changing the exterior design.

5.1.4.3.1. Construction

In a first step, the prefabricated concrete elements are taken off the façade and brought to an on-site workshop. There, the elements are cleaned. In the mean time the concrete structure of the building is insulated with mineral wool. On the top of the ring-beams foam glass is used, because it will have to carry the concrete units. When these are brought back into place they are fixed by new bolts and come to rest some 80 mm higher and further outward than before. The space thus created between concrete element and original top floor provides the optimal connection for a new insulated window system to be mounted from the inside. The Venetian blinds on the outer edge of the service platforms are replaced.

![Diagram of the refurbishment concept](image)

**Figure 5.15** Standard section of the refurbished façade with additional insulation and new windows

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5.1.4.3.2. Climate concept
The existing building service concept is maintained. After the refurbishment, the offices can be naturally ventilated. The original radiator heating can generally be reused. Nevertheless, it is recommendable to place new, more efficient radiators along the façade. Thanks to the improved insulation, the amount and size of radiators can be reduced.

5.1.4.3.3. Results
This concept provides an easy solution for the regular façade detailing. Due to the corner situation, where the thickness of the façade becomes evident, a special detailing needs to be considered. This can either be a special cover for a wider joint or a newly manufactured corner element. The material consumption of this solution is limited to a minimum. The original steel-glass façade can be recycled; the end-of-life quality of the new façade depends on the choice of construction and insulation material.

The exterior appearance of the building is not changed much, in keeping with the demands of the building owner and municipality. On the other hand, the effect on the interior climate is significant. The retrofitted building envelope provides the same insulation as a new façade. Draught and cold radiation is eliminated. Operable windows, new sun blinds, and individually controllable heating installations provide the optimal indoor comfort.

However, the solution is very labour-intensive and therefore costly. Taking out the original façade and the relatively long construction time demands the adjacent office space to be vacated. The shape and fitting of the prefabricated concrete elements allows refurbishing the building floor-by-floor, so that the building does not have to be entirely vacated.

![Figure 5.16](image_url) Corner situation, which needs to be solved by expanding the existing joint

![Figure 5.17](image_url) Perspective view of an office room with additional insulation and new windows

![Figure 5.18](image_url) Potentials of the ‘hidden insulation’ for the CITG building
5.1.4.4. Proposal 4 – Façade replacement (makeover)
By replacing the entire façade a new up-to-date solution can be created. This concept aims to combine the best technical solution with a maximum gain of useable space and an efficient climate concept.

5.1.4.4.1. Construction
The original façade and the prefabricated concrete elements are removed. Thereafter, a new window façade is placed on the outer edge of the floor. The load bearing ring beam is insulated and equipped with a ventilated metal cladding. Thus, the depth of the former balcony is added to the office space.

Figure 5.19
Section of standard office with the replaced façade on the outer edge of the service platforms
5.1.4.4.2. Climate concept

The climate concept is based on supported natural ventilation and the activation of thermal mass. Controlled central exhaust ventilation extracts air from central zones such as bathrooms, kitchenettes, and copier rooms. The negative pressure thus created drags air from the office rooms through grills in the dividing walls. The volume of incoming air can be controlled for each office room by ventilation openings in the top part of the façade. If a higher air exchange rate is desired, small fans support the ventilation. These can either be operated by the user or centrally overruled. Fresh air is led through the suspended ceiling, where it passes along the thermal mass of the concrete floor. Thus, the air absorbs thermal energy from these building parts. In winter this concept prevents cold air draughts. In summer this system is used for efficient cooling. During the day the concrete mass absorbs heat from the incoming air. At night the building is flushed with cold air, which cools down the thermal mass. Optional ‘Phase-Change-Materials’ in the suspended ceiling can further improve this effect.

Furthermore, the office rooms are equipped with a new floor heating. Capillary heating pipes are mounted onto the concrete floor and bound in a new anhydrite top-floor. Elevating the top floor usually demands adjustments of staircases and doors. Fortunately, this building is equipped with traditional wooden doorsills, which are 3 cm higher than the original floor. This height is sufficient for the new top floor in the office rooms. The corridor floor is left at the original height.

5.1.4.4.3. Results

The new façade provides the best possible technical standard. It prevents thermal bridges and creates optimal thermal comfort. The floor heating provides a very comfortable means to condition the ambient temperature. It can be also run on a lower water temperature than the existing radiators. The heating energy can thus be taken from geothermal sources or from the University’s district heating system. The ventilation concept facilitates an efficient night cooling with passive means. If the thermal mass is cooled down at night, no active cooling is necessary.

Replacing the entire façade, suspended ceiling, and top-floor causes major interference with the building structure and the daily work. The structural principle of the original façade makes the building process rather difficult. The concrete panels can only be removed together with the original windows, because these rest on each other. Therefore, it is not possible to refurbish the façade floor-by-floor, but it is necessary to vacate all floors on one side of the building during the refurbishment process. However, placing the new façade to the outer edge of the building frees up additional office space. The interior is fully renovated, which provides the user with a new and up-to-date work environment and the best possible comfort.
5.1.5. Comfort comparison of the different strategies

All proposals and the initial situation have been evaluated on their energy performance and their effect on indoor comfort. Two standard office rooms, one on each side of the building, have been simulated with the simulation tool ‘Capsol’. This simulation has delivered the thermal performance of the office space and thus the heating and cooling energy needed to achieve a comfortable indoor climate. For summer it was set to restrict the hours exceeding 26°C to 85h/a.

As the building envelope is currently responsible for the enormous energy demand of the building, any improvement of the façade achieves a big reduction in the demand for heating. The first proposal (‘Climate Façade’) achieves very good thermal insulation in winter thanks to the new building envelope, and also reduces heating demand through efficient heat recovery. However, the solution also causes the highest demands for cooling. This is owed to the solar gains in the cavity. The Venetian blinds absorb solar irradiation and the ventilation system cannot extract the heat gains quickly enough to prevent them from reaching the office room.

The second proposal (‘Upgrade’) places new glass panes into the original façade profiles. The façade profiles, especially the frames of opening windows, and the cantilevering service platforms form major thermal bridges. Thus, this concept only reaches the lowest level of insulation of all concepts. The alternative proposal with a secondary glass layer in front of the improved primary façade could improve the energy performance. In summer, however, the poorer insulation level becomes an advantage. At night time the building has a better chance to cool down. Furthermore, the exterior Venetian blinds provide a very effective sun protection, which as a consequence leads to a very low cooling demand.

Replacing the original façade, as it is suggested in proposal 3 (‘Hidden Insulation’), reaches the same insulation level as the first and fourth concept. However, in this situation the heating demand is higher.
because the building is not equipped with controlled ventilation. Without heat recovery much thermal energy is lost. The fourth concept represents an elaborated combination of façade construction and ventilation concept. The new building envelope provides the best possible insulation level. By shifting the façade to the outer edge of the floor, more solar irradiation enters the room, which saves heating energy. In summer, the exterior Venetian blinds provide very good sun protection. The biggest reduction of cooling demand is achieved by the supported ventilation and the activation of thermal mass.

The simulation has only offered the final energy demand for heating and cooling. For a more comprehensive comparison it would be necessary to add the operating power to the calculation. The first and fourth proposals are equipped with mechanical ventilation, which would result in a higher demand for operating energy. Particularly the climate façade concept demands a lot of fan-power to extract the solar gains from the cavity.

5.1.6. Conclusion
The thermo-dynamic simulation of the first proposal (climate façade) with the program Capsol has shown that the ventilation concept of the exhaust façade does not function. The cavity is too wide for a sufficient air movement to appear. Only with very much fan-power, a sufficient extraction of solar gains could be achieved. Hence, the climate concept as explained here does not make sense to be applied. Nevertheless, the structural option to mount a new curtain wall in front of an exiting façade is worth investigating. While the new façade is installed, the office work can continue. At a later stage, the original façade is removed and the floor zone along the façade is adjusted. Thus, the interference time for each office room is very short and the floor area of the original balconies is added to the usable space.

The second proposal is most useful if it is desired to refurbish the building while the offices remain occupied. It permits improvements to the building envelope from the outside. The only interference with the interior finishings is the addition of interior insulation on the structural ring beams. This can be applied within two working days per room. Nevertheless, the concept is very fault prone, as many details and façade connections have to be solved. Here, the additional glass screen can help to reduce the thermal bridges as well as the weather
impact on the retrofitted primary façade. Generally speaking, the idea to re-glaze steel profiles with stepped glass and structural silicone has proven to be more practical than expected. However, the example of the faculty building was too complex. It appears to be more applicable to smaller window frames with simpler connections to adjacent walls with no opening windows.

Option three, the cleaning and re-mounting of the original concrete units, is a fascinating combination of monument protection and the wish for an up-to-date technical performance. It does not only preserve the original shape and geometry, but also the materiality of the building envelope. Technically it provides an entirely new façade, which can eliminate thermal bridges even in a building with cantilevering platforms. In this particular case, it can be realised faster and in a more flexible manner than proposal four. The geometry of the concrete panels permits to refurbish the building floor-by-floor, only if the new façade is mounted in the same position as the original one. The refurbishment concept ‘hidden insulation’ is thus not only an interesting option for the presented building. In the Netherlands there are many more buildings of a similar construction. National policy is being developed as to what extent the typical buildings of the late 1960s and early 1970s designs should be protected as so-called ‘Young Monuments’. In such case, the replacement of the façade would be difficult to argue. With this concept, it is possible to combine the often contradictory sustainability-goals to preserve cultural heritage and reduce the consumption of natural resources.

The fourth proposal, ‘Façade Replacement’, would provide the best technical performance of all concepts, because it resembles a proven construction with commonly known products. The ventilation principle is a relatively simple means to activate the thermal mass of an existing building, even if this is equipped with suspended ceilings. The concept shows that the best results can be achieved if the building envelope and the building services are planned in unison.

Summing up the findings of all evaluated proposals, the optimal solution for the given situation would be a combination of the proposals 3 and 4. The refurbishment task to preserve the exterior impression of the building can best be achieved by adding insulation under the original concrete units. The new façade to be placed between these units can on the one hand provide the desired improvement of indoor comfort. On the other hand it holds sufficient design possibilities to step into a dialogue with the authentic concrete balconies. Furthermore, the fourth proposal can contribute an elaborated concept for the building services. It has to be evaluated in further planning steps, to which extend it is helpful to install the proposed ventilation system. However, using the height of the existing doorsills to bring in a floor heating, can provide a very comfortable means of heating and cooling, frees up the space currently occupied by the radiators, and allows for renewable energy resources to be used for the low temperature heating system.
5.2. Office building EnBW, Esslingen am Neckar, Germany

The office building of EnBW in Esslingen provides the most typical construction in Germany of the late 1970s through to present day. This case study focuses on the possibilities of a ventilated cladding in combination with different building services-systems. Four different refurbishment strategies are presented. The focus lies mainly on the thermal and energetic performance. Hence, the assessment focuses on qualitative aspects rather than on the life cycle costs.

5.2.1. Building characteristics

Name: Office building of EnBW Esslingen
Location: Esslingen, Germany
Owner: EnBW Real-Estate, Stuttgart
Occupant: EnBW – Energie Baden-Württemberg
Year of construction: 1979
Architects: Albert Ruf with Bartzsch + Flach
Use: Administration
Gross floor area: Approximately 10,000 m²
Façade area: Approximately 4,500 m²
Façade type: 4.1.2 Load bearing wall with ventilated cladding and service platforms
Main structure: Concrete cast on-site
Challenges: New HVAC concept
Wish for opening windows
Ambitions: Improvement of the thermal performance
Improvement of user comfort
Improvement of outer appearance

Figure 5.23
Elevation of EnBW administration building in Esslingen
5.2.2. Initial situation

5.2.2.1. Architecture
The EnBW building was designed in 1979. The floor plan of the building is shaped like a cross of 90m x 60m. The building contains five floors above ground level and one basement partly above ground. It was designed as an office building and will maintain this use after refurbishment (Ebbert 2007).

5.2.2.2. Structure
The building is supported by an on-site concrete structure with load bearing concrete columns in the central part and concrete parapets supported by steel columns within the façade construction. Support of horizontal loads is realised by two cores and concrete walls at the head of each aisle. The building shows several steps back in the façade, which create space for roof terraces on different floors.

5.2.2.3. Façade construction
The façade is constructed of massive concrete parapets, clad with aluminium panels and rows of windows. Gangways outside the building support the sun shading and are used to maintain the façade. The parapets are insulated with 8cm of mineral wool, a high standard at the time of construction. Eye-sight inspection has shown that the insulation is generally in a good state, though in some positions damages caused by construction work (drilling holes) and animals have been encountered. The u-value of the closed parts of the façade is estimated to be approximately 0.42W/m²K. The existing windows are a customised construction. The frames are equipped with a thermal barrier, which was already common standard at the time of construction. The windows do not open and are equipped with double glazing. This is estimated to provide a u-value of 3.0 W/m²K.
5.2.2.4. Interior finishings
The interior partitions can be placed in the façade grid of 1.25 m. The dividing walls are made of unitised elements clad with coated chipboard. Suspended ceilings consist of powder-coated metal panels, perforated for acoustical reasons and for ventilation.

5.2.2.5. Climate installations
The building is fully air-conditioned with fixed windows. Ventilation and humidification are exclusively provided by a central mechanical system. Supply air to office spaces is brought into the room via induction units at the façade, which provide heating and cooling. The distribution ducts are located in the suspended ceiling and serve the floors above. Exhaust air is extracted through the suspended ceiling. A central heat recovery was installed in the 1990s. The efficiency of the heat recovery unit is estimated to be around 30%. The existing tubing is considered to be in need of replacement.
5.2.3. Refurbishment tasks
The building represents a very high quality for the time of its construction. Even today a u-value of 0.42 is not too bad a standard. The façade is in a very good state of maintenance. It is rather window technology that has improved significantly in the past time. Therefore, here lies the biggest potential for improvement. Furthermore, the building owner demands operable windows to be installed. The building services are outdated. The central mechanical ventilation system needs to be renewed, as well as the induction units in the rooms. All tubing for heating and cooling circuits is considered unreliable and shall therefore also be replaced. These means can not be realised without disturbance of the interior. Half the building is currently vacant. Therefore, the refurbishment may interfere with the interior finishings but should limit the production of noise and dirt.

5.2.4. Refurbishment proposals
Four different refurbishment proposals explore the potentials of the building. Different architectural designs, methods of building services installation, and levels of comfort are compared. The windows and façade cladding are altered to different extent. Some proposals suggest renewing the central mechanical ventilation system, while others prefer a solution without air ducts. The following concepts are analysed:

Proposal 1 – Improvement of the existing façade
- Technical improvement of the existing façade
- Replacement of the ventilation system

Proposal 2 – Removal of the platforms
- Thermal improvement of the existing façade
- Removal of the service platforms
- Basic heating and cooling system
- Opening windows

Proposal 3 – Decentralised ventilation
- Replacement of the ventilated cladding
- Decentralised, façade orientated mechanical ventilation

Proposal 4 – Façade integrated services
- Replacement of the ventilated cladding
- Different HVAC components integrated into the façade

5.2.4.1. Proposal 1 – Improvement of the existing façade
The existing façade cladding provides plenty of space for additional insulation. This proposal brings the building performance up to date by replacing or improving the existing components without changes in the actual function. It has little impact on the façade design and aims to prevent alterations of connections between façade and dividing walls and floors.
5.2.4.1.1. Construction
The façade cladding is removed, cleaned, newly coated, and brought back into place. Additional insulation is placed in the cavity behind the façade cladding. The structure of the service balconies is cleaned and painted on site. To improve the thermal performance of the windows the glass is replaced by up-to-date insulated glass. The Venetian blinds are replaced.

5.2.4.1.2. Climate Concept
The climate concept is unchanged. All technical components are replaced. The mechanical ventilation system is renewed. In order to do so, the horizontal distribution ducts need to be replaced. Also the tubing for the induction units is replaced. All these measures take place in the suspended ceiling, which will have to be replaced in the offices. The induction units are replaced by modern machines with a higher efficiency.
5.2.4.1.3. Results
The outer appearance of the building is not changed significantly. A new coating as only means does not improve users’ perception and identification with the building. An advantage for the users’ comfort is the individual control of the HVAC installations. However, the concept can not fulfil the wish for opening windows. The service gangways continue to block daylight which results in a higher demand for electric lighting.

The refurbishment of the façade can be realised easily, fast, and cost efficient. As the window frames stay in place, the connections to dividing walls are not changed. However, the insulation level is lower than in all the other proposals. Furthermore, the risk of condensation has to be kept in mind. The replacement of induction units can also be realised easily. The changing all ventilation ducts results in the need for an entire replacement of the suspended ceiling.

Figure 5.29
Potentials of proposal 1

5.2.4.2. Proposal 2 – Removal of the platforms
Currently the service platforms and Venetian blinds give the building a rather ‘blurred’ appearance. This proposal aims to find the most cost effective solution to change the outer looks of the building. The renewal of ventilation ducts, as described in the first proposal causes a big effort. Therefore, this concept presents a solution without mechanical ventilation.

5.2.4.2.1. Construction
In this case the façade cladding and the service gangways are taken off. After cleaning and recoating of the aluminium panels, and improvement of the insulation, the cladding is remounted. With the platforms removed it is necessary to provide opening windows for cleaning. As these were also requested for users’ comfort, the windows are replaced completely.

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5.2.4.2.2. Climate Concept
The opening windows make mechanical ventilation redundant. Only the inner zones of the building need to be ventilated. For this, the machines can be smaller and the ducts are significantly shorter. The induction units in the offices are replaced by simple radiators. Those rooms that face a high cooling load are equipped with a chill ceiling.

5.2.4.2.3. Results
The ‘disorganised’ impression, caused by the service platforms, is reduced. With a new coating, the building has the chance to receive a new identity. Functionally, the simple installation concept with separated technical components facilitates maintenance, individual replacement and future upgrade. Being able to open a window contributes to the users comfort. The entire installation concept is self-explaining even for technical laymen. The heating is turned on by a thermostat handle; ventilation is achieved by opening a window.

This concept represents the lowest construction cost. Installing radiators is cheaper than replacing the induction units. As the building is naturally ventilated, the old ducts are not needed any more. These
may stay unused in the suspended ceiling until the interior finishes are renovated. This makes the construction process relatively flexible. Another economic benefit is that the new radiators are slimmer than the existing induction units and thus activate usable space.

The façade cladding is reused and the installations are based on simple standardised components. Thus, the consumption of material and embodied energy is restricted. Also the operational costs are reduced as the building functions with less technical installations. In order to restrict the heat loss through opening windows, these should be equipped with magnetic contacts that turn of heating and cooling automatically when the window is opened.

![Figure 5.31](image)

Potentials proposal 2

5.2.4.3. Proposal 3 – Decentralised ventilation
This concept provides the building with a new outer appearance by replacing the cladding. It wants to eliminate the central mechanical ventilation and provide fresh air directly from the façade. By using decentralised ventilation with heat recovery, the energy consumption shall be minimised.

5.2.4.3.1. Construction
The existing façade is removed completely. It is replaced with a new ventilated cladding, which leaves space for sufficient insulation and allows a new design. The windows are also replaced. In this case, every second window can be opened to facilitate cleaning and to allow the users to get in contact with their environment.

5.2.4.3.2. Climate Concept
The climate concept is based on separating functions. The opening window can be used for ventilation in autumn and spring. For extreme temperatures there is a decentralised mechanical ventilation unit with heat recovery placed between concrete parapet and window. This can either be a cross flow heat exchanger or an accumulator heat recovery.
Thus, this concept eliminates the need for long and energy-consuming air ducts. Fresh air is let in where it is needed, at the façade. A radiator is used for heating. Additional cooling can be installed in form of a cooling baffle where necessary. This system has the advantage that it reacts quickly and therefore can be controlled by the user and/or the building management system.

5.2.4.3.3. Results
Placing ventilation in the façade demands an adjustment of the existing cladding. In this concept the cladding is replaced, which makes a completely new design possible and can give the building the desired new identity. The heating and cooling system follows the principle that the user can control their individual devices directly and manually. The heat recovery reduces draught during cold periods. The opening windows provide the user with a connection to the outside, but are equipped with magnetic contacts that turn off the building services when a window is opened. If all these means are well matched, both efficiency and comfort are achieved.

Figure 5.32
Standard section proposal 3
Replacing the entire façade causes higher construction costs. Then again, the combination of a new façade with the proposed installation concept causes the least energy demand and operational costs. On the one hand, this is due to the decentralised ventilation, which achieves a heat-recovery of up to 90%. On the other hand, the heating and cooling system causes very low operational cost for. For the technical installation applies the same as in the second proposal: The old ducting may stay in the suspended ceiling until the interior is renovated. During the façade refurbishment only the connections between façades and connecting elements need to be adjusted. Here also, the replacement of induction units by radiators frees rental space.

5.2.4.4. Proposal 4 - Façade integrated services
The main focus of this option lies in a strategic approach. A flexible façade- and installation concept provides possibilities for upgrade and successive installation of different levels of services. The façade offers space for a flexible use, such as an ‘installation box’, into which different building service components can be placed. Different parts of the building or even single rooms can have different levels of installation or be adjusted to changing needs. A regular office room, for example, does not need air conditioning, while server-rooms or areas with a high user density demand it. Whenever the function of a room changes the flexible façade system with plug-in components can change easily too.

5.2.4.4.1. Construction
The existing façade is replaced by a new ventilated cladding and new windows. Every façade grid of 2.50m provides one fixed window, one opening window and an ‘installation box’. The opening window is needed for façade cleaning and for the users’ comfort of being able to get in contact with the outside. The installation box provides space for technical components.
5.2.4.4.2. Climate Concept
Inside the installation box different HVAC components can be mounted. These are not depended on one particular manufacturer. The following levels of installation can be achieved:

- **Level 1**
  - Ventilation by opening windows
  - Heating by radiators
  - Optional cooling by chill ceiling or baffles

- **Level 2**
  - Decentralised mechanical ventilation with heat recovery
  - Heating by radiators, optional cooling

- **Level 3**
  - Decentralised units providing ventilation with heat recovery, heating and cooling
The installation box is connected to heating and cooling circuits and electric power. All ducting is placed in the suspended ceiling. The existing ventilation ducts become redundant in the office space. Only for the inner zones of the building central mechanical ventilation is needed.

5.2.4.4.3. Results
Replacing the façade makes a completely new design possible. The innovative installation concept can be used to support the building owner’s corporate identity and the users’ identification with their working environment. Individual control of the room climate contributes to the comfort. Placing the installations in the façade reduces the interference with the interior. No ventilation ducts are needed inside the building. The climate units, placed between the massive parapets, have direct access to outside air without the need to drill holes in load bearing elements. This is the only concept in which ducts are installed in the suspended ceiling of the very floor that is serviced. Thus, the concrete floor is not penetrated, which improves the fire resistance.

Every room can be technically equipped according to its need. This results in higher construction costs for the façade and the preliminary setup for different technical devices. On the other hand, this concept reduces the total number of HVAC components to the necessary minimum. During operational time, the installation implements low energy costs. The maintenance effort for the big number of components is comparable to central mechanical ventilation, if all units are monitored by a building management system.

![Diagram](image)

Figure 5.35
Potential proposal 4

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5.2.5. Energetic comparison of the different strategies
A major point of interest in the refurbishment of façades and building services is the potential energy saving of the project after refurbishment. To get an impression of the effect of the different proposals, two typical office rooms have been calculated according to the German Energy Savings Law EnEV 2004. The calculation is made for a ‘slice’ of the building covering two office rooms of a width of 3.80m, one on the east, and one on the west side of the building. The building depth is 13.20m; floor height equals 3.60m. Of course, the result of the calculation can not deliver exact figures for the entire building, but it gives an impression of the potentials of the different proposals.

![EnBW Esslingen, final energy demand](image)

The result shows clearly that all refurbishment concepts achieve a major energy saving. It is interesting to note that the first and second proposal achieve very similar results. This is owed to the different installation concepts. In the first concept the façade is less well insulated; the service platforms and old window frames form major thermal bridges. However, here the building is fully mechanically ventilated with a heat recovery rate of 50%. Proposal 2, on the contrary, provides a well insulated façade but tends to lose energy by natural ventilation. Proposals 3 and 4 combine the optimised insulation with ventilation with efficient heat recovery. A heating energy consumption of 45 W/m² is very good standard for air conditioned office buildings. The figures of the two concepts only differ very slightly due to different window dimensions.

Table 5.2
Estimated demand of final energy for heating and cooling

<table>
<thead>
<tr>
<th>Situation</th>
<th>Heating</th>
<th>Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial situation</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Proposal 1</td>
<td>110</td>
<td>50</td>
</tr>
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<td>Proposal 3</td>
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</tr>
<tr>
<td>Proposal 4</td>
<td>80</td>
<td>20</td>
</tr>
</tbody>
</table>
5.2.6. Realised concept
The project is currently being realised. Based on this case study one design has been elaborated that forms a combination of proposal 1 and 2.

5.2.6.1. Construction
The original façade is being improved. To do so, the cladding is recoated and the structure of the service platforms is painted on site. Behind the façade cladding the initial insulation is removed and replaced by 16 cm of mineral wool. The existing fixed windows are replaced by new opening windows with up-to-date insulation values and glazing.

5.2.6.2. Installations
The building services installations are entirely renewed. The offices receive a basic installation with radiator heating and chill ceilings. As many rooms as possible are ventilated naturally by opening windows. The interior zones of the building (corridors, rest rooms, archive) are equipped with a new, smaller, and more efficient central mechanical ventilation.

5.2.6.3. Evaluation of the chosen version
The façade cladding provides a very high quality and is therefore suitable for new coating. Due to sufficient free space between the concrete parapet and the metal cladding, it is easy to bring in more insulation. New window frames and glazing are compulsory to achieve today’s standards and prevent building physical problems such as thermal bridges and vapour leaks. It was decided to preserve the service platforms because they are characteristic of the building. Furthermore, it would otherwise be difficult to mount the Venetian blinds. The decision for natural ventilation was taken because the users wished to provide an individual means of ventilation and contact to the outside (corporate standard). Additionally, the limitation of technical components, and thus of operational costs was desired by the building owner.

In such way the realised concept has promised to be the most feasible solution. Construction costs are low, as most of the components can be reused without alterations. The maintenance of the new system is easy. The service platforms can be used for window cleaning; the technical installations demand little service energy. Thanks to the very high level of insulation, which can be achieved within the initial façade cavity, it is expected that the heating demand will be very low. The very good sun protection limits the cooling load in summer and, being able to open a window, users accept higher indoor temperature than in a fully air conditioned building.
5.2.7. Conclusions
The case study for the office building of ENBW in Esslingen delivered many useful findings for the treatment of ventilated façades and air-conditioned buildings. An initial ventilated cladding provides the possibility to improve the thermal performance by adding insulation within the existing cavity. Provided the structure and cladding elements are of a high quality and state of maintenance, many components can be reused. This reduces the consumption of material and energy, and can result in very feasible solutions.

Existing windows demand a very close look into their capacities and potentials for improvement. Wooden windows may provide a u-value of the frame that can be improved to meet current standards. Aluminium and PVC windows, on the other hand, often show a performance that can not be combined with current highly insulating glass. To prevent thermal bridges and condensation, it is therefore often necessary to replace the window-frame, which results in the need to re-model the connections to dividing walls and interior finishings.

Placing building services near the façade, or even integrating components into the façade, reduces the interference with the interior. If new installation ducts are placed along the façade, it is possible to leave old components in the suspended ceiling or top-floor. These can be removed at a later stage, which makes the building process more flexible. Also, the use of decentralised ventilation is often sensible as it makes old air ducts redundant. If these are removed, the suspended ceiling can be reduced or even removed, which provides more floor height. Furthermore, by removing a suspended ceiling, the thermal mass of a concrete floor can be activated for a better comfort or for night-time cooling. Technically, eliminating long ventilation ducts contributes to the efficiency of ventilation units. It is therefore sensible to place the air-intake and outlet as close as possible to the workspace. Of course, decentralised solutions only make sense in locations where there is no pollution in the surrounding of the building.

Being able to open a window contributes to the users’ comfort and productivity. People accept a wider range of temperatures when they have contact to the outside climate. Thus, the energy consumption can be reduced, because the heating and cooling periods are shortened. Unfortunately, this effect is often turned into the opposite, if windows are permanently opened during heating or cooling period. To prevent this, it is essential that users consequently practise intermittent, full ventilation. Equipping opening windows with magnetic contacts that turn off heating and cooling automatically can support familiarisation with this and reduce energy consumption.

The flexible and upgradeable building service concept as explained in proposal 4 facilitates the installation of different building service units. It makes it possible to create rooms with individual qualities, and is therefore mainly sensible for buildings with often changing functions.
5.3. University of Bielefeld, Germany

The main building of the university in Bielefeld, Germany provides a façade structure that was common in the early 1970s, not only in Germany but also in other North-European countries. In the case study three common refurbishment strategies were evaluated for one standard office part of the big complex. A fourth concept, covering the complete building complex in a green house, proved to be a suitable, and both ecologically and economically interesting alternative.

5.3.1. Building characteristics

Name: University of Bielefeld, main building
Location: Bielefeld, Germany
Owner: Bau- und Liegenschaftsbetrieb NRW Bielefeld
Occupant: University of Bielefeld
Year of construction: 1971 - 1976
Architects: Klaus Köpke, Peter Kulka, Katte Töpper, Wolf Siepmann, Helmut Herzog
Use: Central zones: library, auditoria
Outer zones: offices, lecture rooms, laboratories
Gross floor area: Approximately 300,000 m²
Façade area: Approximately 73,500 m²
Façade type: 5.2.1
- Prefabricated concrete parapet and windows
Main structure: Steel skeleton with concrete floors
Challenges: Difficulty to remove parapet units, particularly in courtyards
- Toxic asbestos for fire proofing of structure
- Toxic PCB in sealants of concrete units
Ambitions: Removal of toxic material
- Successive refurbishment for the building
- Cost effective solution
- Elaboration of synergetic effects and marketing potential

Figure 5.36
Aerial view of Bielefeld university campus (University of Bielefeld 2009)
5.3.2. Initial situation

5.3.2.1. Architecture
The concept for the university building resulted from a design competition that was won in 1969 by a group of young architects. The architectural design aimed to provide a ‘university campus under one roof’. It wanted to tackle the tasks of industrialised society and take maximum advantage of the possibilities of industrial building (Weisner 1975). The university building is placed on a wide lawn. All other buildings keep a respectful distance. This is due to the original plan which provided space for expansion. Although the university would like to attract visitors (Weisner 1975) the huge building volume and the rather hidden entrance situation tend not to attract people that are not already affiliated with the university.

![Figure 5.37](image)

Elevation of the university campus as it is today

The desired concept of a ‘university under one roof’ is achieved by a spatial concentration with very close connections between all functions. The central university hall is the interconnecting element that links to all faculties, lecture halls, and public functions. All other functions are located according to their frequency of use. Similar functions are placed on the same level. For example, the central library interconnects all faculty libraries on the first floor. The lower the frequency of use, the further away from the central hall the zones are located. Therefore, the upper floors and outer building house the office and laboratory space for scientific and other staff. The university management, staff, and students agree that the campus is very functional, but not attractive in terms of architectural design (Ebbert 2007).

5.3.2.2. Structure
Both the architectural and functional concept, as well as the size of the building, and the tight construction schedule resulted in an industrialised style of production that uses pre-fabricated elements.
The lower floors up to building level 0.00 are realised in on-site concrete. The upper construction is a steel skeleton structure. Steel columns at a grid of 7.20m carry the vertical loads. Depending on span and local payloads, beams or trusses of different heights carry the floors. The floors themselves are made of pre-fabricated concrete elements that are connected to each other and to the beams by on-site concrete. The structural height of the floors is 13 cm. While vertical loads are brought into steel columns, the horizontal loads are transferred to the so-called ‘towers’, which house vertical installations and staircases, and are cast on-site.

5.3.2.3. Façade construction
The façade is constructed of pre-fabricated parapets of light-weight concrete. These span 7.20m and are connected to the load bearing columns. The parapet has a height of 1.43m and a thickness of 30cm. It weighs roughly 4,500kg. According to structural calculations the bearings only provide an extra capacity of 3-5kN each.

The parapets carry the window units. These are realised as a series of window frames. A guideline in planning was an optimal variability of room sizes. Hence, the façade grid is set off the structural grid by 60cm to allow variability of dividing walls. The windows are composed of 30cm wide vertical fixed glazing that can also serve to connect dividing walls, and 90 cm wide elements with operable windows.

All building sides are equipped with exterior Venetian blinds. These were originally placed to serve one office room. As the interior layout was altered, they now span across dividing walls over different rooms. Due to the impact of weather many blinds have been damaged. Some rooms are equipped with curtains for individual glare protection. The façade does not supply sufficient thermal insulation. The window profiles were designed specially for this project and are not equipped with thermal separations. The insulated glass dates back to the 1970s.
The façade is not wind resistant and provides a very low insulation level. Special zones, such as the library, show a curtain wall of steel profiles that is equipped with single glass. These façades do not meet any current standards and are characterised by thermal-bridges and condensation.

The following U-values can be estimated:

<table>
<thead>
<tr>
<th>Material</th>
<th>U-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete parapet</td>
<td>2.13</td>
</tr>
<tr>
<td>Window</td>
<td>3.15</td>
</tr>
<tr>
<td>Roof (partly refurbished)</td>
<td>0.13 – 0.43</td>
</tr>
</tbody>
</table>

Figure 5.39
Standard section initial situation
5.3.2.4. Interior finishings

The dividing walls are light-weight structures. Some are built from plastered aerated concrete blocks, others from plaster board. The PVC flooring is placed directly onto the concrete slab. There is no top floor. This causes problems with noise protection between floors and does not fulfill the fire resistance requirements. To achieve a fire resistance of 90 minutes, suspended ceilings were built in. These consist of metal plates or plasterboard and are topped with a layer of man-made mineral fibres (MMM) for fire proofing. Horizontal fire compartments are formed by each building separated by the towers. Each building floor functions as one compartment, which eliminates the need for dividing walls.

Several toxic materials were found in the building. Asbestos reinforced fire boards cover the steel structure. In several locations, mainly within the suspended ceiling, artificial mineral fibres (MMM) have been used. Furthermore, PCB has been used in the sealants between concrete units in the façade. According to an expert’s report there is no acute danger from asbestos and MMM as long as the suspended ceilings and fibre boards are undamaged (Richardson 2006). The PCB causes more severe problems and is indicated to be removed as soon as possible (Richardson 2006).

5.3.2.5. Technical installations

The different zones of the building are equipped with different technical installations. The heating energy for the entire campus is generated in a central heating plant. Chillers are placed on the roofs of building parts with laboratory use. This is sensible, as the laboratories also are equipped with mechanical ventilation and air conditioning. In addition, interior zones, such as auditoria and the library, are equipped with a central air-conditioning system. Fresh air intake is located in the courtyards between two buildings.

The standard office buildings, on the contrary, only show a basic level of installation. Standard radiators provide the heating. Ventilation is realised by operable windows. All these functions are controlled individually by the user. The basic electric installations in the offices are distributed in an installation channel in the façade. This channel has proven to be very useful, as it provides electric power and IT cabling at all window-orientated desks. As the channel is integrated into the concrete parapet it does not interfere with dividing walls.

5.3.3. Refurbishment tasks

The Campus building is owned by the ‘Bau- und Liegenschaftsbetrieb NRW (BLB)’, which is an independent real-estate company founded by the state government. The university has rented the building from BLB. Hence, the investment in refurbishment has to meet the interests of both stakeholders. On the one hand it must be feasible and return rental income. On the other hand, the university wants to improve its public image to attract both students and teaching staff. Hence, the
refurbishment planning wants to deliver innovative solutions that
generate an added value for the campus. It has to create a building
with up-to-date building physical properties and technical installations.
The limited structural capacities as well as the need to remove toxic
materials are special tasks in this project.

A major restriction for the refurbishment process is caused by the
instance that the concrete parapets are difficult to remove. During the
construction process they were placed during the construction. Today
the building contains inner courtyards that are closed on all sides.
Parapets in these zones could only be reached by special cranes and
would have to be lifted over building parts that are supposed to be kept
in operation during the refurbishment. Due to the size of the campus,
it is planned to refurbish one part of the building per year. Therefore,
one department shall be relocated to a new building and after one
year – during holiday period – move back into the refurbished part.
Thus, the refurbishment is expected to take 15 years and shall take
place while the biggest section of the campus is in operation.

5.3.4. Refurbishment proposals
Based on a two-step process in consultation with the building owner,
the following refurbishment proposals were worked out:

Proposal 1 – Ventilated cladding
- Replacement of windows
- Additional insulation and ventilated cladding on parapets

Proposal 2 – Double façade
- Thermal upgrade of the existing parapet
- Replacement of windows
- Application of an additional glass layer with all necessary
structural elements
- Appropriate HVAC installations

Proposal 3 – Atria
- Preservation of the existing façade
- Covering of all courtyards with transparent atria

Proposal 4 – Modular façade
- Removal of concrete parapets
- Replacement by a unitised modular façade
- Integration of building service components in the façade

Figure 5.40
Façade structure
5.3.4.1. Proposal 1 – Ventilated Cladding
The first solution presents the necessary renovation that has to be done in order to allow the future use of the building. The aim of this ‘minimal solution’ is to achieve a good building physical performance of the façade at minimal cost.

5.3.4.1.1. Construction and climate concept
Additional insulation and a ventilated metal cladding are added to the outside of the parapets. The windows are replaced with new façades that provide proper wind resistance, air tightness, and insulation. New sun blinds reduce solar irradiation and thus cooling loads.

Figure 5.41
Standard Section of the ‘Ventilated Cladding’;

5.3.4.1.2. Results
This concept provides a fast, easy to apply, and safe solution to solve the major construction problems of the building. It improves insulation and energy performance with the lowest possible construction cost. In this particular project the main restriction results from the very limited load bearing capacity of the existing parapets, which do not allow a heavy cladding or big eccentric loads.
As the proposal preserves big parts of the existing structure and adds only few components it offers very efficient use of material. The concept is labour intensive to seal all possible leaks of the façade, and the HVAC concept is only marginally altered. Therefore it is difficult to achieve very good energy efficiency.

The architectural design is renewed by the new cladding. Nevertheless the major task must be to prevent the cost-effective solution from appearing cheap. In terms of health and safety, the PCB must be mentioned. This is removed from the joints between the parapet units, but it is almost impossible to remove it completely, as it diffuses into the concrete. If the parapet is clad, the remaining PCB is sealed from the outside. It can not be predicted, if this solution leads to a stronger evaporation of PCB on the inside.

The ventilated cladding is the easiest way to provide good thermal comfort. The insulation level is up-to-date, and users are able to open their windows and control their heating individually. While this contributes to their perception of comfort, it makes energy consumption difficult to control. A later part of this chapter will focus on the energy and cost efficiency of the he different proposals in detail.

5.3.4.2. Proposal 2 – Double Façade
The aim of this refurbishment task is to conserve as much of the existing façade as possible, reduce the wind loads on the parapet elements, and develop a new, energy efficient climate concept for the office rooms.

5.3.4.2.1. Construction
In order to do so a single glass screen is placed in front of the old façade. The load bearing structure of the additional façade is suspended from new beams on top of the building that bring the loads into the main...
supporting columns. In winter the air in the façade cavity can reach very low temperatures because the cavity is used to bring in outside air to the rooms. To prevent thermal bridges, condensation, and heat loss, the primary façade layer therefore has to be insulated. This is achieved through new windows and additional insulation of the parapet elements.

Figure 5.43
Standard section of the ‘Double Façade’

5.3.4.2.2. Climate concept
The climate concept uses pre-conditioned air from the cavity in winter as inlet air for the workspaces. Exhaust air needs to be let out through the central corridors and air shafts. In the summer situation the direction of the air flow is reversed. A natural updraft in the façade-cavity is used to extract exit air from the rooms Fresh air is brought in through shafts and ducts within the building. All these technical installations have to be built new, as the standard office buildings are currently not equipped with any mechanical ventilation.
5.3.4.2.3. Results
This proposal leads to a very complex and thus expensive façade with very big influence on the existing building’s structure. The energy demand of this concept, and even more, the maintenance costs tend to be relatively high. Replacing part of the old façade and adding a second layer causes the biggest flow of material of all compared concepts. Being a specialised system, the façade offers little potential for future changes.

The double façade holds the potential to create a new identity for the building. But, it will be a major task to design it appropriate to the original concept. Removal of the PCB leads to the same result as the first proposal. All hazardous material that is not removed, will be trapped inside the façade cladding and tend to evaporate to the inside. Additionally, the double façade demands a new fire protection concept that may have to be based on a sprinkler system.

The cavity provides the space for daylight-directing sun-blinds. These improve the visual and thermal quality of the office space. A double façade with opening windows always causes an acoustic problem. While exterior noise is blocked, the double façade transports sound from one room to another inside the cavity.

5.3.4.3. Proposal 3 – Atria
The main aim of this concept is to create a buffer climate in which the air is pre-conditioned by solar radiation. The shape of the existing building forms a series of courtyards and inner atria. Currently these are outdoor spaces surrounded by huge façade surfaces. Closing the courtyards and atria creates covered spaces or ‘winter gardens’ and thus reduce the surface of the building from 110,000m² to 70,000m² (including roofs).
5.3.4.3.1. Construction
Tree-columns carry the roof structure, which is clad with ETFE cushions. The roofs over the inner courtyards rest on the load-bearing stair-case ‘towers’. The outer atria are closed with suspended glass façades that transfer their loads to the outer ‘towers’.

Figure 5.45
Layout of covered atria

Figure 5.46
Possible elevation of covered atrium

5.3.4.3.2. Climate concept
Due to the large size of the atria the air temperature will always remain above a level for which the existing façades provide enough insulation without further treatment. In summer, the incoming air is lead through an adiabatic cooling (water curtain) before entering the atria. All office rooms get their fresh air directly from the atria. Additionally, the air intake for the central areas, such as libraries and auditoria, is also located in the courtyards and thus supplied with pre-conditioned air. In summer the covered atria need to be well-ventilated in order to discharge excess heat.
5.3.4.3. Results

By covering the courtyards this proposal requires less façade area to be constructed than the double façade. Hence, the cost per square meter of the façade is lower. It is generally possible to mount the roofs independent of the ongoing office work. This permits very flexible planning. The atria provide two major additional benefits. Firstly, the university obtains a unique feature that can serve as an image to attract students, teachers and funds. Secondly, the large atria provide additional covered space, which can be occupied by university functions. These gains are represented in the ‘wheel of potentials’ by the improved functionality and the economic benefits.

The concept demands only a little further treatment of the existing façade to reduce the building’s energy consumption, because the temperature inside the atrium never drops below 0°C. The particular problems of this concept lie in the need for new roof structures and façades for the courtyards that require additional foundations and connections to the existing building. An important safety aspect of all atria closures is fire protection. The closed roof demands a concept for ventilation and accessibility in case of an emergency.

Figure 5.47
Ventilation concept of covered atrium with adiabatic cooling

Figure 5.48
Potentials of proposal 3
The new concept can easily provide the offices with an improved view into the atria. The shading effect of the roof needs to be considered. The closed atria hold the risk that noise is reflected into the office space. A proper ventilation concept for the atria limits the risk of overheating in summer. The biggest comfort advantage is that users can open their windows whenever needed, as the buffer climate makes the leaks of the old façade less significant. Unlike other concepts, there is no need to teach the users how to operate their building.

5.3.4.4. Proposal 4 – Modular Façade
So far all strategies followed the restriction of preserving the existing façade. Additionally, the fourth concept removes the windows and parapet elements. Removing an existing non-load-bearing façade gives the planner a kind of ‘tabula rasa’ situation for almost any new curtain wall solution.

Figure 5.49
Standard section of the modular façade
5.3.4.4.1. Construction
For the university building we have created an adaptable and upgradeable concept that includes building services in the façade construction. This concept is based on the idea that different rooms have different demands for heating, ventilation and air conditioning depending on their use or location within a building. For example, an office room on a northern side does not need air conditioning at all, while a meeting room on the southern side does need it in summer, and a server room needs cooling all year round. Particularly in universities, the functions of rooms tend to be altered quite frequently.

5.3.4.4.2. Climate concept
The prefabricated façade unit provides the basic tubing for all types of building services. Instead of fixed climate components the façade supplies installation space in which different standardised components can be installed. The concept proposes that the user of a room can order his or her personal level of installation, which then can easily be installed and individually billed.

![Figure 5.50](image)
Different possible HVAC concepts to be integrated into the modular façade

5.3.4.4.3. Results
On the one hand, this concept provides the desired level of building services and comfort for each room. On the other hand, only the absolutely necessary number of components needs to be produced and purchased. This reduces the demand of energy, both in production and usage and allows perfect cost control. Nevertheless, this concept creates two major complications. The existing façade units have to be removed, which is easy in the accessible outer courtyards but complicated and expensive for those courtyards that are fully surrounded by buildings. When the building is in use, this concept demands good cooperation between building owner, user and the facility manager to consequently restrict the number of HVAC components and to optimise the operational time.
5.3.5. Comparison of the different strategies

The different refurbishment concepts show a broad variety of solutions with different levels of labour and impact. In the following, the four different refurbishment strategies are compared in terms of construction cost, energy saving and life cycle cost, giving an impression of the possible repayment period of these concepts.

5.3.5.1. Construction Cost

In order to achieve comparable figures the estimated cost for the new façade or roof structure has been divided by the square meters of the existing façade covered by it. The installation cost for building services are calculated per GFA. It does not take into account the cost for the removal of toxic material, as this needs to be removed regardless in a similar process. As only the standard façade of an office is assessed, costs for other building parts such as the staircases are not included.
The ‘Ventilated Cladding’ (proposal 1) is the cheapest solution as it provides only the most necessary refurbishment. Installation costs are very low because they only cover the replacement of old radiator heating. The high investment cost for the ‘Double Façade’ (2) results from the complicated load bearing structure and the necessary treatment of the existing façade layer. Installation costs are high in this option, because a new ventilation system has to be installed. It is very interesting to see that the ‘Atrium Solution’ (3) is comparable to the other options. This is due to the fact that the façade surface is reduced and the existing façade needs no treatment. Installation costs in this case cover the replacement of the heating system in the rooms and the ventilation for the atria. The Construction cost for the ‘Modular Façade’ (4) also covers the installation space for building services. For the installation-costs it has been estimated that 3% of the GFA is fully air conditioned, while the rest is only equipped with heating.

5.3.5.2. Energy Demand
In order to determine data on the energy demand after refurbishment, the volume of the fifth floor of one outer building part was assessed using the thermo-dynamic simulation tool Capsol. It was defined that the temperature level always stayed above 20°C during operational time, and did not exceed 25°C for more than 5% of the operational time, to determine the heating and cooling demand. The results show the energy demand for heating, cooling, electric lighting and operating power in kWh per m² GFA. a in comparison between the different proposals and the existing situation (0).

Obviously the smallest refurbishment achieves the least energy saving. Nevertheless, the ‘Ventilated Cladding’ (1) saves around 40% in comparison to the existing situation. The ‘Double Façade’ (2) causes a high demand for heating because the ventilation concept, based on operable windows, is difficult to control. Decentralised mechanical ventilation with heat recovery would provide a better performance, but also results in higher installation and maintenance costs. The

![Energy demand graph]

Table 5.4: Bielefeld University Energy demand [kWh/m² GFA, a]
reduction of electric lighting is achieved by daylight-reflecting sun blinds, installed in the cavity.

The ‘Atrium Solution’ (3) delivers interesting results: Although the old façade has not been upgraded, this solution demands the least heating energy. This shows the effect of the solar pre-conditioned climate in the atria which reduces the effect of the lack of insulation and the leaks in the old façade. A higher demand for lighting energy is caused by the shading of the roof. The ‘Modular Façade’ (4) allows the optimal contemporary building standards. By applying controlled ventilation to more than the calculated ¼ of the space, the heating demand could be reduced even further.

5.3.5.3. Operational Costs
Operational costs cover not only the costs for heating, cooling, electric lighting and operation of building services, but also the costs for maintaining the façade and building services, as well as window-cleaning. In the existing situation the costs for maintenance are particularly high, as both façade and technical installations, being more than 30 years of age, demand a lot of attention. The impact of façade cleaning on the operational costs becomes clear for the ‘Double Façade’ (2). Electric lighting is an important factor for the ‘Ventilated Cladding’ (1) as this solution is not equipped with presence sensors, which on the contrary have been applied for the other proposals.

5.3.5.4. Life Cycle Cost
Life cycle costs include the construction and operational costs presented before. To evaluate future developments an increase in energy costs of 7% per year has been estimated. All other costs are expected to rise by 2% per year.

All refurbishment strategies provide significantly lower operational costs than the current situation. The graphs of all the different strategies intersect the line of the existing situation within the next 25 years. This means that any refurbishment proposal can pay off on the saving of operational costs within the expected technical lifespan of façade and HVAC-components of 30 years.
Under the given circumstances, the ‘Ventilated Cladding’ is the cheapest solution in the beginning. But, after 15-20 years the better performances of both the ‘Modular Façade’ and the ‘Atrium Solution’ become evident. The ‘Double Façade’ takes the longest time to break even on costs. Keeping in mind that the ‘Winter Garden’ concept creates additional useable space, it is an option worth considering.

5.3.6. Conclusion
Taking all aspects into account one can conclude that all proposals are technically possible in this project. Naturally, they show their strengths in different areas. The complete replacement of the existing façade achieves the best quality but at a high cost and high material consumption. The ventilated cladding achieves a good standard, which holds the risk that the low cost is observable in the building’s appearance. The double façade is too labour intensive, and causes high costs and material consumption with too little gain in quality and performance.

It is very interesting to see that the atrium solution is economically comparable to all other concepts and technically functional. It contributes to the quality of the common space, creates additional room, and can function as a unique selling feature for the university. If all these aspects were taken into the feasibility calculation, the pay-off period could be even shorter than the estimated 18 years. This case study has shown clearly that, even if the task is ‘façade refurbishment’, it is necessary to look at the entire building. In this case, the building geometry makes a refurbishment solution possible that provides the necessary technical improvement in a feasible way, but it also generates many synergetic effects that would not have been achieved by the other solutions.
5.4. Sparkasse Vorderpfalz, Ludwigshafen, Germany

Sparkasse Vorderpfalz is a regional bank in Ludwigshafen, Germany. The head-office building is located in the city centre. The building was interesting for a case study, because it provides three different façade types. The façade structure of the ‘tower’ with cantilevering service platforms was relatively common in Germany in the 1960s and 1970s. The ‘flaps’ are equipped with a typical ventilated metal cladding. The ‘base’ shows a unitised façade, which is set back inside the actual structure. The refurbishment project also provides a combination of common tasks in construction, ventilation concept, and the requirements for the construction process. The task was to find a solution for refurbishing without interference to the interior. This applies to many buildings, which are to be renovated while remaining in use.

The author conducted this case study analysis with ‘Evers Ingenieurgesellschaft’ (façade consultant) and ‘Balck and Partner’ (climate engineers). In the case-study three concepts are developed, which deal with the theme of double façades in combination with climate installations (Evers et al. 2006). The comparison of these concepts has delivered a final version which has been realised in 2009 under the project management of Evers Ingenieurgesellschaft.

Figure 5.52
Sparkasse Vorderpfalz, Ludwigshafen (GER), initial situation
5.4.1. Building characteristics

Name: Sparkasse Vorderpfalz, Hauptverwaltung
Location: Ludwigshafen, Germany
Owner: Sparkasse Vorderpfalz
Occupant: Sparkasse Vorderpfalz
Year of construction: 1974
Architects: Egon Weiß
Use: Base zone: conference centre
Tower floors: offices
Gross floor area: Approximately 4,400 m²
Façade area: Approximately 1,100 m²
Façade type: Tower: 5.4.2
Stick system with service platforms
Flaps: 4.1.1
Ventilated metal cladding
Base: 1.2.2
Window units set back from load
bearing concrete structure
Main structure: Steel skeleton with concrete floors
Challenges: Minimised disturbance of the interior
Restricted structural capacity
Ambitions: Renewed outer design with reference to the original concept
Climate concept in combination with the double façade
Mounting the new façade and climate components from the outside
Limiting user relocation time to a maximum of two days per room

5.4.2. Initial situation

5.4.2.1. Architecture
The building occupies a prominent position on the cross section of the major shopping streets of Ludwigshafen. It stands one block away from the river Rhine. Hence, it is also visible from the city of Mannheim on the other side of the river. The building was constructed in 1974 and is composed of a 3 storey base which serves as conference centre and a nine-storey office-tower on top of this base which is the focus of the research.

5.4.2.2. Structure
The supporting structure of the office-tower is formed by steel columns and beams. The floors are made of on-site concrete. Only four structural columns carry all vertical loads. The horizontal stiffening is achieved by the stair-case and elevator shaft.
5.4.2.3. Façade construction

The building provides three different façade structures. The main focus of this chapter lies on the tower façade. The solutions for the flaps and base are presented further below. The façade structure of the tower was originally intended as a post-and-beam façade. Nevertheless, the realised solution appears to be a combination of a curtain wall and ventilated cladding in one structure. It is supported by a framework of steel profiles, placed as a curtain wall in front of the floor edge and concrete parapet. This framework is filled by using pressure plates known as stick-systems. The window units are equipped with insulated glass and provide the thermal layer.

In front of the massive parapets, the façade is clad only with a non-insulated aluminium panel, which is ventilated in order to let air into the ventilation unit. The concrete parapets show 40mm of insulation on the inside. It is not possible to say if there was originally a separation between the façade cladding and the suspended ceiling or further insulation in the façade. At the beginning of the refurbishment project, this space was open.

![Diagram of façade construction](image)

*Figure 5.53*
Standard section initial situation
On the outside of the space-enclosing façade there are service platforms that are carried by cantilevering steel consoles. These platforms serve for window cleaning and carry Venetian blinds. The zones of the façade that do not provide windows (the so-called ‘flaps’) are clad in a similar fashion to the parapets. Anodised aluminium panels are fixed to a steel-framework. The walls behind are made of porous concrete blocks without further insulation.

5.4.2.4. Interior finishings
The interior of the building has been renovated successively between 2000 and 2005. During this process, the asbestos-reinforced fire-boards were also removed, which originally clad the steel structure.

5.4.2.5. Climate installations
All office-spaces are fully air-conditioned by means of decentralised units. Fresh air is taken in directly through the façade. It is heated or cooled by a HVAC unit in the parapet cladding and brought into the room. Exhaust air is then let out through the same unit without recovering heat energy. The system is controlled centrally and is not adjustable by the user.

5.4.3. Refurbishment tasks
Major constructional problems of the façade lie in rain-water entering the construction along the consoles, as well as in lacking insulation and wind-tightness. Currently, the building consumes over 1.2m kWh/a (315 kWh/m²a) of energy, of which approximately 80% is used for heating and cooling (Evers et al. 2006). All building physical aspects have to be brought up to current standards. This shall reduce the operational costs and energy consumption significantly. The users must be allowed more influence on their personal indoor climate.

Today the building is used by the owner and their staff but it is intended to rent out office space in small units in the near future. Keeping this in mind, the owner wishes to reduce operational costs and give the building a new and modern appearance. Special consideration is needed for the fact that the interior has recently been refurbished and the building is in use. Therefore it is neither affordable nor desirable to disturb interior finishings and the working staff.

5.4.4. Refurbishment proposals
Three different proposals have been developed for the office façades within a feasibility study. These proposals aim to find the most appropriate solution for an upcoming realisation.

Proposal 1 – Replacement of the existing façade
- Replacement of the office façade with box windows
- Renewing the building services installations
Proposal 2 – Second skin façade
- Thermal improvement of the existing façade
- Addition of a second façade layer in front of the service gangways
- Integrated climate concept

Proposal 3 – Climate skin
- Addition of a second façade layer
- Installation of solar chimneys in the building corners

5.4.4.1. Proposal 1 – Replacement of the existing façade
The first proposal aims to minimise construction costs by providing the necessary level of insulation and technical installations without additional features.

Figure 5.54
Impression proposal 1

Figure 5.55
Standard section proposal 1
5.4.4.1.1. Construction and climate concept
The existing façade is removed completely and replaced by a new curtain wall. This is filled with new windows or insulated panels. The existing service gangways are preserved and integrated into the façade construction. Visible parts of the gangways are cleaned and painted in a new colour. In order to protect the Venetian blinds from wind and weather conditions an additional glass pane creates a box window. The new climate installation follows the present principle. The decentralised units inside the interior parapet cladding are replaced by modern components that are connected to the existing piping. These are equipped with heat recovery and individual, room specific controls.

5.4.4.1.2. Results
The outer appearance of the building is not changed significantly. The building preserves the existing look only with a different colour. The shading effect of the service gangways is a disadvantage. Being able to control the individual ventilation is a major improvement for the user.

This proposal causes the least material consumption of the three alternatives. Replacing the façade completely makes it easy to install a tested and certified system that solves all vapour sealing problems. Nevertheless, the service balconies remain as severe thermal bridges. While this is a disadvantage in energy demand, the maintenance cost, mainly window cleaning, are particularly low in this concept.

This concept provides a cost effective solution with no influence on the building’s load-bearing structure. Technically the concept creates a very good standard. But, it does not take into account the working staff and additional possibilities for improvement. Replacing the complete façade demands the relocation of staff.

![Figure 5.56: Potentials of proposal 1](image-url)
5.4.4.2. Proposal 2 – Second skin façade

The second proposal wants to take advantage of the existing service platforms, find a solution with minimal disturbance, and improve the building’s appearance. An optimised climate concept shall improve the building’s efficiency.

5.4.4.2.1. Construction

As the interior is not to be disturbed more than necessary, this concept proposes to place an additional façade layer on the outer position of the service platforms. Vertical profiles, suspended from a steel-framework, which rests on the main bearing structure, carry vertical loads. Horizontal loads are brought into the existing consoles. Within the cavity, thus created, the primary façade can be improved. In this case the sub-structure stays in place. Only the filling elements are replaced by new windows and insulated panels.
5.4.4.2.2. Climate concept
The climate concept uses the gained space in the cavity to place new de-centralised climate units. These units provide individual mechanical ventilation with heat recovery and combine this with heat exchangers for both heating and cooling. Every room is equipped with controls for individual regulation of ventilation and heating/cooling.

In winter fresh air is let in at the bottom of the cavity and preconditioned by solar radiation. Additionally, the air can be transported from the east to the west cavity in the morning and vice versa in the afternoon in order to optimise the air temperatures in both cavities. The climate units then take in the air from the cavity. Exhaust air is let out through an additional duct directly to the outside. In summer the system is reversed. Fresh air is drawn in from outside. The cavity is opened on the top. The solar chimney effect creates a stack effect in the cavity, which extracts the air from the rooms. Thus, less electric energy is needed to run the mechanical fans in the climate units.

5.4.4.2.3. Results
The original architectural concept is a composition of a horizontal base that carries a vertical tower. The double façade sharpens the shape of the tower and reduces the effect of very dark, deep window openings. Showing the façade profiles emphasises the verticality of the tower. This gives the building a new identity with reference to the original concept.

The new façade brings additional loads into the existing structure. It demands additional steel beams on the roof and an improvement of the load bearing-columns on the top floor. This causes higher construction costs and a greater material consumption. On the contrary, placing the secondary façade first allows updating the inner façade independently of weather conditions. Disturbance to the interior is minimised. However, keeping the sub-structure in place makes it more problematic to seal all connections against vapour.
The cavity is used to place effective daylight reflecting Venetian blinds. These blinds improve the level of natural daylight in the rooms. In terms of fire prevention, the double façade demands a sprinkler installation both in the cavity and near the façade inside the office room. Alternatively, a horizontal separation of the cavity would be necessary, which would counteract the ventilation concept.

5.4.4.3. Proposal 3 – Climate skin
The third concept aims to take the second proposal further and maximise energy savings. It wants to gain as much solar energy in the façade as possible and change the appearance of the building even more than the other concepts.

5.4.4.3.1. Construction
The façade structure is based on the second proposal. Here also, the existing consoles are used to support a double façade. The inner façade should be renovated in the same way. Additionally, the double façade also covers the outer corners of the building. Thus solar chimneys are created that are integrated in the climate concept. The south façade of the building covers only the emergency staircase.

5.4.4.3.2. Climate concept
The solar chimneys are used to support the ventilation of the building. A stronger natural updraft can be created in these than in the façade. In winter the chimneys provide the ventilation power; while the façade in front of the offices function as a solar collector as described in proposal 2. As the chimneys are placed in every corner of the building, there are different air temperatures and velocities in each chimney at different times of the day and year. Connecting the ventilation ducts to each other makes it possible to supply the office rooms with the most appropriate air quality. The exhaust air is led through an air-water heat exchanger on the top of the solar chimney to recapture even energy that was not recovered in the decentralised units in the rooms.

5.4.4.3. Results

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Figure 5.62
Impression proposal 3

Figure 5.63:
Potentials of proposal 3
The building appearance is changed significantly. It can be argued, if the effect contradicts the slender appearance of the high-rise. The interior qualities will be improved in the same way as the second proposal. The large glass façade brings very high structural loads into the existing building, which demands the improvement of the load-bearing structure. This causes major interference with the interior and imposes additional costs. The climate concept demands many components and a complex control system. Even though it can gain much renewable energy, it requires a very high consumption of material that reduces the positive effects.

5.4.5. Comparison of the different strategies
In the following, the different concepts are compared in terms of construction costs, energy consumption, operational costs, and life cycle costs. This comparison shows the long-term advantages of the different proposals.

5.4.5.1. Construction cost
Proposal 1, the box windows, and proposal 2, the double façade, have very similar construction costs. This is caused by two factors. The double façade consists of a relatively simple secondary façade that reduces the demands for the primary façade, which can hence be cheaper. The box window façade of proposal 1 has to be an entire replacement of the existing structure, which has to comply with all demands in one element. Additionally, the first proposal causes relocation costs which do not apply in the other two options. The third proposal causes the biggest costs both for construction and technical installations. It contains a surface for the double façade almost twice as large as the second proposal. The HVAC installations, mainly the ventilation system, are far more complex than in the other options.

5.4.5.2. Energy demand
The biggest economic and ecologic gain lies in the improvement of the building performance. Already the first proposal can halve the energy demand. This is due to the improved insulation, air tightness, and to the replacement of old technical equipment by modern efficient ventilation
components with individual control. The even better performance of the double façade (2) results from the improved ventilation concept. In winter the solar gains in the façade are used, in summer the natural updraft in the cavity reduces the need for operating power. Thus, the final energy demand can be reduced by 75% to the very low standard of 70-80 kWh/m². Compared to this result the climate skin solution (3) can only achieve minor improvement.

<table>
<thead>
<tr>
<th>Energy demand [kWh/m² GFA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Power</td>
</tr>
<tr>
<td>Lighting</td>
</tr>
<tr>
<td>Cooling</td>
</tr>
<tr>
<td>Heating</td>
</tr>
</tbody>
</table>

5.4.5.3. Operational cost
The operational cost covers the energy demand plus the costs for maintenance of the building services and the façade. Obviously, the operational cost for the initial situation is very high due to the energy demand and the outdated HVAC machinery. The other proposals reach an improvement between 40% and 50%. The new technical installations cause much less maintenance effort. Using individual monitoring makes it possible to optimise service intervals. In the 2nd and 3rd proposal the ventilation units are placed in the cavities and thus easier accessible than inside an office room. The table also shows the effect of window cleaning among the operational costs. Proposals 2 and 3 are equipped with a large amount of glass. The cost for the necessary cleaning cradle for these options has been included in the construction cost.
5.4.5.4. Life cycle cost
The comparison of life cycle costs shows the investment and the annual costs of the different proposals in comparison to the initial situation. All refurbishment options intersect the curve of the unaltered situation within 20 years. This means that within the technical lifespan of façade and HVAC it is cheaper to invest now than leave the building unchanged and repair successively.

The curves for the double façade and the box windows are quite close to each other. The better performance of the double façades makes this concept cheaper after seven years. After 15 years this refurbishment is the first to amortise. The climate skin represents a very expensive solution. Although it causes low operational costs, the big investment allows no reasonable pay-off period.

The feasibility study has not taken into account further added value like better lettability and higher rental rates that can be achieved. One example shall illustrate this. New, smaller, air-conditioning units are placed in the cavity. By removing the interior parapet cladding panels that currently cover the HVAC units 14 m² of usable area can be activated per floor. This equals an increase of rental space by 4%.
5.4.6. Realised proposal

Based on the feasibility study, the double façade was further elaborated and realised. The exterior façade, consisting of laminated glass (size 3.50 / 2.40), was placed in autumn 2008. Additional steel beams that are necessary to transfer the loads of the new façade to the existing structure were installed on the roof. Inside the building only four diagonal beams as shown in Figure 5.65 had to be added to original structure.

For cleaning of the new façade a new cleaning cradle had to be installed on the roof. During construction time, this cradle was used as a crane to mount the outer glass panes. After the outer façade was closed the interior façade could be renovated independently of the weather. Replacing of windows and climate units turned out to be faster than planned. Including relocation of staff and cleaning this process took only eight working days.

5.4.7. Solution for the ‘flaps’

The building does not only provide the façade described so far. The outer corners, also called ‘flaps’ are equipped with a ventilated cladding (type 4.1.1). For this façade a very simple and effective solution could be found. The original aluminium panels have a very high quality and a thickness of 4mm. The sub-structure initially provided a ventilated cavity of 150mm. These facts made it possible to reuse most of the façade cladding.
The cavity is insulated with 100mm of mineral wool. The aluminium panels are cleaned, anodised to prevent filiform corrosion, newly coated, and re-mounted onto the existing structure using the old pressure plates and new gaskets. Thus, more than 80% (approximately 700m²) of the old façade can be preserved.

5.4.8. Solution for the ‘base’ – An insulating ‘top-up-profile’ for a window façade

The original façade consisted of a window façade dating from 1974 and exterior concrete louvers for solar protection. These louvers were neither technically nor visually acceptable. They shaded the interior to such extend that electric lighting was necessary all day. The client also wanted to change the appearance of the building from a closed block to an open and communicative design. Furthermore, since erection of the building it had been impossible to prevent pigeons from nesting between the louvers.

During the refurbishment these louvers have been removed and replaced by a glass screen. The primary façade had to be improved technically. The special concern in this case was that the interior of
these floors had been renovated only one year previously. The interior finishings such as parapet cladding, dividing walls, and suspended ceiling frequently connect to the original façade. A refurbishment solution had to be found for the window façade that did not interfere with these finishings.

The refurbishment concept proposed to install a double façade. Thus, the weather impact on the original primary façade could be reduced. Rainwater tightness and drainage do not need to be considered. The façade mainly has to provide the necessary thermal and vapour insulation. Replacing the glass is essential for the insulation value. Unfortunately, the non-insulated window profiles cause very severe thermal bridges, which would result in condensation on the profiles.

This problem is solved by mounting insulated profiles on top of the outside of the original window profiles. The aluminium profiles have been specially made for this project. They are attached by small brackets screwed to the old structure. The insulation bridges the space between the glass panes. Of course, this structure can not provide the same performance as a new thermally separated façade. But, in combination with the double façade it achieves a reasonable result, effectively prevents condensation, and permits a refurbishment without interference with the interior.
5.4.9. Conclusion
In many aspects, this project presents common tasks. It demands optimal logistics for an inner city location. The building is constantly in use. Hence, much care has to be taken for the users. The proposal has to be applied fast, safely, and with minimal nuisance.

A double façade certainly is not the solution of choice for any project. But, in this situation it turned out to be the optimal concept. The existing service platforms in front of every façade provided enough supporting structure that to make construction cost efficient. ‘Wrapping up’ the building created a protected space in which the original façade could be improved independently from the weather but still outside the office room. The cavity provides the space to install new building service ducts and units. Thus the interference with interior finishings and nuisance for the user could be minimised. During the entire refurbishment process the building could stay in use.

The example to reuse cladding panels, by cleaning and recoating them, shows that it is possible to save a lot of material in construction. This concept can also be suitable for other buildings, equipped with the very common ventilated cladding.

Figure 5.73
Sparkasse Vorderpfalz with refurbished façade (2009)
5.5. **EnBW Head office, Stuttgart Germany**

EnBW is a major German energy provider. Planning to relocate to a new building complex, the original inner-city head office requires a new function. The building presents itself as a case study on façade refurbishment because it provides a common post and beam façade and frequently occurring design tasks. It forms a block perimeter with inner courtyard, in which the neighbouring buildings interact with each other. This situation may inspire different concepts than a solitary building. In the case-study four proposals are developed that range from a necessary renovation to an entirely new appearance of the building. The quantitative and qualitative analysis, realised in collaboration with a structural engineer, works out the potential and consequences for the different concepts (Ebbert 2007).

5.5.1. Building characteristics

<table>
<thead>
<tr>
<th>Name</th>
<th>Head office EnBW Sparkasse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Stuttgart, Germany</td>
</tr>
<tr>
<td>Owner</td>
<td>EnBW Real-Estate, Stuttgart</td>
</tr>
<tr>
<td>Occupant</td>
<td>EnBW – Energie Baden Württemberg</td>
</tr>
<tr>
<td>Year of construction</td>
<td>1977</td>
</tr>
<tr>
<td>Architects</td>
<td>Hans Kammerer, Walter Belz</td>
</tr>
<tr>
<td>Use</td>
<td>Administration</td>
</tr>
<tr>
<td>Gross floor area</td>
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</tr>
<tr>
<td>Façade area</td>
<td>Approximately 4,000 m²</td>
</tr>
<tr>
<td>Façade type</td>
<td>5.4.2</td>
</tr>
<tr>
<td>Main structure</td>
<td>Curtain wall with exterior service platforms</td>
</tr>
<tr>
<td>Challenges</td>
<td>Optional separation into different rental units</td>
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<tr>
<td></td>
<td>Improvement of façade quality and renewal of technical installations</td>
</tr>
<tr>
<td>Ambitions</td>
<td>Definition of new design, in relation to neighbouring building</td>
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<td></td>
<td>Additional benefits to appeal to tenants</td>
</tr>
<tr>
<td></td>
<td>Long term feasibility</td>
</tr>
</tbody>
</table>

5.5.2. Initial situation

5.5.2.1. Architecture

The building (A) dates from 1977. It forms one block with the adjacent building, which was added in 1990. Both buildings show a very high design quality relative to their year of construction. The designs interact with each other. The original design for building A has wanted to highlight the corner situation on a very busy street. It gives a sculptural, planar expression with cantilevered parts and roof terraces. The façade wants to express the technical character of an electricity company (Kammerer 1983).
Figure 5.75
Floor plan of both building parts. Building A is assessed in this study

Figure 5.76
Standard section initial situation, street elevation (with service platforms) and courtyard façade
5.5.2.2. Structure
The building consists of six floors above ground and four underground levels. The supporting structure is made of on-site concrete and based on a grid of 7.50m. In the façade layer, steel columns at a grid of 1.875m carry the vertical loads. The 4th and 5th floor cantilever 1.875m along the western elevation.

5.5.2.3. Façade construction
The façade is based on a grid of 1.875m. It is a post-beam façade with additional cantilevering service platforms on the street elevations. The non-transparent panels are filled with a sandwich element, composed of fibre-concrete boards and 60mm of mineral wool insulation. On the outside the façade is clad with 4mm strong anodised aluminium panels. These cover the post-and beam structure as well as the closed panels. Thus they create the desired planar appearance.

The service platforms cantilever 75cm. They are constructed of steel consoles topped with an aluminium grating. Their balustrade is made of reflective glass. Together with the primary glazing, this also serves as sun protection. On the street façades, vertical blinds provide the necessary glare protection. The courtyard façades are equipped with interior sun shades.

5.5.2.4. Interior finishings
The office space is equipped with a concrete top floor of 5cm, which houses electrical installations. The top floor is in a very poor state, as it has shrunk almost 1cm. While the floor is in need of replacement, the suspended ceiling and dividing wall system are of a high quality. Nevertheless, in this project it is desired to renew all interior finishings in order to create an all new appearance and allow a more flexible layout.

Some toxic material has been found that was used for fire protection. Asbestos reinforced panels cover openings in the floors through which technical instalments were made. The connections to the façade are also covered with these panels. The load bearing steel columns are encased with AMF and an aluminium cover.

5.5.2.5. Climate installations
All office-spaces are fully air-conditioned. Fresh air is supplied through induction units in the parapet cladding. These units heat or cool the air, which is provided by a central ventilation system. Air ducts are placed in the suspended ceiling of the floor below. Stale air is extracted along the electric lights in the suspended ceiling. The building is connected to a district heating system. Cool towers on the roof of the new building partially supply the cooling circuits. Currently the technical installations are connected between both buildings.
5.5.3. Refurbishment tasks
The load bearing structure is in a very good state that allows different façade solutions with minor structural improvements. The façade itself currently provides a U-value of 3.0W/m²K. The double glass dates from 1977 and shows many leaks and damages. The complex façade detailing with additional outer aluminium panels makes it difficult to replace damages glass panes.

The new solution must present a building with up to date technical standards, but shall also keep in mind the adaptability and maintainability of the façade. The design should react to the new building part and nourish the interest of future tenants. It shall be possible to use the building as office space for one tenant, as well as separating smaller zones. Even the use as medical surgery should be an option. It is desired to renew the entire technical building services, both machines and ducts. The renewed building should provide the option to be fully air conditioned. Nevertheless, opening windows are requested by the owner, just as innovative HVAC concepts. The major restriction for opening windows is the main street causing noise and toxic immissions. The client wants interior finishings to be renewed; however, the refurbishment concept should be able to provide a very flexible planning and building process. It should be possible to renew exterior and interior parts individually.

5.5.4. Refurbishment proposals
Four different refurbishment proposals have been developed and assessed. These cover the span from a minimal necessary renovation to an entire redesign of the building block.

Proposal 1 – Renovation of the post-beam façade
- Thermal improvement of the original façade
- Renewing the building services installations

Proposal 2 – Atrium and double façade
- Replacement of the façade cladding
- The Addition of an opening second façade layer in front of the service gangways
- Covering the atrium
- Climate concept based on natural ventilation

Proposal 3 – Glass house
- Replacement of the façade
- The Addition of a multi-storey glass façade

Proposal 4 – Modular façade
- Replacement of the curtain wall with a unitised façade
- Building services integrated in the façade units
5.5.4.1. Proposal 1 – Renovation of the post-beam façade
The first proposal aims to minimise the construction costs by providing the necessary level of insulation and technical installations. The appearance of the building shall not be altered. The production of waste and use of material shall be minimised.

5.5.4.1.1. Construction
The original post-beam façade stays in place. The fillings are replaced by up-to-date glass and opaque elements. Every second fixed glazing is replaced by an opening window. At the parapets, additional insulation and proper vapour sealing is needed. The outer cladding panels are cleaned and replaced. The necessary sun-protection is achieved by the combining the glass qualities of windows and service gangways. To do so, the glass of the service platforms is needs to be replaced. An interior screen provides the necessary glare protection.

Figure 5.79
Standard section proposal 1
5.5.4.1.2. Climate concept
The climate concept continues the original principle. The existing induction units are replaced by new elements with the same function but better performance. Thanks to the improved insulation and sun protection, only half the units are needed. All ducting and piping for these will be renewed. In order to take advantage of the natural ventilation, the windows are equipped with magnetic contacts that turn off mechanical installations when a window is opened.

5.5.4.1.3. Results
The outer appearance of the building is not changed significantly. Only the colour of the façade cladding and the glazing of the service platforms give a new look to the building. For office use, the building will function very well. Dividing the building for independent tenants has a big influence on the technical installations. Defined zones have to be set that are equipped with controls and metering. Distributing ventilation ducts in the suspended ceiling of the lower floor complicates the metering and fire separation between floors.

The proposed solution improves the indoor comfort. Better façade insulation reduces cold radiation from the window, as well as the air volume and speed of the mechanical ventilation. Being able to open a window contributes to psychological well-being. However, the fixed sun-protection holds the risk of blocking too much daylight on a cloudy day. This not only influences the need for electric lighting but also reduces the visual comfort.

This concept provides a very cost-efficient solution. Not only the construction costs are very low, also the building process can be realised relatively flexible. The façade filling and outside finishing can be realised independently of the interior works. The improved u-value will reduce the heating demand significantly. Cooling loads, on the contrary, are more important for this building. To limit these, much care has to be taken for the sun-protection.

![Figure 5.80](image-url)  
Potentials of proposal 1
This proposal has the least influence on the load bearing structure of the building. It is structurally possible to replace the façade filling even with triple glass. The major problem lies in solving the building physical aspects. To replace the filling of a post-beam façade it is essential to provide, for example, new gaskets that suit the old profiles. Even more critically, it is almost impossible to improve the thermal performance of the window profiles. Also, the vapour tight connection of additional interior insulation to surrounding elements demands attention.

5.5.4.2. Proposal 2 – Second skin façade
The second proposal wants to renew the appearance of the building without changing the geometry. The interference with the interior shall be minimised, while the comfort and climate concept should be improved.

Figure 5.81
Minimising the façade surface by covering the atrium

Figure 5.82
Standard section proposal 2
5.5.4.2.1. Construction
The courtyard façade is improved by covering the atrium with a transparent roof. The roof structure is formed by a 3-dimensional framework that rests on the structural grid of 1.875m. The original façade is improved as described in proposal 1. All filling elements are replaced. The load bearing sub structure of the post-beam façade stays in place. The original façade on the street side is improved in the same way. Additionally, it is equipped with a double façade. The balustrades of the service platforms are removed. Instead, the new façade is placed in the same position. While horizontal loads can be taken up by the existing consoles, the vertical loads need to be suspended from a new steel structure on the roof. The outer façade is equipped with horizontal louvers that can open in order to fully ventilate the cavity in summer. The cavity also provides the protected space for daylight deflecting sun blinds.

5.5.4.2.2. Climate concept

Figure 5.83
Climate concept proposal 2, winter situation

Figure 5.84
Climate concept proposal 2, summer situation
The climate concept takes advantage of the buffer climate in the double façade and atrium by proposing controlled natural ventilation. In different seasons air can either be taken in from the atrium or from the outer façade. Radiators installed in front of the parapets provide the necessary heating. Cooling is achieved by a suspended chill ceiling. In winter the atrium functions as heat buffer. Fresh air is brought into the cavity by connecting the existing air-intake shaft to the atrium. Thanks to the surrounding façades and solar irradiation, the air heats up. The natural updraft in the double façade, caused by solar irradiation and open exhaust flaps, creates a low pressure in the building that forces air from the atrium into the offices. In the case of insufficient irradiation, decentralised mechanical fans support the airflow.

In summer the functional principle is reversed. The double façade can be opened to prevent solar overheating. The upper ventilation openings in the Atrium are opened too. Thus the rising air in the atrium drags fresh air through the building. The ventilation fans also serve to flood the building with cool outside air at night-time. As the airflow is also led above the suspended ceiling, the thermal mass of the structure can thus be activated.

5.5.4.2.3. Results
This solution deals with the original design. While the overall shape is preserved, the building receives a new look. The opening blinds of the secondary façade refer to the other, newer part of the building. Covering the atrium creates additional space that can be used for different common purposes. Next to the improvement achieved by the better thermal performance, the new sun protection system provides a better use of daylight. It is generally well appreciated by building users to be able to individually adjust heating and cooling devices, and to open a window.

As the weather does not influence the primary façade any more, the detailing does not need to take rainwater or wind loads into account.

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Figure 5.85
Potentials of proposal 2
Even the thermal bridges are less significant, as the temperature in
the atrium is estimated to level between 15°C and 30°C all year. This
situation leads to simpler and less expensive details of the primary
façade. On the contrary, the opening double façade is a very expensive.
The supported natural ventilation can achieve very low operational
costs. Activating the thermal mass helps to reduce cooling loads.
Daylight reflecting sun blinds installed in the cavity reduce the need
for cooling and electric lighting.

The additional façade and roof structure bring extra loads into the
existing structure. The capacity of the original structure allows the
construction of the atrium roof and double façade with only minor
improvement of existing columns. If it were not for the part of the
building that cantilevers in the top two floors, the support structure
would be very complex. Naturally, the additional structure causes a big
flow of material. On the other hand, with the reduced demands the
primary façade can be solved with less effort.

The building process can be organised relatively flexibly. If the
secondary façade is placed first, the renovation of the inner façade
can be done from the cavity. With the new decentralised ventilation
concept, the interior refurbishment can also take place successively.

5.5.4.3. Proposal 3 – Glass house
This concept takes the second proposal further. It aims use the
principle of the atrium also on the other side of the building. It wants
to play with the volume of the original building and re-deign its outer
appearance.
5.5.4.3.1. Construction
The atrium roof is constructed as described in proposal 2. The street-side façade is equipped with a big glass house. The façade of this can be clad with glass or alternatively with transparent plastic foils or cushions. The volume leaves the ground floor open to the public. The load bearing structure is partly suspended from the building, where this is technically possible. The corners that stand very far off the building receive new foundations or rest on the foundation walls of the underground car park, which reaches out under the building.

The primary façade is replaced by a new post-beam system. This is equipped with opening windows and sliding doors that provide access to the platforms within the glass house. These platforms cantilever from the main structure and are suspended from the structure of the new secondary façade. They take advantage of the volume of the glass house and thus form smaller and wider terraces that serve additional functions.

Figure 5.87
Standard section proposal 3
5.5.4.3.2. Climate concept
The atrium and glass house function as a thermal buffer, which reaches a temperature between inside and outside level. Rooms can be ventilated individually and naturally from these buffer zones. Additionally, mechanical ventilation with central air supply and heat recovery can be installed that provides the basic air exchange when the buffer zones can not supply sufficient air quality. When a window is opened, the machines are turned off automatically. This concept demands a fast and individual heating and cooling system. As the demand for this is relatively low, the rooms are equipped with a climate ceiling. This can be controlled individually and leaves the parapet zone free for opening doors.

5.5.4.3.3. Results
The building appearance is changed significantly. Nevertheless, the design allows for playing with the polygonal volume of the original building. Providing extra space in the cavity makes it possible to change the floor layout easily. For example, the platforms can be used as lobby space and access routes to offices. Hence, smaller and variable zones can be rented out to different tenants. Also public and common functions such as a bar or café can be integrated in the glasshouse or the atrium.

Being able to open the façade to the atrium or glasshouse allows choosing the individual environment and climate. It can even be possible to work on the ‘balcony’. A protected cavity also provides the space for optimal sun protection and blocks the noise of the street.
However, noise within the cavity can cause disturbance. To prevent overheating, it is essential to sufficiently ventilate the cavity and atrium in summer.

The big volume of the façade functions, just as the atrium, as a solar collector that improves the insulation of the building. Only basic demands apply to the renewed primary façade, such as insulation and noise reduction. Air, wind, rain, and vapour tightness are of less importance. Thus, the inner façade can be a cheaper construction. The outer façade, on the contrary, forms a big intervention, which causes a major structural, organisational, and economic effort. The result of the redesign, nevertheless, holds several additional benefits. The new identity of the building, flexible floor layout, and extra qualities are unique selling points for acquiring tenants.

The buffer zones and ventilation with heat recovery lead to a very low heating demand in winter. The summer situation is more problematic. The cavity and atrium tend to overheat. Although, users accept higher indoor temperatures when they can individually open windows, the cooling demand is relatively high, if the atrium and cavity are not ventilated sufficiently.

5.5.4.4. Proposal 4 – Modular façade
If the existing façade is removed completely, it is possible to implement an entirely new façade concept. This concept wants to prepare the building for the different and ever changing functions it may encounter in the future. It is inspired by the modular façade presented earlier for the University of Bielefeld. The façade system can provide the basic technical equipment today; and it can be upgraded to different levels of installations according to the desired function.
5.5.4.1. Construction
The original façade is removed completely. Instead a new unitised façade is mounted. Every unit contains an opening window. Along the main street, these windows are equipped with an outer glass pane to block noise and protect the Venetian blinds. Furthermore, the façade unit provides installation space for technical components.

5.5.4.2. Climate concept
Every office room is conditioned from the façade. Heating and cooling ducts are pre-installed in the façade-zone. From here the technical components are supplied. Depending on the client’s wishes and the climatic conditions, every room can be equipped differently. In a basic installation concept the opening windows provide ventilation, a radiator is used for heating. Additionally, decentralised mechanical ventilation, cooling, or integrated climate units can be installed in the façade. The control system allows monitoring every room individually.
5.5.4.3. Results
Replacing the façade allows to entirely change the appearance of the building. The new façade can be designed in such way that it fulfils the desired functionality. Allowing installation space for a future upgrade will help to easily adjust the building to almost any possible future use.

The climate concept makes it easy to install the necessary equipment in every room. Thus, the optimal thermal and visual comfort can be achieved. The user will be able to control service components and operable windows individually. But, particularly on the façade facing a busy street it may not be possible to use decentralised ventilation, as it would aspirate potential pollutants. Here instead, the rooms would still demand central mechanical ventilation.

The original building provides an adequate load bearing structure. Removing the service platforms activates enough capacity to carry the new unitised façade without the need to improve the structure. Nevertheless, this concept demands an entire renovation of the building’s interior and can only be applied, if the building is empty. Installing only the necessary technical equipment reduces the total number of components just as the maintenance effort. Being able to offer a potential tenant any level of building services he desires gives the building owner many options for pricing and contracting.

A new façade can provide all current standards of insulation and solar protection. This facilitates energy saving. Limiting the number of technical components to a minimum, the operational costs can be optimised.

Figure 5.91
Potentials of proposal 4
5.5.5. Comparison of the different strategies
In the following, the four proposals will be compared with each other and the initial situation in terms of construction cost, energy consumption, operational cost, and life-cycle cost. These estimations give a general idea of the potential of each concept.

5.5.5.1. Construction cost
The construction cost only takes into account those costs that differ between the proposals. Costs for scaffolding, crane use, interior design, and electrical installations have not been estimated. Table 5.11 shows the estimated construction cost for the façade refurbishment and HVAC installations.

The renovation (1) is by far the cheapest façade construction because it only provides minimal basic improvement. The technical installations, on the other hand, are relatively expensive, as the entire system inside the building has to be renewed. The two solutions with double façades (2 and 3) are the most complicated and expensive structures. They demand an atrium roof and the supporting structure for the new façade. In the case of the double façade (2), it is even more expensive than the glass house (3) because of the complex opening system of louver in the double façade. The modular façade (4) can be a very cost efficient solution. The installation cost for HVAC has been estimated in such way that 50% of the space is fully mechanically conditioned, while the rest is equipped with opening windows and a climate ceiling.

![Building costs EnBW Stuttgart](image)

**Table 5.11**
Comparison of construction costs

5.5.5.2. Energy demand
In order to achieve an estimation of the current and future energy demand of the building, three office rooms on different positions inside the building have been assessed by the thermo dynamic simulation tool ‘Capsol’. The results allow the comparison between the different solutions.
The renovation (1) can reduce the heating and cooling demand in comparison to the initial situation (0) by 40-50%. The biggest reduction can be reached with the double façade proposal (2). On the one hand, this is reached by the controlled natural ventilation in combination with the puffer climates on both sides of an office space, which makes a controlled night-time cooling possible. But on the other hand, the biggest effect can be achieved by the reduction of the building surface by covering the inner courtyard.

Proposal 3 – the glasshouse – also takes advantage of the buffer zones. But here the outer façade does not open and the ventilation concept can not provide controlled night ventilation. This results in very high cooling loads. The modular façade (4) creates an up-to date standard. Here the heating demand is higher than in the previous example, because the effect of the covered atrium is missing. The cooling demand is strongly related to the installed level of technical components.

![Energy demand graph](image)

Table 5.12
Comparison of finale energy demand

5.5.5.3. Operational cost
For the comparison of operational costs, the energy costs were estimated, just as the operating power and maintenance effort for the HVAC equipment. Façade cleaning is another aspect. The results show clearly that the double façade proposals (3 and 4) almost cause twice the costs in this aspect.

The operational cost for maintenance of HVAC depends strongly on the complexity of the system and the amount of mechanical components. For the modular façade (4) a mechanical installation has been estimated for 50% of the space. The proposed decentralised units can achieve low maintenance costs because the individual monitoring of each unit allows optimised service intervals.
5.5.5.4. Life cycle cost

Based on the investment and operational costs, the life cycle costs can be estimated. The graph shows that on the longer term the different proposals have a very individual performance. The renovation is the cheapest solution in the beginning. However, after 17 years the improved performance of the modular façade shows its value. It is interesting to see that the double façade is the most expensive solution in the beginning, but thanks to its better performance beats all other proposals within 20 years. Even the very complex glass house solution manages to intersect the initial cost curve within 20 years. This means that any proposal has the chance to amortise its cost outlay within the technical lifespan of the façade and HVAC components.
5.5.6. Conclusion

The assessed proposals show very different solutions for the refurbishment task. The main aim of these has been to explore the possibilities of a block perimeter and a post-beam façade with exterior service platforms. The different concepts should not be seen as final designs. The final solution will probably be a combination of various aspects:

The renovation of the original façade can achieve a good actual standard without changing the outer appearance of the building. But, re-cladding an existing post-beam structure is difficult. One has to rely on the old structure. The thermal separation has to be achieved by using the old screw channel. It may be difficult to provide new gaskets that fit the old profiles and provide proper protection against rainwater and vapour. Therefore this solution is particularly interesting in combination with a double façade or atrium. These additional structures protect the original façade and thus reduce the demands on the new cladding. In general, covering an atrium can be a good solution to improve the building’s surface/volume ratio.

The modular façade (4) is a relatively common structural solution of a unitised façade. The special concern is that all building service ducts are located within the façade and that different service components can be installed in the building envelope. This bears the potential to reduce components and ducts, but also demands very close collaboration between façade and installation manufacturers.

Generally it can be concluded that in refurbishment planning the entire building has to be taken into account. Façade and technical installations have to be planned together. Only then, it is possible to encounter synergetic effects. Furthermore, refurbishment always has the capacity to show additional benefits. These can be an increased rental space by reducing the thickness of the façade, eliminating technical installations, or providing extra common space, be it in an atrium or in the façade cavity. The redesign should thus also highlight the unique marketing features of an individual office building.
5.6. Solutions for the two most common façade types

The market analysis presented in Chapter 3 delivered two very common façade types: Post-and-Beam facades and load bearing structures. The evaluation of case studies has shown that it is often desired to refurbish the façade while the building is in operation. In this case, the market asks for solutions which reduce the impact on the load bearing structure, dividing walls and interior finishings. Furthermore, the concept of upgradeable building services integrated in the façade has been considered very promising by building owners. Hence, the following part of this chapter will take a closer look at the two most common façade types and develop refurbishment concepts, which can provide an up-to-date building envelope in minimal construction time. For the load-bearing window facades, it also develops the concept of upgradeable installations further. The research of this section has been supported by Kawneer - Alcoa Architectural Systems.

5.6.1. The Post-and-Beam Adapter

5.6.1.1. Problem definition
There is a very big amount of post-beam façades in the market that were constructed in the 1960s, 1970s and 1980s. The spot check delivered market shares of 7% in the Netherlands, 17% in the UK and 21% in Germany (Ebbert 2008). There are many different manufacturers and profile-systems on the market. Each system provides its own special form of fittings and gaskets, which are responsible for different construction qualities.

However, the general form of construction of post-beam façades is very similar. Figure 5.92 shows the cross sections of three current post-and-beam façade constructions. On the inside of the façade there are posts and beams that form a load bearing framework. On their outer edge, these profiles provide a screw channel. Glass or other filling elements are placed with dry gaskets into the frame. Pressure plates are screwed into the screw channel and thus fix the filling. The pressure plates can then be decorated with different cover caps. The post-beam façades of the 1960s to 1980s do not comply with today’s energy efficiency standards. Usually the profiles are not thermally separated; neither does the thermal insulation of the glass and filling elements meet current needs. After 20 years one can expect the insulated glass to lose its filling with inert gas. Gaskets start to become brittle (IEMB 2006).

Figure 5.92
Standard profiles of post-beam façades
The common treatment of these outdated post-and-beam façades is to demolish the old façade completely and rebuild a new post-beam structure complying with today’s standards. Such completely new constructions have several disadvantages:

- The need to solve all connections to dividing walls and floor-slabs
- Significant disturbance to the interior, as the façade is entirely removed
- Expenses involved in the relocation of working staff and their loss of productivity
- A big consumption of material for the façade and connecting building parts that may lead to a bad ranking in a Life-Cycle-Assessment

The alternative solution, to replace only the actual glazing- and filling elements, also raises problems: The thermal performance is changed. The old façade profiles form severe thermal bridges between the better insulated filling elements. These thermal bridges lead to condensation and corrosion. Proper gaskets for the new filling elements are missing, because the profile system has been discontinued by the manufacturer.

5.6.1.2. Design aim
The aim is to develop a refurbishment strategy that allows for upgrading of old post-and-beam façades to an up-to-date standard with minimal interference with the interior and minimal use of material. Construction time is to be kept as short as possible.

The solution must allow a new architectural design by placing different exterior profile covers and filling elements. The interior façade structure is maintained, which eliminates the need to adjust connections to

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**Figure 5.93**
Concept sketch of the post-beam-refurbishment-adapter

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dividing walls and interior finishing. Optionally, this interior structure can be decorated or covered by a system component. While the loads are carried by the exiting façade structure, the building physical performance is to be equal to an all new façade. Both zone drained and mullion-drained structures must be possible.

The refurbishment solution has to be very economical. It removes as few components as possible (waste reduction). It provides a base on which a façade system supplier can build on with standard products. Therefore, the façade adapter has to be reduced to a very limited number of different profiles. Last but not least, the construction time must be as short as possible and disturbance to the daily work of building users has to be limited.

5.6.1.3. Concept Idea
As previously described, post-beam façades of different manufacturers are constructed in a very similar way. While cover caps, pressure plates, and filling can easily be removed from outside, the insides of posts and beams are connected to dividing walls, interior finishings, floor constructions, and parapet claddings. Removing the façade completely causes a lot of interference with these elements.

Consequently, the proposed refurbishment concept leaves posts and beams in place and only removes cover caps, pressure plates, gaskets, and fillings. An adapter profile builds up on top of the remaining structure. This profile covers different dimensions of screw channels and bridge tolerances. The outside of the adapter provides the same shape and screw channel as the standard stick system of one provider. From this level the façade can be built up with regular components. Figure 5.93 presents the principle idea in sketch form.

5.6.1.4. SWOT analysis
The SWOT-analysis shows a summary of the properties and possibilities of a post-beam façade refurbishment adapter:

Strengths (positive attributes)
- A cheap way to achieve a base on which standard profiles can be attached.
- Most of the substructure can be maintained

Weaknesses (harmful attributes)
- reliant on a high quality existing structure
- A very specialised product: the façade-construction becomes thicker, thus there are consequences for structure and design
Opportunities (external helpful conditions)
- Suitable for curtain-walled buildings and post-beam-façades in other buildings
- Minimal use of material
- All connections between walls and floors can stay unaltered
- Minimal interference with interior
- Short construction time

Threats (external harmful conditions)
- There are many different existing systems in the market
- Unknown quality of existing structures and connections

5.6.1.5. Profile development
Based on this concept idea and list of requirements, the development of the refurbishment adapter was taken further. This process took three steps. The first step tries to apply an existing profile to different common façade systems. The second step aims to develop an adapter of minimal dimensions for zone drained façades. In the third step, this profile is adapted to allow mullion drained structures too.

Step 1: Using the existing Kawneer profile 171 621
The logical starting point for product development was to take an existing profile and apply it to the new purpose. Almost every system provider has a profile in stock, which can be mounted on steel or timber mullions and transoms. The profile by Kawneer serves as an example to determine the common challenges.

This profile was applied in drawings to different common older façade profiles by various system providers. These profiles were:
- Reynaers CW 50 (from 2000)
- Schüco FW 50 (from 1999)
- Wictec 50 (from 1998)
- Reynotherm RT 50 (from 1995)
- Reynotherm 500 (from 1995)

Figure 5.95 shows the application of the top-up profile to different older façade profiles. This geometric analysis delivers a list of unsolved problems. As the profile builds up to the outer edge of the screw
channel, it results in a big eccentricity of 48 mm. The new glazing is thus relatively far away from the load-bearing structure. Screwing into the old screw channels causes a weak connection. Loads perpendicular to the screw channel can hardly be taken up by the structure. The stability of the structure depends fully on the quality of the old screw channel. As the profile itself can not take up tolerances, it demands different spacers and gaskets for each different old façade profile.

Step 2: Development of a new profile – the minimised adapter
The application of an existing profile highlighted the major points for improvement. Therefore, a new profile was designed, which aims to solve these problems. The construction height, and thus the distance between new glazing and old structure are minimised. The connection to the old structure is no longer achieved by screwing straight into the old screw channels. By screwing perpendicular into the web of the screw channel the connection gains stability. Furthermore, the new screw channel of the adapter is not damaged and the screw does not penetrate the layer of the profile that serves as a second-level water-proofing and vapour barrier. The groove for the fitting screw can be closed with cover caps. This construction also provides the option to cover the interior existing mullions and transoms with new decorative cover caps that fit into the adapter profile.

The graphical application to different profiles Figure 5.97 shows that the new adapter profile can bridge many tolerances of different systems: The eccentricity (distance between old and new screw channel) is reduced to 21 to 29 mm depending on the size and shape of existing screw channels. The Reynotherm 50 profile demands spacers as its screw channel is very high. The Schüco façade system deals with different heights of screw channels for transoms and mullions. Hence, to refurbish this system additional spacers or different gaskets are needed to top up the mullions.
Step 3: Adaptation for zone-drained and mullion-drained façades

The minimal adapter profile as presented before solves many problems and provides the base to mount a standard façade system. But, as the structural height has been minimised, this adapter only functions for zone drained façades. In a further step the profile is adapted to allow mullion drained façades too. Figure 5.98 and Figure 5.99 present the compatible profiles for zone-drained and mullion-drained façades.

These two profiles have also been tried on different older structures. The graphical application shows that the adapter profile has the same properties for fitting on different existing profiles and in bridging tolerances as the minimised adapter. But, in this case the distance between old and new screw channel reaches up to 45 mm, which is owed to the shape of the mullion-profile.
5.6.1.6. Conclusion
The refurbishment adapter provides is a profile system for the refurbishment of existing post-and-beam façades. Only the pressure-plates, cover-caps, fillings, and gaskets are removed. The load bearing mullion and transom profiles stay in place. Thus, no connections to structural components or interior finishings need to be altered. The building process is fast and causes only a minimum of disturbance or dirt.

The adapter profile is fixed on top of existing façade profiles by screwing perpendicularly into the old screw channels. The adapter can take up tolerances within one façade or of different profile systems. For extreme tolerances a spacer profile or special gasket is needed. The outer shape of the adapter profile equals the standard stick system of the system provider. Hence, all standard components can be built onto the profile. In order to provide new interior finishing, the old façade profiles can optionally be covered with cover caps fitted to the adapter. Depending on the desired function of the façade (zone- or mullion-drained) or the structural capacity of the old structure (eccentricity of loading) either the ‘minimised adapter’ or the bigger ‘mullion drained profile’ can be used.

Economically this product makes a very fast refurbishment possible without having to relocate staff or make major changes to interior finishings. The retrofitting demands little more work and time than a simple re-glazing. Ecologically it provides insulation up to the current standard with reduced waste and material consumption. In terms of planning, only few profiles have to be added to the portfolio of a system provider, which makes it easy to train the assembler.

Nevertheless, the refurbishment system always depends on the quality of the existing mullion and transom structure. This has to be evaluated individually for every project. Legal responsibility for the façade is another aspect that has to be solved. Practically, the exact shape and dimension of the adapter and additional profiles have to be further developed. The acceptability of such a system among customers and clients needs to be surveyed.

Figure 5.101
Detail of a mullion-transom connection with adapter profiles.
5.6.2. The refurbishment window and installation concept for load-bearing façades

5.6.2.1. Problem definition
The majority of office buildings in the Netherlands, Germany, and the UK are constructed with load-bearing façades. These can either be skeleton or planar structures. Later buildings are often equipped with additional outside insulation and a ventilated cladding. Together, the building types 3.1, 3.2, 4.1 and 4.2 of the local spot checks make out 56% of the German stock, 50% of the UK stock, and 39% of the Dutch stock (Ebbert 2008).

Figure 5.102
Standard details of load-bearing façade with outside insulation and ventilated cladding (Type 4.1)
Figure 5.102 shows the typical section of a façade type 4.1 with additional insulation and cladding. These façades are composed of a load bearing structure and window elements. The more additional insulation there is, the better the thermal performance. Nevertheless, buildings of 25 years of age or older do not fulfil current demands on thermal insulation. The same applies for window frames and glazing. Additionally to these building-physical aspects, the outer appearance of the façade is often outdated and lacks acceptance by the users.

In terms of building services, one can find different levels of technical installations. Most commonly these buildings are equipped with a basic installation of radiator heating. Only few examples are fully equipped with mechanical ventilation and air conditioning. Buildings of the façade types 3.1, 3.2, 4.1, and 4.2 with operable windows make out 75% of the British, 79% of the Dutch, and even 89% of the German spot check. On average, heating installations have a life-span of 25 to 40 years, air-handling units of 15 years (IEMB 2006). This means that these installations are also subject to refurbishment-planning. Interviews with real estate developers revealed that building owners want to replace heating-ducts but tend to keep radiators in use. This is simply due to the easy accessibility of these, while damages in unreliable piping often cause high replacement costs.

5.6.2.2. Design aim
The design aim is hence to develop a concept for the fast and efficient refurbishment of load bearing façades that achieves an up-to-date building physical and technical performance. The concept must allow many different designs of windows and cladding. It has to be combinable with ventilated claddings or external insulation systems by different system providers. The windows have to be suitable for different dimensions and depths of existing window openings. The focus shall lie on construction that can easily be disassembled for future adaptation and recycling.

The concept has to provide the option to renew the technical building services in an equally easy way. Installation ducts and piping must be mounted without renewing the interior finishing. The installation of new HVAC components must be facilitated. Installation ducts and windows will be mounted separately, because they demand different professionals. A short construction time reduces costs and the nuisance to the building user. It should be possible to refurbish a window façade without moving the user out of their office.
5.6.2.3. Concept idea

The façade refurbishment concept is composed of an exterior insulation and a ventilated cladding combined with an innovative refurbishment window, and an installation concept for HVAC components and piping. As it should allow for different claddings and as there are many functional and affordable cladding systems available, the focus for product development lies on the window unit and the installation concept.

The window itself can provide space for the installation of modern HVAC units within the façade. Thus, installation components can be built in without the need to drill holes for air intakes or outlets and piping. Installation ducts can be installed inside or outside the load-bearing façade. The exterior installation has the major advantage that new pipes can be mounted without disturbance of the interior. Figure 5.103 shows the principle idea of the refurbishment concept. In the following, the window system, the possible HVAC concepts, and the different solutions for the piping are explained.
5.6.2.4. The Refurbishment Window

The central idea of the “Refurbishment Window” is a window system with a limited number of profiles that make different designs possible, as well as the integration of additional technical functions. Figure 5.104 presents a vertical section of the window frame. The profile system contains a central profile with various add-on profiles. The central profile can be used in the way presented or alternatively mirrored, dependent on the given situation or desired design. This would shift the window level further inside. The “centre-profile” provides the thermal insulation and the load bearing function for the glass and the add-ons.

The window frame is prefabricated without the interior add-on profiles. Thus the window unit can be placed from the outside, without disturbing the interior. The sealing between window frame and surrounding wall is achieved by dry gaskets only. This reduces on-site labour and construction time.

The add-on profiles provide additional functions. Outside, the window sill can be mounted directly to the centre-profile. This reduces the number of components needed for the façade cladding and cuts construction time shorter. Different depths of window sills are possible. The fixing for a secondary glazing will be another add-on for the outside. Particularly in higher office buildings or in locations with high wind-loads or noise immissions, a second glass layer provides protection for sun-blinds and improves the noise protection.

Figure 5.104
Vertical section of the standard central window frame with add-on profiles inside and outside.
On the inside, the frame system covers the edges of the wall-opening. Hence, no later work is necessary to seal or repair minor damages that are unavoidable when old windows are removed. Furthermore, the interior add-ons provide installation space for electro ducting. Thus, there is no need for additional cable ducts, and these become a design unity with the window. Other interior add-on-profiles form the ‘installation-box’ or provide the connection to dividing walls. Figure 5.105 gives an overview of the profile-set.

**Figure 5.105**
Set of profiles and filling elements for the façade refurbishment window
5.6.2.5. Building service installation box
With the refurbishment-window profile one can also create an installation space in the window zone of the façade. This space can be occupied by different building service installations. The reason to place these installations in the window zone is that, for example, decentralised ventilation units need a direct connection to the outside for air intake and outlet. Placing them in the window level avoids the need for drilling holes through parapets or walls. This reduces nuisance and construction time.

The installation boxes themselves provide a standardised space that allows the installation of different components, independently of one defined manufacturer. During the life-cycle of a building, different demands occur for different rooms: North and south façades have different cooling loads. Air exchange rates differ for different room functions. Building users may prefer individual levels of technical equipment. With a flexible system rooms can individually and successively be upgraded or downgraded depending on the use. Even in case the building is not fully occupied, it is possible to turn off unused rooms or floors and thus save energy and maintenance work. The following installation concepts are imaginable:

A minimal solution
The building is equipped with high insulation and a ventilated façade. Thus, it only demands minimal heating. Existing radiators can be kept in use. Operable windows supply ventilation. Window contacts, thermostats, and a central override control for the heating operation help to save energy or allow opening designated windows for natural night time cooling. The installation boxes are left empty.

![Diagram](image)

**Figure 5.106** Minimal solution: operable window and radiator heating
Improved energy performance by heat recovery
As natural ventilation may lead to higher energy demands due to the direct exchange of air of different temperature levels, mechanical ventilation with heat recovery can be an option. Small individual ventilation units can be mounted in the installation-boxes and thus provide fresh air without the loss of thermal energy. These can either function as cross-flow heat recovery or as absorbers with reversed air flow, such as the ‘breathing window’ developed by Jon Kristinson (Kristinson 2004). Such small decentralised units provide a high efficiency, as no ducts are needed to transport conditioned air.

![Image](image.png)

Figure 5.107
Improvement by ventilation with heat recovery

The all-in-one solution
Climate installation devices, which provide ventilation with heat recovery and air conditioning by heat exchangers, can be placed into the installation space provided. These are connected to hot water and chilled water circuits, and thus replace radiators or central air-condit

Low temperature heating/cooling
Alternatively, the cooling and heating can be achieved by low temperature systems. A chill ceiling provides comfortable cooling in summer by transporting water of a temperature slightly below room temperature through small tubes within a suspended ceiling. In a highly insulated office building heating is only rarely necessary. Thus the ceiling can also be used for heating in winter. For a surface heating the temperature of the water only needs to be around 25 °C instead of the 70°C hot water needed for radiator heating. The changing of
the climate installations to such a low temperature system makes the old machinery redundant and opens the field for sustainable solutions. The desired temperature level can e.g. be reached by geo-thermal energy, solar collectors, or heat pumps.

**Figure 5.108**
Decentralised HVAC units

**Figure 5.109**
Low temperature heating and cooling combined with heat-recovery
Economic and ecologic advantages
The flexible and easily accessible installation space makes it possible to install building services without structural intervention. Different rooms can be equipped with the exactly necessary level of installations. An ‘over-installation’ is prevented. Hence, only the number of units is produced and built that is necessary. The total number of service units is reduced. It is imaginable that with the change of use, the individual components are changed too. An interesting marketing concept could be, to offer ‘Façades for Rent’. Users rent façade components or installation parts according to their need. When they are not needed any more, the supplier takes them back into stock to rent them out to other clients. This does not only extend the life span of the building, but also the one of every component.

5.6.2.6. Building service installation ducts
With the combination of refurbishment window and installation box, there are generally three possible levels of refurbishment that have direct effect on the building cost and on the flexibility of building services.

Level ‘A’ – Maintenance
The minimal solution provides a fast refurbishment that is done by replacing the windows and the façade cladding. Building services are installed independently of the façade, usually by maintaining or replacing the existing piping. This solution does not provide a technical advantage in comparison to a “regular ventilated cladding”. It nevertheless can be installed faster, as the dry sealant and different add-on-profiles allow a higher level of prefabrication. Most of the components can be mounted from the exterior, which reduces construction time inside the building.

Level ‘B’ – Retrofitting
In the second refurbishment level, the windows are replaced and new installation ducts are mounted to the outside of the load-bearing wall. The pipes are fitted in a fast and simple way by clamps or clips. Figure 5.110 shows how the ducts are mounted to the outside of the wall and combined with an optional installation box.

As the piping is mounted to the outside of the façade, the connections to radiators or chill ceilings may have to be brought inside by drilling holes through the walls. Components within the window elements can be connected to the piping by reaching through the installation space. This concept provides an up-to-date façade and a fixed level of installation of building services. Nevertheless, it causes nuisances to drill holes through load-bearing walls. When changing or replacing building service components one can only reach the installed pipes from outside.
Level ‘C’ – Retrofitting with full flexibility
Refurbishment level ‘C’ allows a high grade of future adaptability as the piping and electrical installation is placed in ducts that are mounted to the outside of the load bearing façade wall. The ducts are covered with thermal insulation and accessible from the inside. They need a sufficient dimension to take up two pipes for a cooling circuit, and two pipes for a heating circuit (diameter 50mm each). Furthermore, they should take up electro and IT cabling, and provide some tolerance for future changes. All these installations can be placed inside rectangular ducts as they are already available for electrical installations. All piping is based on systems that can be connected without using tools. Figure 5.111 presents a possible construction with installation ducts. As all technical installations are easy to reach from inside the building, this concept allows an easy and fast future upgrade or change of components. This refurbishment concept causes the highest construction costs but also provides the biggest flexibility for HVAC concepts, which reduces future installation or refurbishment costs.

Figure 5.110
Possible fitting of installation ducts and connection to installation box. (Not shown: Insulation and façade cladding)

Figure 5.111
Installation ducts alongside the installation box with accessibility from inside. Not shown: Insulation and façade cladding
5.6.2.7. Application examples
In order to show the practicability of this façade concept it has been applied to common building constructions. The following drawings present exemplary solutions for a load bearing window-façade (Type 3.1) and a typical 1950s skeleton façade (Type 3.2).

Figure 5.112
Application of the ‘Refurbishment Window’ to a load bearing window façade (Type 3.1): Installation ducts are mounted to the outside of the original wall. After placing the window unit, the façade is equipped with an Exterior Insulation and Finishing System.

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Figure 5.113
Application of the ‘Refurbishment Window’ to a skeleton façade (Type 3.2): Installation units are placed in the parapet zone. The façade is protected with a ventilated cladding.
5.6.2.8. Conclusion
There is a major market section of load bearing façades with or without additional cladding. Many of those buildings can be refurbished with a combined window and installation-concept. The refurbishment window is composed of a centre profile and different add-ons that provide further functions, such as ducts for electrical installation or pre-fabricated connections to dividing walls. This window system reduces the number of building tasks on-site and thus the construction time and nuisance to the user.

Different levels of quality and building services installations are possible. An installation space, taking up service components can be integrated in the window system. This allows different installations, appropriate to the demands of each room. Mounting the new piping on the outside the load bearing wall, inside the insulation layer, provides reliable, new technical installations without disturbing the interior.

The application to different building types shows the possible variety of designs. As the cladding is not part of the window system, it permits all materials for ventilated claddings. Nevertheless, such construction delivers some design limitations. It would be important to find out, if such products are accepted by planners and designers. Furthermore, there are very functional and economical combinations of windows and ventilated claddings available on the market. In comparison to those, this strategy reduces the construction time and provides the possibility to integrate building services and other functions. Particularly for situations where the refurbishment must take place without moving the users out of the building and where new installation ducts are demanded, this strategy will be interesting.
5.7. References


6. Refurbishment Strategies and their Applicability to Different Façade Types

The previous chapter has presented the intensive analysis of different refurbishment strategies for a variety of office façade types. The results show that certain strategies are better applicable to one façade type than to another. This chapter combines the knowledge gathered in these case studies and gives a guideline on how the owner of an office building can judge, which refurbishment strategy is most applicable to the very case.

The different refurbishment strategies follow a logical order, which is based on the position of the interference. The original façade can be entirely replaced (strategies ‘A’), the building can be equipped with additional façade layers, while the original façade stays in place (strategies ‘B’), and the initial façade can be upgraded on the outside by adding components or replacing parts (strategies ‘C’). Furthermore, the façade can be upgraded from the inside (strategy ‘D’), or a new façade can be mounted inside the original building envelope (strategies ‘E’).

The first part of this chapter presents a flow chart of the refurbishment process based on the findings of this research. The next section looks at the general applicability of different refurbishment strategies to the possible existing façade types. A matrix provides the overview of possible combinations. The following text describes the chances and challenges, which lie in the refurbishment of the various façade types, and explains the applicability of different refurbishment strategies.

The fourth section of this chapter explains the strengths and weaknesses of each refurbishment strategy in the form of ‘data sheets’ with an explanatory text. The results are presented according to the characteristics of the ‘wheel of potentials’: Architecture and function; Comfort; Material and energy; and Economic aspects. Furthermore, the data sheets explain the general restrictions for application and refer to the case studies elaborated in chapter 5, as well as to the best practise examples, which can be found in appendix A. The chapter concludes with comprehensive tables showing the features of each refurbishment strategy in direct comparison.

The information provided in this chapter thus allows approaching the refurbishment task from three sides: Firstly, it is possible to start with a given building and quickly find out, which solution is most reasonable. Thus, the variety of design approaches to be tested can be reduced. Secondly, the list of demands can be checked with the matrix of refurbishment strategies. Thus, it also becomes evident which solution is most likely to solve the given problems. And thirdly, it may be the case that the decision has already been taken for a certain refurbishment solution, because of a desired architectural design,
legal requirements, or functional restrictions. In this case the final matrix shows the potentials of each strategy and allows a quick look at alternatives, which may be able to contribute positive features that solve problems of the original concept.

6.1. How to judge how to refurbish

The design and evaluation of case studies in the previous chapter has delivered refurbishment solutions, which are particularly suitable for different façade types. It also tested assessment and evaluation tools in practise. With this knowledge at hand, it is possible to quickly decide, which refurbishment approach delivers the most promising results for a project. Figure 6.1 presents the flow chart of a planning process for refurbishment. In the beginning of a refurbishment planning, a building (1) is given and a list of demands is set up. At the first planning phase, the attention lies on specifying the refurbishment task. The façade typology (2), which has been explained in Chapter 2, delivers two pieces of information. On the one hand, the common problems and refurbishment tasks of a certain façade type become evident (3) and thus help to specify the list of demands (4). On the other hand,
with the façade type defined, the number of possible refurbishment strategies can be reduced. The overview matrix (5), which will be presented in this chapter, shows the general applicability of different refurbishment strategies for possible given façade structures. It leads directly to the tables showing the characteristics of each strategy (6). In combination with the results generated by a thorough assessment of the building (7), these overviews lead to a collection of refurbishment strategies, which are reasonable for the given task (8).

Thus, the planning targets are set and the number of technical solutions, which have to be compared during the design phase, is limited. It is now easy to develop conceptual draft designs (9), which cover the range of possibilities each project offers. Already at this early stage of the design process, the graphical tool of the ‘wheel of competences‘ facilitates comparison and discussion of the possible concepts with project stakeholders (10). Consequently, this evaluation (11) shows to which extend the redesign proposals meet the project demands. It also illustrates the possible points of improvement and how the eventually selected concept can benefit from the not-to-be-realised alternatives. Thus, the further planning can adjust the draft designs, combine some of their properties, or develop further alternatives. Finally, the project receives a redesign concept which fulfils the desired demands in the optimal manner.

6.2. Promising refurbishment strategies for different façade types

The flow chart presented above has drawn the map for refurbishment planning. The central position in this map is the matrix that permits a quick decision of promising refurbishment solutions for a given façade type. Table 6.1 presents this combination of façade types and refurbishment strategies. It explains in a simple rating, which combinations are most promising. Of course, thorough planning can make further combinations possible. However, here the task is to find reasonable solutions that are most interesting for evaluation. Once a façade type and the planning demands are defined, this matrix helps to choose those solutions, which are recommendable to be considered in the preliminary design phase. While the table gives the general overview, the results are explained in more detail in the following sections.

The rating of the following matrix focuses on the practicability of the application of a refurbishment concept to a façade type.

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Table 6.1

Applicability of refurbishment strategies to the different façade types

(∗: The applicability of a climate skin depends primarily on the geometry of the building.)

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The combinations to be presented want to serve as indications, which applications are practical. These indications thus want to help the planner, client, or architect to choose those refurbishment strategies, which are interesting to be assessed in the first planning phase. They are only the start of the planning process and do not mean that further combinations are impossible. As each project is very individual, there will be further combinations, which do not occur in this scheme.

The refurbishment strategy ‘Wrap Up’ is also present in this matrix, but it cannot be related directly to the façade typology. The concept proposes to cover open atria or three-sided courtyards with a secondary façade and roof, in order to improve the surface/volume ratio of a building. Therefore, its applicability depends mainly on the building geometry. The new construction only rarely connects to the structure of the original façade. Thus, it can be applied to many different façade types.

6.3. Challenges and potentials of different façade types

6.3.1. Types 1.1.2 and 1.2.2 Exterior load bearing structure
The façade structure consists of a dominant load bearing structure and window elements set into this framework. Characteristic of this façade type are structural components, which perforate the thermal layer. Hence, thermal bridges form a major problem. Additionally, building physical aspects demand a special attention: The joints between load bearing structure and window infill are difficult to seal against air and vapour penetration. Service platforms have to be treated as terraces in order to prevent rainwater from entering the construction. Furthermore, the exterior concrete structure tends to suffer from carbonatisation, which is particularly dramatic, as the load bearing capacity may be reduced. On the other hand, the multi-layered construction creates a strong architectural image. In refurbishment planning special attention has to be paid to the question of how to deal with the oppositional demands for design and thermal performance.

Figure 6.2 Office building with exterior structure, University of Karlsruhe (GER), architect unknown
The replacement of the entire existing façade is not possible, because the structural components have to stay in place. If only the window elements are replaced as infill, the risk of condensation and moulding increases, because the difference of insulation values between new parts and existing structure becomes larger. Therefore, the replacement of units has to be combined with further means.

Adding insulation on the load bearing structure, such as a ventilated cladding or an Exterior Insulation and Finishing System, can prevent the risk of condensation, but it can hardly provide a thermal insulation level, which is sufficient for current building legislation. Insulating the load bearing structure, which stands perpendicular to the façade level, influences the thermal bridges in such way that the dew point is shifted from the interior surface to a point inside the massive construction. Thus, condensation and moulding is prevented. However, still a lot of thermal energy is lost. Furthermore, the complex geometry of the façade with many horizontal components makes an exterior insulation very complicated. Therefore, the additional insulation of the thermal bridges is more effective and easier to apply in combination with double façades, in which the rain impact is eliminated.

Figure 6.3  
Refurbishment of a façade with exterior load bearing structure: Replacement of windows and insulation of the thermal bridges

If the exterior impression of the building is to be changed, the predominating load bearing structure can be used to attach new façade units. The façade partitioning depends on the shape of the existing load bearing structure. With a buffer zone thus created, the primary façade leaf still needs to be insulated, but the demands are reduced. The structural elements that perforate the thermal layer have to be insulated. Thus, the thermal bridges can be reduced. Furthermore, the double façade can provide the space to renew the technical building services independently of the interior.
However, most technical problems are solved by adding an insulated façade layer to the exterior of the given structure and thus basically wrap up the entire building in a thermal layer. This solution imposes an entirely new design. The characterising load bearing structure is lost. If the original building was equipped with a double façade, the original design can be reconstructed. Shifting the thermal layer to the outer edges also generates usable space. Depending on the original layout, the initial façade can be removed and the cavity space added to the room.

If the exterior impression of the façade is not to be altered, an interior renovation has to be considered. In this case, the replacement of windows and addition of insulation is possible. However, the connecting building parts (floors and walls) also need to be equipped with additional insulation. The addition of a second façade leaf to the inside of the existing façade is an option, if the original façade does not provide sufficient planar surface for fitting insulation.

**Figure 6.4**
Refurbishment of a façade with exterior load bearing structure: Addition of a new façade on the outer edge of the structure and removal of original windows.

**Figure 6.5**
Refurbishment of a façade with exterior load bearing structure: Addition of a rain screen; the original windows can be improved from the protected cavity.

**Figure 6.6**
Refurbishment of a façade with exterior load bearing structure: Preservation of exterior impression; replacement of windows and insulation of the thermal bridge on the inside.
6.3.2. Types 2.1.1, 2.2.2, 2.2.1 and 2.2.2 – Interior insulation

These façade types are characterised by a certain amount of interior insulation and dominant structural elements on the outside. Just like the first type, these façades mainly deal with thermal barriers of floor slabs and the connections of dividing walls, which perforate the insulation layer, and thus often lead to condensation and moulding problems in the corners of these elements. Interior insulation, if badly fitted, not properly sealed against vapour, or poorly maintained holds the risk of condensation between the insulation and the inside of the load-bearing structure. In order to prevent these problems, all connection details demand special attention.

The interior upgrade goes along with the original façade concept. It is the only means to improve the properties of the building skin without changing the exterior impression. Planar façades can be improved by replacing the windows and adding insulation on the parapet. Framework structures demand a window frame to support the new façade. The application of a non-insulated interior layer is interesting, if the original façade can be sufficiently improved. Thus, both façade layers together can achieve a good result with relatively little effort.

For exterior refurbishment solutions, one has to look at single double layered structures separately. The application of an EIFS or a ventilated cladding promises good results for the improvement of single layered structures. Here, it can create an uninterrupted thermal layer on the load bearing façades. The connection to window frames is essential for the reduction of thermal bridges. Thus, usually, new windows are placed to the outside of the load bearing structure. The cladding then remodels the original design with the same depth of the outer reveal but deeper window sills inside. However, the solution changes the original design significantly.

The exterior addition of a multi-storey or partitioned double façade is not the method of choice for the single layered structures. Although it is structurally possible, the detailing and connections tend to be very difficult to solve. The original insulation and windows are placed on the inside of the load bearing structure. Thus, the necessary additional insulation for the primary façade layer has to cover the entire parapet and window sill, which interferes with the original windows. Alternatively, the interior insulation has to be improved, which undermines the concept of a refurbishment without disturbance of the office work. In any case, the thermal bridges and vapour tightness are very complicated to solve. Such solution usually turns out not to be economically comparable with alternatives.

A significantly better solution is the exterior application of an insulated façade. This takes advantage of the exterior load bearing structure. The new façade can function in combination with the original interior windows and thus form an exhaust façade, which houses the sun blinds and allows extracting excessive heat gains before they reach...
the room. Alternatively, the original window can be removed, which provides easy access to the cavity and increases the usable office space. Especially in this case, the cavity can be used to bring in new installations without interfering with interior finishings: Ducts and decentralised HVAC components are mounted to the outside of the existing façade. After placing an exterior façade, the inner window is removed. Thus, all installations come to be inside and fully renewed, while the office work has not been disturbed.

The situation differs, if the original structure already provides a secondary façade layer for service platforms or an original double façade, like the CITG building of Delft University of Technology. In such case, the existing structure can be used to transfer loads of the secondary façade layer into the main structure. A non-insulated façade layer forms a buffer zone in front of the original façade. The cavity space is protected from rain and wind, and therefore the optimal zone for sun-protection means. Additional insulation, which is necessary to

![Figure 6.9](image1.png)
Refurbishment of a load bearing wall with interior insulation: removal of the interior windows, application of new windows and an exterior insulation system

![Figure 6.10](image2.png)
Refurbishment of a load bearing wall with interior insulation: the exterior insulated façade functions as an exhaust façade in combination with the original windows. The cavity space is used to bring in building services and ventilation ducts.

![Figure 6.11](image3.png)
Refurbishment of structural balconies (Type 2.2.2): The windows are replaced, an additional rain screen reduces the risk of thermal bridges. See Case study CITG
prevent severe thermal bridges can be realised in a much simpler way. Such solution also holds the chance to give the building a modernised exterior impression, which still builds up onto the original design concept, as has been done in to the ‘Ministry of Finance’ in The Hague (NL).

6.3.3. Types 3.1.1, 3.1.2, 3.2.1, 3.2.2 – Single Layered load bearing façades

The market analysis and the practical experience of the case studies have shown that massive planar load-bearing walls are usually well dimensioned and allow many different refurbishment strategies. Building physically, these constructions are also relatively easy to handle. The structure provides much surface to connect new components, and craftsmen are familiar with the standard constructions.

Skeleton structures, on the contrary, are usually more complicated to handle. They are a development in order to reduce construction material. Particularly the buildings from the early 1950s were constructed under difficult economic circumstances. Hence, one must expect very limited structural capacity. This may, for example, result in restrictions for the weight of glass and cladding material. The architectonic design with very slim window profiles contributes to this problem. New profiles, capable to carry insulated glazing, often interfere with the desired slender appearance of the façade.

The most common refurbishment strategies for load bearing façades are exterior claddings. They take advantage of the load bearing façade surface which can be used for attaching insulation and cladding. The ‘refurbishment window’, presented in chapter 5, has been developed for this situation and combines the new cladding with building services installations. Many examples have been found, in which the original load bearing façade has been refurbished with a ventilated cladding. Some of these already are in need for re-refurbishment again. The addition of a double façades to a single layered load bearing façade brings much additional load into the system and causes much effort to improve the existing façade. Thus, this option is usually not economically feasible, as many other approaches solve the task in an easier way. If a secondary load bearing structure is present, which can be reused, the additional façades become a more interesting option. Nevertheless, the original façade still has to be improved and windows are usually replaced. An additional exterior insulated curtain wall can only be applied, if it is possible to provide proper vapour sealing. Otherwise, uncontrolled condensation occurs in the façade construction.
Additional interior insulation is only sensible if the exterior impression of the building skin is to be preserved. Planar walls can be equipped with insulation material and finishing. Skeleton structures with non-carrying filling elements demand an additional window frame, which can be placed as a second façade layer against the original structure. Depending on the capacity of the original façade, also a non-insulated inner second layer is sometimes sufficient. In any case, special care has to be taken for connection details and thermal bridges.

Figure 6.14
Refurbishment of a load bearing wall by adding a ventilated cladding. The original windows are removed.

Figure 6.15
Refurbishment of a skeleton façade (Type 3.2), which preserves the original exterior appearance: an additional façade is mounted behind the original façade layer and creates box window with this.
6.3.4. Types 4.1.1 and 4.2.2 – Exterior insulation and cladding
A ventilated cladding provides a comparable situation as a load bearing façade. If the additional cladding is removed, the façade can be treated in a similar way. However, these façades are usually younger than the load bearing walls without additional insulation. Placing the insulation level outside the load-bearing structure reduces the number of thermal bridges significantly. As the façade is load-bearing and designed to carry an additional cladding, the structural capacity is usually also sufficient. Thus, this façade type is often relatively easy to refurbish.

Often, the exterior cladding can be removed and renewed. If the cavity space permits, it is sometimes even possible to improve the insulation and replace the cladding. Such has been done with Sparkasse Ludwigshafen and the EnBW office in Esslingen. Here, the original cladding was newly coated and reused. Although it is generally possible to apply an EIFS to a planar façade structure after the original cladding is removed, it is no solution of choice if the original façade was already equipped with a ventilated cladding. Instead, a new ventilated cladding gives more design and technical freedom. Also, technical components can be integrated into the ventilated cladding, as the design for the „Refurbishment Window“ has shown.

Figure 6.16
Improvement of a ventilated cladding: If the original structure provides sufficient room, insulation can be improved and many components reused

Figure 6.17
A new curtain wall allows removing the original windows and creates a new impression
The addition of an insulated curtain wall in front of the original load bearing structure makes sense, if the original façade claddings and windows are removed. This solution also implies the need to adjust the interior window fittings and dividing walls, and thus is only recommendable, if the building is substantially refurbished and an entire redesign of the outer appearance is requested.

The options for interior insulation depend on the structural restrictions. Planar walls can be insulated by addition of insulation material and finishing. Skeleton frameworks rather ask for the replacement of façade units or an additional façade on the inside of the original wall. In any case, the interior improvement is the method of choice, if the outer appearance is to be preserved.

6.3.5. Type 5.1.1 – Parapet plus window

This façade type is constructed of prefabricated parapet units, which are fitted from the exterior and usually suspended from only a few points. Window elements are later built in from inside. The entire façade system tends to be very delicate, as the analysis of Bielefeld University has shown. Fittings, for example, are today made of stainless steel, which was not common in the 1960s and 1970s. Furthermore, the insulation and air tightness of these façades often does not comply with today’s demands anymore.

As the façade is an independent element, it is relatively easy to replace. The best technical results can thus be achieved by replacing the entire façade. This solution makes sense, particularly if the load bearing fittings are considered unreliable. Furthermore, the joints of concrete units made before 1978 may be sealed with PCB-containing material, which is highly toxic and has to be removed while the façade is being refurbished. Of course, the façade replacement causes major interference with the interior. But then, the new curtain wall can be designed in a way that it reduces the dead load and provides the quality of a new building envelope. Furthermore, the replacement allows giving the building an entirely new outer appearance.

The addition of a climate skin or other types of double façades does not make much sense. These refurbishment strategies demand a complex load bearing structure and need to be connected to the main structure. This connection has to penetrate the existing façade panels. Moreover, the original façade units usually need to be equipped with additional insulation and new window elements. This is technically possible, but stands in no reasonable economical relation to the cost of a façade replacement.

If the parapet can not be removed or the interior is not to be disturbed, it is possible to apply an exterior insulation. This addition has to keep in mind the limited structural capacity of the main load bearing structure and the fittings of the original façade units. An EIFS is the most light-
weight solution, as well as the most cost effective. A ventilated cladding can provide a better quality and wider range of design options, but also may demand an improvement of the existing structure.

If interior insulation is desired, for example to preserve the exterior impression of the building, the existing windows have to be replaced. Additional insulation can be fitted to the parapets, if they provide sufficient structural capacity. An additional interior façade, which spans from floor to ceiling, is a solution that does not interfere with the fittings of the original parapet units. However, it is difficult to bring its structural loads into the main structure, and it causes several problems with thermal bridges and the risk of condensation. Generally speaking, an interior insulation for a façade type 5.1.1 can only be the ultimate option, if a façade replacement, which would cause comparable nuisance, is not possible.

Figure 6.21
Improvement of a heavy curtain wall with an Exterior Insulation and Finishing System

Figure 6.22
Interior addition of an insulated façade forming a box window with the original outer façade, no additional loads in the original curtain wall
6.3.6. Type 5.2.1 – Unitised concrete curtain wall

Unitised concrete curtain walls are made of floor high units from either light-weight concrete or with a three-layered section that contains a certain amount of insulation. These units are suspended from two or four anchors. Often the façade is mounted successively from bottom to top. If the façade is to be replaced, this means that the entire building has to be refurbished as a whole and therefore must be completely vacated.

However, the safest refurbishment solution is the replacement of the entire façade. This provides the building with an up-to date façade, in which any desired function and combination with technical components can be applied. With the original heavy façade units removed, some load bearing capacity of the main structure is freed. Furthermore all potentially present toxic material, such as PCB, which was common in concrete façades dating before 1978, can be eliminated.

The addition of a second façade layer, be it a multi-storey or partitioned façade, implies the thermal improvement of the existing façade and connections to the main load bearing structure of the building. These connections perforate the prefabricated elements, which is possible with concrete units, but still very labour intensive. Therefore, the additional exterior façade is only an option, if the interior is not to be changed and a new outer appearance is desired. Adding an insulated façade to the outside of a unitised curtain wall is no option. The connection details, sealants, and load transfer tend to be so complex, that a façade replacement, even with all necessary interior adjustments, is more feasible.

If the façade is to be improved, while the building is in operation, only an exterior insulation can be considered. An EIFS, however, is not a very safe option. All sealants and joints have to be covered to prevent cracking. A ventilated cladding, on the other hand, demands many structural connections to the original façade and brings additional
loads into the original concrete units. Their trustworthiness is reduced by the anchors to the main structure and the effect of concrete carbonatisation, which reduces the grip of anchors. Furthermore, exterior insulation can only be applied to façades which provide a planar surface.

The ‘Local Court’ in Siegen (GER), for example can not be solved in this way. Being a building of cultural value, it would come into consideration for interior insulation. If the windows can be replaced and the façade unit is capable to support the interior insulation and finishing, this could be a relatively simple solution. If the façade units cannot support additional loads on the inside, but are desired to stay in place, it is necessary to place an additional insulated façade unit behind the original façade. An exhaust façade with a non-insulated inner leaf is only possible, if the original façade leaf can be sufficiently improved and the climate installations can be adapted. In this case an interior insulation can even be the solution with least disturbance of working staff. As no exterior refurbishment solution is sensible, it is the only refurbishment concept that can take place successively, while the façade replacement demands the entire building to be empty.

6.3.7. Types 5.3.1 and 5.3.2 – Light-weight unitised curtain wall

A unitised aluminium curtain wall has similar structural problems like the other unitised façade. It is commonly constructed of an aluminium frame which is suspended in four points. Often, the façade is mounted successively from bottom to top, which means that it can only be removed in the reversed order. The construction itself is usually very sophisticated and can hardly be technically upgraded. Older constructions often do not provide the desired level of insulation any more; profiles are not thermally separated, glass qualities insufficient. Furthermore, gaskets tend to become porous and leaking.

To certain extend, it is possible to replace and upgrade façade components. Depending on the façade structure, the glazing and filling elements can be replaced. All other components are often very difficult to replace, because the façade system has been discontinued by the manufacturer. Furthermore, post-frame façades can possibly be retrofitted by leaving the posts in place and replacing the frame units. In this case most interior connections can be kept. Thus, the replacement of the building skin is the option that brings the best technical and design results. It provides a new façade performance and creates an entirely new look for the building. However it demands complex logistics and causes major interference with the use of the building.

The addition of an exterior second layer façade is very difficult. On the one hand, it is not possible to penetrate the existing façade units to attach the second layer. On the other hand, the primary layer would have to be insulated, which is difficult with this type of façade. An EIFS
or a ventilated cladding can not be mounted, because the original façade units provide no suitable surface and construction material for these. Only if the original façade is equipped with exterior service platforms or a second façade layer, it is an interesting option to reuse this structure to fit an extra façade layer, which creates a cavity that improves the thermal performance of the façade, provides a protected space for sun blinds, and can be integrated in the ventilation concept.

The improvement by additional insulation placed against the inner surface of the existing façade, as described for EnBW Stuttgart, is possible. However, this process is very labour intensive and results in difficult detailing for vapour tightness and thermal bridges. An additional interior façade unit, set against the original façade, can improve the insulation while preserving the exterior impression. Also, the option of an exhaust façade is possible with this solution, if it can be combined with the ventilation concept and the outer façade leaf can be upgraded sufficiently. However, these options are very labour intensive, costly and fault-prone. They are only sensible, if the façade structure is a valuable monument of modern building history.
6.3.8. 5.4.1 and 5.4.2 – Post-beam-façade

In post-and-beam façades, each post is attached to the load bearing structure. The façade is based on the profile-system of one manufacturer and filled with different transparent and opaque elements. The major technical problems occur, when these filling elements are outdated: the insulation value is insufficient, insulated glass leaks, or opaque panels are contaminated with asbestos fibre. Furthermore, the original profiles often do not provide a thermal separation, and the original components and gaskets are not available any more to replace broken parts.

It is possible to re-glaze an original façade, if the load bearing structure permits the additional loads, and if the gaskets are reliable or can be replaced. However, the thermal separation of the profiles becomes the point of interest. Condensation occurs, if these are poorly insulated. The ‘Post-and-Beam Adapter Profile’, invented during the course of this research project, aims to solve this problem and makes it possible to reuse the original post and beam structure. All connections to interior finishings can stay intact.

If the interior finishings may be changed, the best technical results are achieved by replacing the entire façade. This option provides the chance to create the desired modern technical standards and bring in almost any façade concept. The architectural impression of the building can also be changed.

Additional façade layers are also an interesting option, if the interior of the office is not to be changed, and if the cantilevering structure of façades with service platforms can be used to support an additional façade layer. The cavity thus created provides the space for integrated HVAC components and ducts, as it has been shown in the projects ‘Sparkasse Vorderpfalz’ in Ludwigshafen (GER) and ‘EnBW head office’ in Stuttgart (GER). It is difficult to mount an additional façade to an initially single-layer façade, as the connections have to puncture the primary façade. The addition of an insulated façade, is neither possible. It brings more loads into the structure. The detailing of structural connections, vapour, sound, and fire barriers causes equal nuisance as an entire façade replacement and are less reliable.

The addition of a second interior façade layer is also possible to a certain extend. It presents one new reliable façade unit, which has to be connected properly to the surrounding building parts. Such façade unit can also contain technical components, which provide new building services from the façade and thus regain some of the space lost by the interior addition. Following the same idea, an improved exterior shell can also be equipped with a non-insulated inner façade leaf in combination with the climate concept. However, these options hold many risks of thermal bridges and vapour leaks; they demand a lot of labour on site and interfere with the building operation. Thus, they are only sensible, if the exterior impression of the building is to be preserved.
6.4. Refurbishment strategies

The following section explains the general construction of different refurbishment strategies and highlights their potentials. Each approach is evaluated using the ‘Wheel of Potentials’. The results are shown in the data sheets and explained in the following text. They cover the influence of the refurbishment strategy on architecture and function of the original building (1), the improvement potentials for the user comfort (2), the material and energy demand as an indication of ecological sustainability (3), and the economical aspects, which are responsible for the financial sustainability of a project (4). Furthermore, the applicability of each strategy to different façade types and the necessary boundary conditions are explained. The data sheets also refer to the case studies, which have been evaluated in chapter 5 and the collection of best practice examples, which can be found in appendix A.

6.4.1. Strategy A1: Replacement of a curtain wall
Removing the original façade opens a broad variety of possible solutions. Commonly the original façade is replaced with a new curtain wall, which is connected to defined positions on the original load bearing structure. The new façade can either be composed of floor high unitised elements, such as the ‘Mannesmann tower’ in Düsseldorf (GER), or as a prefabricated parapet with additional windows, such as the ‘Allianz regional office’ in Linz (A). Alternatively, the façade is realised as a stick system. This structure can then either be finished as a warm façade with insulating panels or as a cold-warm façade, in which the windows are built into the profile-system and the opaque zones are equipped with insulation and a ventilated cladding. The ministry ‘BMVEL’ in Bonn is an example for this.
Figure 6.32
Characteristics of refurbishment strategy A1: ‘Replacement of a curtain wall’

1: Architecture and function
2: Materials and energy
3: Potentials
   New design
   Technically up-to-date
   Reduced dead load
4: Limitations
   Interference with interior
   Connection to primary structure

Suitable for
   Curtain walls
   Vacant buildings
   Prefabricated concrete claddings

Not suitable for
   Buildings in use

Case Studies
   EnBW Head Office, Stuttgart (GER)

Best Practice Examples
   Mannesmann Tower, Düsseldorf (GER)
   LEG, Erfurt (GER)
   Allianz Regional Office, Linz (A)
   KfW Head Office, Frankfurt, Main (GER)
   Nürnberger Hypothekenbank, Düsseldorf (GER)
6.4.1.1. Architecture and function
Replacing the entire façade gives the architect a kind of ‘tabula rasa’ situation with almost full freedom for the design of the building envelope. The only restrictions are the existing primary structure and the load bearing connections. The new façade can easily provide an up-to-date performance in terms of building physics and fire safety. When removing the original cladding and adjusting the interior, also all possible hazardous material can be treated in the optimal way. It lies in the nature of a replacement that the building’s appearance can be changed easily. If no exact copy of the original design is demanded, due to monumental reasons, this concept is commonly used to give the building a new look with little reference to the original. Also, the future adaptability of the new façade can easily be integrated into the new planning.

6.4.1.2. Comfort
An entirely new façade provides the latest technical standards. As long as no geometrical or technical features, such as cantilevering balconies or structural elements, interfere with the design, an optimal insulation can be achieved. As in any new façade design, the replacement can take all necessary measures for acoustical and visual comfort. Also, the new façade can be combined with a great variety of HVAC concepts. Especially, when the building is substantially refurbished, it is possible to bring in those technical installations, which fit best to the integrated façade and climate concept.

6.4.1.3. Material and energy
The consumption of material and energy is related to the form of redesign. In comparison to other, more cautious, concepts, the replacement removes as lot of the original structure and thus needs to bring in more material for the new building skin. Nevertheless, this more energy and material consuming construction often also achieves the best energy performance during the period of use. If the building envelope is entirely newly designed, its end-of-life performance can be planned in the beginning of the project by choosing re-usable material and separable constructions.

6.4.1.4. Economic aspects
The same as for material consumption applies for the economic aspects. The replacement causes a major interference with the interior, which has to pay back on other financial advantages. Usually the façade replacement is only applicable, if the building is completely empty. The expenses for the relocation of staff have to be considered in the feasibility assessment. Then again, an empty building facilitates the building process, shortens the construction time on site and may also reduce the construction cost. The high quality of the new façade, which can be expected, leads to low operational costs. The operational energy demand is reduced by an optimal combination of building skin and building services, the good insulation, and optimised natural day lighting. Furthermore, the maintenance cost of the façade can be kept
short, if aspects such as façade cleaning and adaptability are kept in mind during the planning process. Further economical benefits can be activated if the building is remodelled completely. Particularly, the floor layout can be optimised, which improves the usability of the building and the workflow. If heavy concrete façade units are replaced by a lighter façade structure, additional load bearing capacity can be gained.

6.4.1.5. Applicability
Façade replacement is currently the most common form of refurbishment and applied to many façade types. Nevertheless, it also has some restrictions, which makes it particularly interesting for certain conditions. The original building should be equipped with a façade that can easily be removed. This applies to curtain walls and prefabricated concrete claddings. As the replacement imposes a big interference with the interior, it is predominantly interesting, if the building interior is in need for refurbishment too. Therefore, the building has best to be vacant, which also eliminates extra expenses for relocation of staff. Furthermore, the removal of the original façade allows giving the building an entirely new appearance. Hence, it is an interesting option, if the original design is not accepted any more, and the owners or users desire a change of the built image of their company or an improvement of the public urban surrounding.

6.4.2. Strategy A2: Replacement with a double façade
Just like the other replacement concept, the new double façade demands the original building skin to be removed. In this case, not a ‘simple’ replacement takes place, but the new façade incorporates sophisticated building services and a new ventilation concept. The solution can be a ‘multi-storey façade’, a ‘corridor façade’ or a ‘box window’. The new façade is usually realised as a unitised structure, which connects to defined structural points on each floor. The ‘Münchener Rückversicherung’ is a good example, in which a unitised corridor façade is realised to replace an original curtain wall. The most important structural task lies in the additional weight of the double façade and the eccentricity caused by the width of the façade units.

6.4.2.1. Architecture and function
The façade replacement provides full freedom of design with only little relation to the original building skin. The only design restrictions are the structural connections, which define the grid of the new façade. An entirely new double façade brings building physics and safety measures into line with current standards. Fire safety demands more attention than in a single layered structure. Depending on the façade system a sprinkler might be necessary to prevent heat and smoke transport inside the cavity. A double façade usually represents the latest technical standard of the time of construction. However, due to limited space within the façade structure, future adaptations or changes are difficult.
A2: Replacement with a Double Façade

<table>
<thead>
<tr>
<th>Potentials</th>
<th>Limitations</th>
</tr>
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<tbody>
<tr>
<td>Building redesign</td>
<td>Interference with interior</td>
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<tr>
<td>Technically up-to-date</td>
<td>High material consumption</td>
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<tr>
<td>Elaborated ventilation system</td>
<td>Additional loads</td>
</tr>
<tr>
<td></td>
<td>Expensive</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Suitable for</th>
<th>Not suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtain walls</td>
<td>Buildings in use</td>
</tr>
<tr>
<td>Buildings with capable structure</td>
<td></td>
</tr>
<tr>
<td>Need for new technical installations</td>
<td></td>
</tr>
</tbody>
</table>

Case Studies
- University of Bielefeld (GER)
- EnBW Head Office, Stuttgart (GER)
- Sparkasse Vorderpfalz, Ludwigshafen (GER) (not realised)

Best Practice Examples
- Stadtparkasse, Düsseldorf (GER)
- Gebouw Westraven, Utrecht (NL)
- Münchener Rückversicherung Munich (GER)

Figure 6.33
Characteristics of refurbishment strategy A2: ‘Replacement with a double façade’
6.4.2.2. Comfort
The latest standards of the façade arrange for a very good technical performance comparable to a new building. Nevertheless, the typical problems of double façades apply: reduced daylight performance due to the thickness of the façade, and the risk of overheating. Therefore, the HVAC concepts combined with a new double façade are usually very elaborated. In this respect, the width of the façade can be used to install building services, such as decentralised HVAC-components. Pure natural ventilation is difficult to realise, as condensation may occur on the secondary layer in winter and the cavity functions as a heat trap in summer.

6.4.2.3. Material and energy
Replacing an existing façade with a new double layered structure demands the removal of many original components and in addition a lot of new material. During the period of use, the optimised new standards lead to high energy savings. The need for heating in winter is almost eliminated. Provided the building is managed well, the cooling demand can also be kept small. The end-of-life-performance of a building is always subject to today’s design. The planner has the freedom to choose appropriate materials and constructions.

6.4.2.4. Economic aspects
Removing an existing façade and installing a double façade causes very high construction costs. Therefore, this solution needs to be considered in correlation with a redesign of the entire building. Also, the building process causes major interference with interior finishings and the building use, which makes this strategy rather interesting for the refurbishment of vacant buildings. A new façade usually provides a good technical performance. Nevertheless, the maintenance effort depends on the façade structure and HVAC components. The expenses for façade cleaning, for example, are naturally higher in double façade, due to the duplication of surfaces. However, the double façade also provides additional benefits. Technical ducts and mechanical components can be placed inside the cavity, which frees extra usable space inside building formerly occupied by technical equipment. The use of solar gains in the façade can support energy saving, provided the ventilation concept and the sun protection means react quickly on changing weather conditions.

6.4.2.5. Applicability
Just as the previous concept, the façade replacement is an interesting option if a new design is desired and the construction process allows vacating the building. Thus, those buildings are interesting for this concept, which demand a substantial refurbishment of the façade, the technical equipment and the interior finishings. A double façade brings higher loads into the building carcase. Thus, a good quality of the original structure is demanded. Façades, which are constructed of prefabricated concrete units, are interesting candidates for façade replacement, because the removal of heavy façade components frees
structural capacity. Also, the location of the building sets the demands. Particularly buildings in locations with high wind loads and noise impact can benefit from a second façade layer, which protects the sun screens and permits opening windows.

6.4.3. Strategy B1: Cover-Up
The conceptual idea of this strategy is to ‘cover up’ an existing building in a new climate skin. This skin covers a large volume of air that creates a buffer climate, in which the original building is protected. The goal is to use as little new structure as possible to cover a large surface of adjacent façades and thus improve the A/V-ratio of the building. The original building is protected from weather impact. Rain and wind do not reach the old façade. Direct solar irradiation is reduced. Thus, the building physical deficiencies of the façade become less important.

The easiest way to reach this goal is to cover an interior courtyard. In this case, a load bearing structure for the new roof is needed. The roof trusses of this structure are placed onto defined connections to the existing building. An improvement of the original load-bearing structure may be necessary. Depending on the span of the roof, additional columns with corresponding foundations can be demanded inside the atrium. The roof structure can be covered with opaque cladding, glass or synthetic material, such as ETFE cushions.

Atria, which are not closed on all four sides, demand an additional façade. Depending on the load bearing structure this façade needs to transfer loads to the ground or to adjacent building parts. The example of the refurbishment of the Architecture Faculty as Delft University of Technology shows a straightforward solution with load bearing columns and vertical girders.

6.4.3.1. Architecture and function
Covering a courtyard or atrium of a building is a major design intervention. A covered inner atrium opens the field for new and additional functions. The atrium can become a semi-public meeting space and provide social functions for the users inside the building and/or the public, as has been realised in the ‘Ministry of Finance’ in The Hague. Covering a three-sided courtyard, as it has been proposed for the University of Bielefeld, is a major urban intervention. It changes the entire exterior impression of the building and the shape of the public space. On the one hand, this formerly public space is privatised. On the other hand, the covered space can be valuable semi-public space for. Thus, the applicability of this concept depends not only on the shape of the building but also on the urban design and the ownership status of the open space.

The designing task of the new façade itself is limited to the new façade and roof structure. The aim should be to preserve as much as possible of the existing construction. The future adaptability of the building is restricted. On the one hand, the exterior shell is defined. On the other
Figure 6.34
Characteristics of refurbishment strategy B1: ‘Cover-Up’
hand, the big covered space provides a room, in which the original façades can be maintained and improved independent of the weather. A major task in this concept is fire safety. Heat and smoke are trapped in the covered atrium. Therefore, the exhaust of heat and smoke has to be planned well, just as the accessibility for fire fighters. A similar problem occurs with toxic material. It is caught in the atrium and from there transported to the surrounding rooms. Therefore, all possibly volatile toxic material needs to be removed.

6.4.3.2. Comfort
Due to solar gains and the heat transmission through the original façade, the winter temperature inside the atrium is higher than outdoors. Thus, individual window ventilation has no negative influence on the energy performance. Neither have air leaks in the façade. In summer the atria need to be well ventilated in order to prevent overheating. It has to be ensured that no zones of still standing air occur. An effective sun shading and additional adiabatic cooling with water or plants lower the atrium temperature. The office space surrounding the atrium only receives indirect sunlight, filtered by the atrium roof. Neither is it possible to control the sun shading of the atrium individually. The acoustical effect of the roof and façade has to be seen in a nuanced light. Exterior noise sources are blocked, but interior noise is reflected from the roof. The sound of rain on the roof cladding may also be disturbing.

The initial idea of this concept proposes to leave the original building unaltered. The refurbishment strategy functions with many different (existing) climate concepts. Nevertheless, as the conditioned building part is not hermetically sealed against the atrium, mechanical cooling and ventilation are not the optimal solutions. The climate skin works best with radiation heating and cooling, and opening windows.
6.4.3.3. Material and energy
Depending on the geometrical relation, the material used for the new structure can be less than it would be for retrofitting all building surfaces. In the optimal situation, no means need to be applied to the original façade. Thus, the total material consumption is reduced. In planning, the number of connection points to the existing structure has to be optimised, which limits the structural interference with the original building and the need for additional foundations. The separated structures and reduced material consumption are also in favour of a good end-of-life performance. Recycling of the new structure is facilitated. The life span of the original façade is extended.

6.4.3.4. Economic aspects
Construction cost follows a simple relation: the more original surface is covered with as little new façade the lower is the cost per m². Thus, the design should aim for the optimal building geometry. If the necessary thermal simulation shows that an improvement of the original façade is needed, the construction costs rise severely. The construction process holds a big advantage. The roof can be placed independently of the treatment of the original façades. If necessary, their improvement can take place in the protected surrounding of the atrium. The biggest additional benefit is the enormous gain of usable space. Former exterior zones now provide an intermediate climate and can be used for temporary functions. Further occupiable units can be built inside the atrium. The façades of these buildings only have to fulfil reduced demands and can be realised as interior walls.

6.4.3.5. Applicability
The cover-up strategy is only suitable for buildings with an appropriate geometry, such as perimeter block developments or buildings with big courtyards that are closed on at least three sides. While these courtyards can be covered with a climate skin, the exterior (street-side) façades of the original building demand a different treatment. Furthermore, the original courtyard façades need to be in a state that they do not demand major effort to remove toxic material, repair sealants, or to improve the optical appearance. A thermo-dynamic simulation has to verify the over-all energy balance of the building, because many synergetic effects cannot be displayed in thermostatic energy calculations.

An additional façade placed on the exterior of an existing building reduces the technical demands for the original façade. Compared to the climate skin presented above, a double façade is directly placed in front of the original façade and covers a smaller air volume. The temperature in this cavity can be as low as the outside temperature. Therefore, the primary façade layer usually has to be improved too. Nevertheless, this improvement has to deal with reduced demands, as the façade is protected from the weather and only needs to provide thermal insulation and vapour tightness. With an appropriate design,
### B2: Exterior Addition of a Multi-storey Façade

#### Economic Aspects

- Construction cost
- Operation and maintenance costs
- Energy consumption

#### Architecture and Function

- Integration with existing building
- Compatibility with architectural design
- Aesthetics

#### Material and Energy

- Material selection
- Energy efficiency
- Durability

### Potentials

<table>
<thead>
<tr>
<th>New design possible</th>
<th>Complex structure</th>
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<tbody>
<tr>
<td>Limited interference with interior</td>
<td>Overheating risk on upper floors</td>
</tr>
<tr>
<td>Elaborated climate design</td>
<td>Need to upgrade primary façade</td>
</tr>
<tr>
<td></td>
<td>New cleaning concept</td>
</tr>
</tbody>
</table>

### Limitations

<table>
<thead>
<tr>
<th>Buildings with service platforms</th>
<th>Façades with volatile toxins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noisy and windy locations</td>
<td></td>
</tr>
<tr>
<td>(Medium and high-rise buildings)</td>
<td></td>
</tr>
<tr>
<td>Refurbishment without change of interior</td>
<td></td>
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</tbody>
</table>

### Suitable for

- Sparkasse Vorderpfalz, Ludwigshafen (GER)
- University of Bielefeld (GER)

### Not suitable for

- BP Solar Skin, Trondheim (NOR)
- Dorma Head Office, Ennepeetal (GER)

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Figure 6.38
Characteristics of refurbishment strategy B2: ‘Exterior Addition of a Multi-storey Façade’
planning, and organisation the refurbishment of the primary façade can be realised from the cavity. The additional façade layer is suspended either from the roof or per floor. Regular connections are needed to transfer horizontal loads into the original structure. Glass or synthetic materials (textile, ETFE) are used as cladding materials.

6.4.4.1. Architecture and function
The addition of an exterior façade layer leads to a new exterior impression. The new façade is relatively open for different designs. Restrictions apply with the shape of the building, the structural capacity, the grid of the original façade, and with the connections to the building. The original building will often be recognisable. The new secondary façade can try to emphasise the original design, put the old building into a showcase, or create an entirely new look.

Fire safety is a major safety challenge. The multi-storey façade facilitates flash over from floor to floor. Therefore, a sprinkler may be demanded inside the cavity. Potentially existing toxic material needs to be removed or encapsulated, depending on the ventilation concept. For example, highly volatile PCBs, which had been in the outer sealant of the old façade, would be trapped in the cavity.

6.4.4.2. Comfort
A double façade has two major impacts on the visual comfort. On the one hand, the second layer of glass, the depth of the façade, and the necessary service platforms block a certain amount of sunlight and view. On the other hand, the protected cavity provides the necessary space for optimised sun shading. Individually controllable and daylight deflecting Venetian blinds can be safely installed here. Placing an additional façade layer in front of the original façade improves the acoustic protection from outside. Therefore, this concept is interesting for noisy locations and higher buildings. On the contrary, the sound transfer from room to room along the façade may be problematic.

A multi-storey façade has to be combined with the climate concept. If inside-air flows into the cavity, it can lead to condensation in winter. Also, used air can stream from one floor to another via the cavity. In summer, high temperatures occur in the cavity, particularly on the upper floors. All of these factors support the decision for controlled mechanical ventilation. Decentralised mechanical units, which individually take air of the desired quality from either the cavity or from the outside, can use the cavity in summer as an exhaust, and as a solar collector in winter. In consequence, this solution achieves a good thermal and energetic performance, with the drawback of very little influencing possibilities for user.

6.4.4.3. Material and energy
The multi-storey façade represents a relatively simple addition which preserves a lot of the original structure. Nevertheless, it adds a lot of material to the building. Connecting the secondary façade to the primary layer is the major structural task. Suspending vertical loads
from the roof has proven to be a good option. It creates more slender façades and less complicated connections. However, it does demand additional structural components on the roof. Horizontal loads have to be brought into every floor. Here it is a big advantage if existing consoles of original service platforms can be reused. The structural connections in every floor need to be treated with special care, as they can form thermal bridges. The energy consumption of the refurbished building depends on the quality of the primary façade and on a smart HVAC concept.

6.4.4.4. Economic aspects
Although, both the secondary façade and the improvement of the original façade are relatively simple constructions, the additional multi-storey façade is often more expensive than a façade replacement. This is caused by a great deal of work on site. The big advantage of the exterior addition is that almost all work can be done from the outside. If well planned, the disturbance of the interior can be reduced to a new glazing or replacement of windows. Staff can stay in the building, which saves relocation costs and double rents. The HVAC installation demands an exact controlling and monitoring to ensure the optimal energy performance and savings. Façade cleaning is always costly in double façades. Especially, if a second layer is applied to a building, which originally provided open service balconies, the installation of a cleaning cradle may be necessary.

Additional benefits of the concept are the use of thermal energy and the chance to place HVAC components in the cavity, which frees additional office space. The solution also has a certain marketing potential. For example, the client Sparkasse Vorderpfalz uses the ‘refurbishment without staining the carpet’ intensively to promote their innovative and creative character also as a financial institution.

6.4.4.5. Applicability
The addition of a secondary layer is predominantly interesting for buildings in windy or noisy locations. Particularly high rise buildings are interesting for a the application of a multi-storey façade, because this demands at least five floors for the desired stack effect to be reached, which has to support the ventilation concept. Especially, buildings with original service platforms come into consideration, as their structure can be reused. Furthermore, an exterior solution is interesting for buildings, which have to be refurbished independently from interior changes, e.g., buildings which are to be kept in use. As the primary façade layer often also needs to be improved, the exterior double façade can be combined with the refurbishment strategies for exterior upgrade (C or D) for the primary façade. Especially, the exterior upgrading is interesting, as it can be realised inside the cavity. The multi-storey façade is not applicable to those façades, which are contaminated with volatile toxic material, such as PCB. The pollutant would be trapped in cavity and could not evaporate.
6.4.5. Strategy B3: Exterior Addition of a Partitioned Double Façade
Subdividing an additional façade layer opens further technical possibilities. Unlike the multi-storey façade, this strategy provides an existing façade with an additional non-insulated exterior layer that forms box windows or a corridor façade. The new façade is constructed in prefabricated units and mounted to the original building. The detailing is subject to the façade and installations concept, as well as the possibilities for connections to the existing building. The vertical loads can either be brought into every floor, or an additional structure is needed, which suspends the new façade layer from the roof. In any case, the horizontal and — where necessary — vertical separations of the cavity connect to the original façade. Furthermore, the primary façade needs to be upgraded technically in order to provide the necessary thermal and vapour insulation.

6.4.5.1. Architecture and function
Adding a new façade layer with horizontal and vertical divisions is always a complex technical concept. The refurbishment allows a wide range of design options, which can have only little reference to the original. Nevertheless, several design restrictions apply, such as a technically imposed horizontal emphasis of corridor façades or the necessary trusses for a suspended façade. As the concept is very specialised, it is hard to facilitate future adaptability. The cavity provides room for the integration of installation ducts and decentralised technical components, but the limited space therein usually does not allow future additions or upgrading. As explained before, a double façade needs to deal with special concerns in terms of fire safety, such as the spreading of smoke and fire in cavity. Toxic materials, possibly present in the original building skin would be trapped in the new façade cavity and therefore have to be removed or encapsulated.

6.4.5.2. Comfort
The strong façade construction blocks a part of the natural daylight, but then again, the cavity is the optimal location for an adjustable sun blinds with daylight deflecting properties. Unlike the multi-story façade, the subdivided construction does not only protect from exterior noise sources, but it also prevents sound propagation inside the cavity. The thermal comfort is closely related to the ventilation concept. The cavity provides space for decentralised components, which can use air of different temperatures either from the cavity or from outside. An individually controllable ventilation of the cavity also permits opening windows and natural ventilation. A promising ventilation concept is the return to the traditional box window, in which both layers can open individually for natural ventilation. Thus, the solar gains are used in winter and overheating is prevented in summer. This concept either demands technical devices to control the openings or well informed and responsible users.
B3: Exterior Addition of a Partitioned Double Façade

**Potentials**
- New design possible
- Limited interference with interior
- Elaborated ventilation system
- Integration of building services

**Limitations**
- Connections to original façade
- Need to upgrade primary façade
- New cleaning concept
- Costly

**Suitable for**
- Buildings with service platforms
- Medium and high-rise buildings
- Refurbishment without change of interior

**Not suitable for**
- Toxins in façade cavity

**Case Studies**
- BMVEV, Bonn (GER)
- Refurbishment Concept 3x
- Westraven Building, Utrecht (NL)

Figure 6.41
Characteristics of refurbishment strategy B3: ‘Exterior Addition of a Partitioned Double Façade’
6.4.5.3. Material and energy
The relatively complex structure demands more material than a simple multi-storey façade. Also, the connections to the original façade are more numerous and complex, which results in a bigger impact on the building structure. Nevertheless, the refurbished façade provides a very good thermal insulation and energetic performance. The structural focus has to be on possible thermal bridges and vapour tightness. Precisely these details determine the future adaptability and recyclability. Often, specialised sandwich structures or laminated units are used for the improvement of the primary layers, which are problematic for mono-fraction recycling. The secondary façade itself can relatively easily be designed to be demountable.

6.4.5.4. Economic aspects
A partitioned double façade is a very expensive solution. The construction costs result from the complex new structure, the necessary upgrade of the primary layer, and a good deal of required labour on site. However, the possibility to upgrade a building skin and the technical components entirely from the outside saves a lot of interference with the interior and even allows refurbishing while the building is in use. When the HVAC system and the building envelope are updated as a unity, the energy demand of the building can be significantly reduced. On the other hand, a double façade imposes higher maintenance costs for cleaning and technical equipment. Further financial stimulations of this concept can be seen in the chance to place all climate installations into the cavity, which activates additional usable space, and in the marketing potential of an innovative building renovation instead of a ‘simple retrofit’.

6.4.5.5. Applicability
The additional double façade demands buildings with a sufficient load bearing structure. Especially those façade types are interesting for this solution, which already provide a second layer such as service platforms. Also the building location is a predominant factor. In noisy or windy locations a double façade allows placing sun blinds inside the cavity and opening windows. This strategy can generate the best synergetic effects, if the technical building services are in need of major maintenance, but the interior of the office is not due for renovation.

While the previous examples showed non-insulated façades being added to the existing building, this strategy places a new insulated façade to the outside of the original building envelope. This new façade is either constructed as a post-beam structure or as a unitised façade, which can be fixed per floor or alternatively be mounted on an additional structure suspended from the roof. The original windows can either be removed, which creates a wide window sill or bigger rooms. Alternatively they are integrated in the climate concept and form an exhaust façade together with the new exterior layer.
B4: Exterior Addition of an Insulated Façade

<table>
<thead>
<tr>
<th>Potentials</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>No improvement of original structure necessary</td>
<td>Demands capable load structure</td>
</tr>
<tr>
<td>Entire installation from outside</td>
<td>Eccentric loads</td>
</tr>
</tbody>
</table>

Suitable for:
- Load bearing façades
- Skeleton structures of good quality
- Refurbishment without change of interior

Not suitable for:
- Façades with hazardous materials

Case Studies

Best Practice Examples
Research Institute OTB, Delft University of Technology, Delft (NL)

Figure 6.43
Characteristics of refurbishment strategy B4: ‘Exterior Addition of an Insulated Façade’
6.4.6.1. Architecture and function
The concept provides the building with an entirely new façade, which gives big freedom of design. It basically only needs to respect the connection points and can be clad in any preferred style. The Research Institute OTB at Delft Technical University, for example, has placed a standard post-beam façade in front of the original concrete structure and taken out the original windows. An exterior addition demands a thorough detailing of the connections between floors in order to prevent fire flash over or sound transport. Special attention has to be paid for the possible presence of toxic material. A new exterior building envelope would leave the material, which was originally outside, now inside the room.

6.4.6.2. Comfort
The additional exterior insulated façade has the same consequences for indoor comfort as any double façade. An additional glass layer and a deeper reveal reduce natural daylight. The acoustic comfort is usually improved, as noise from outside is sufficiently blocked by the new façade. Room-to-room sound transport has to be avoided by thorough detailing of connections. The insulation effect is equal to that of a new façade. The existing HVAC installations can be kept in use. Furthermore, the new façade can easily be used for natural ventilation. In combination with the original, non insulated window, the new façade can function as an exhaust façade. Although being a very specialised option this concept opens interesting HVAC solutions, which are supported by the possibility of placing air ducts inside the newly created cavity.

6.4.6.3. Material and energy
An insulated façade, mounted to the exterior of a building, is a relatively simple structure. It leaves the existing façade unchanged and removes only what is necessary. The old building skin also provides some of the technical performance, thus the material consumption for the new façade is less than that of a total façade replacement. The technical detailing has to focus on optimising the connection points between new and old façade and the separations of rooms in order to provide the best possible insulation.

6.4.6.4. Economic aspects
The additional façade can be of a commonly known construction, which allows a high level of prefabrication. The complexity depends strongly on the quality of the sub structure, the geometry of the building, and the room partitions. The disturbance of the interior can be limited. Most labour takes place outside the office room. Furthermore, prefabricated elements reduce the need for drilling. In optimal conditions it is not necessary to even enter the actual office rooms. The technical performance of the added façade is equal to that of a new façade. Insulation performance is brought into line with current standards. The façade maintenance can be facilitated by an
appropriate design. Thus, this strategy presents a reasonable solution, which on the other hand only offers little further benefits. It delivers a functional, good quality building with relatively easy means.

6.4.6.5. Applicability
Mounting a new façade to the outer edge of an existing structure demands the load bearing structure to be of a high quality and provide sufficient capacity. Thus, a carrying wall or skeleton façade are most appropriate for this concept. Especially if the building is to stay in use during the refurbishment, it provides a sensible option. On the other hand, the presence of volatile toxic material in the original façade prohibits this solution. In the initial situation, the toxin used to be outside the building. With an additional cladding it is captured inside. Particularly concrete façade units produced before 1978 have to be assessed for PCB. If that is present, no additional façade should be placed to the building’s exterior, even after removal of the toxin.

6.4.7. Strategy C1: Exterior Insulation and Finishing System (EIFS)
An ‘Exterior Insulation and Finishing System’ is a common solution for massive walls. It replaces the existing windows and adds insulation onto the exterior wall facing. This insulation can be polystyrene, polyurethane, or mineral wool. It has to be glued and screwed to the structural wall, because the old façade coating is not sufficiently reliable for gluing alone. Synthetic or mineral plaster forms the finishing. Furthermore, specially manufactured decorative coating elements, imitating other materials, can be glued onto the plaster.

6.4.7.1. Architecture and function
The range of designs is limited to the material and colour of the coating and the choice of decorative materials. The EIFS is only applicable to load bearing façades. Its major advantage of being the most cost effective solution also holds the risk of creating a rather cheap appearance. The choice of insulation material for high rise buildings is restricted to mineral wool for fire safety. In any other office building at least the lintels of windows have to be insulated with mineral wool to prevent fire from spreading inside the EIFS. The future redesign options are very limited. A plaster wall can be repainted. If a technical improvement is desired, the system has to be – at least partly – removed.

6.4.7.2. Comfort
An EIFS is a simple method to improve the thermal insulation significantly. In combination with new windows and a good glazing the thermal comfort can easily be improved. Adding insulation on the exterior leads to deeper reveals and thus a poorer daylight ratio. Also, the sun blinds, if mounted on the exterior, often reduce the window size. The noise protection of the façade is usually improved. It depends predominantly on the type of windows. The room-to-room noise protection depends only on the original structure. The façade
Figure 6.46
Characteristics of refurbishment strategy C1: ‘Exterior Insulation and Finishing System’
refurbishment is independent of the interior and HVAC concept. Thus, the original building services can be maintained. Often a simple solution is preferred, in which operable windows are combined with radiation heating.

6.4.7.3. Material and energy
The system consumes only the absolute necessary minimum of material: windows, insulation and coating material. Furthermore, the system is very light weight. Provided, the original structure can take the drilling, no further structural demands apply. On the contrary, the EIFS has a rather poor end-of-life performance. Being a laminated system it is impossible to separate the materials. Currently it is not known, how the used insulation material will have to be treated in the future. The toxicity of PS and PUR has not yet been fully researched. Thus, it is likely that these materials become special refuse.

6.4.7.4. Economic aspects
An EIFS is a well known concept. It is currently the cheapest possible solution to improve the thermal performance of a building. Only the replacement of windows interferes with the inside. All further work takes place from the outside with the major disturbance being the drilling of anchors. The ‘Null-Heizkosten-Haus’ by Luwoge in Ludwigshafen (GER) even succeeds to renew technical building services without disturbance of the interior. New ducts are mounted onto the outside of the original façade and later embedded into the EIFS. During practise, the light weight structure of an EIFS tends to suffer from dew condensation on the outside. This leads to relatively fast staining and growth of algae. Hence, an EIFS needs to be cleaned and repainted in relatively short periods (approximately 10 years depended on environmental conditions).

6.4.7.5. Applicability
An EIFS demands a planar load bearing wall structure, in which the necessary anchors can be fitted. This wall also needs to be very even, as insulation plate material cannot compensate much tolerance and no air must be present between wall and insulation in order to reduce the risk of vapour entering the construction. An EIFS is suitable for the fast and cheap retrofiting of thermal insulation, as long as no further refurbishment tasks need to be tackled.
6.4.8. **Strategy C2: Ventilated Cladding**
A ventilated façade cladding consists of a substructure mounted onto the load bearing façade, insulation placed between the substructure, and a ventilated cavity between insulation and cladding. A great variety of cladding materials is possible. Their task is to protect the insulation from the weather and give the façade its materialisation. The substructure consists of linear profiles mounted onto carrying walls or spanning from floor to floor. Loads are thus brought directly into the structure.

6.4.8.1. **Architecture and function**
Based on the given building geometry the substructure of the ventilated cladding allows a wide range of designs and even adaptations of the geometry. Many different cladding materials are possible, such as metal, glass, natural or artificial stone and composite materials. The cladding system is made of individual components, which also facilitates the future adaptability. If the cavity is well dimensioned, even additional insulation material can be placed therein, if demands change in the future. Mounting the entire system onto the outside does not affect the interior except for the replacement of windows.

6.4.8.2. **Comfort**
Adding insulation on the exterior leads to deeper reveals and thus a poorer daylight ratio. But then again, the layered and modular structure of the cladding allows placing sun blinds above the windows, so they do not reduce the window opening. The acoustic quality of the new façade depends on the new windows. Placing the insulation to the outside provides a good thermal insulation. Furthermore, the massive inner walls serve as thermal mass. Thus, the thermal comfort can be improved easily.

A ventilated cladding can be combined with many different HVAC systems, or even leave the original concept unaltered. The systemised substructure makes it possible to provide sufficient space within the cladding to install HVAC ducts and decentralised components. The ‘refurbishment window’ presented in chapter 5 is based on this principle.

6.4.8.3. **Material and energy**
Only little material is brought into the façade structure during the construction phase. The adaptability of the system is in favour of a long lifespan. Sparkasse Vorderpfalz has been an example, in which the 30-year old aluminium panels could be newly coated and reused after the insulation in the cavity has been improved. Even at the end of the technical life of the façade system, the construction is fully separable.

6.4.8.4. **Economic aspects**
A ventilated cladding is a well known and proven system. Its relatively simple form of construction makes it possible to be realised at low construction costs. The interference with the interior is reduced to
### C2: Ventilated Cladding

![Image of C2: Ventilated Cladding](image)

<table>
<thead>
<tr>
<th>Potentials</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively cheap solution</td>
<td>Demands good quality of load bearing façade</td>
</tr>
<tr>
<td>Fast</td>
<td>Drilling causes nuisance</td>
</tr>
<tr>
<td>Well-known system</td>
<td></td>
</tr>
<tr>
<td>Possible integration of building services</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suitable for</th>
<th>Not suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good quality load bearing façades</td>
<td>Toxic material in original facade</td>
</tr>
<tr>
<td></td>
<td>Curtain walls</td>
</tr>
</tbody>
</table>

### Case Studies

- University of Bielefeld (GER)
- The Refurbishment Window
- EnBW administration building, Esslingen (GER)

### Best Practice Examples
- Police Station, Chemnitz (GER)

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Figure 6.48
Characteristics of refurbishment strategy C2: ‘Ventilated Cladding’
the replacement of windows and the drilling for the substructure. The maintenance of a ventilated cladding is simple and depends mainly on the finishing material and detailing. Smart combinations with ventilation concepts, such as the refurbishment window, allow improving the entire HVAC from the outside without disturbing the interior.

6.4.8.5. Applicability

A ventilated cladding demands a load bearing structure to fit the anchors. This can be a planar wall or a skeleton structure, which has to provide sufficient structural resources to carry the new cladding. This new cladding is often wider than the original façade, which increases eccentric loads.

Figure 6.49
The façade structure models the shape of the building – The Hague University of Applied Sciences, Delft (NL), architect: S. van Breda

Figure 6.50
Test Mock-up of cladding panels, the original façade panels could be newly coated and reused. The original substructure provided sufficient space for additional insulation - Sparkasse Vorderpfalz, Ludwigshafen (GER)

Figure 6.51
Principle sketch of the refurbishment window
6.4.9. Strategy C3: Partial Replacement
The partial replacement tries to reuse most of the existing structure. Post-beam-façades, for example can be improved by replacing the filling elements with new glass and sandwich panels. The ‘Post-and-Beam Adapter’ presented in chapter 5 solves the thermal bridges of the original profiles with structural profile that is mounted on top of the original structure and thus creates the thermal separation. Another example for the improvement of original window profiles has been realised in the case study for Sparkasse Vorderpfalz. An insulated profile is mounted on top of existing window frames to prevent the thermal bridge. This is only possible inside a cavity which protects the primary façade from rainwater. Furthermore, the original façade structure has to provide the connection to the load bearing system. This means that this original structure has to be fully reliable for the future purpose and capable of carrying additional loads imposed by new glazing and additional parts.

6.4.9.1. Architecture and function
The re-cladding is strongly related to the original façade structure, as this is not fully removed, but only partly replaced. This opens the path for a new interpretation of this design or a remodelling of the original impression. The future adaptability of the façade is only possible to the same extend as the refurbishment. The partial replacement aims to bring the existing structure as close as possible to current standards. This includes the removal of potentially present toxic material, such as asbestos reinforced sealants.

6.4.9.2. Comfort
The partial replacement can only be an improvement of the given situation but not deliver the maximum possible solution. The performance depends strongly on the quality and potential of the original façade. The noise protection depends on original connections and detailing. The new glazing can only add on to this. The same applies to the thermal performance. The posts and beams have to provide a reasonable insulation. If only the filling elements are insulated, the effect of thermal bridges becomes more evident and problematic. The partial replacement wants to provide a fast improvement of the building skin. The existing HVAC concept is usually maintained, but many other options are technically possible, though independent of the façade.
Figure 6.52
Characteristics of refurbishment strategy C3: ‘Partial Replacement’
6.4.9.3. Material and energy
Replacing only the necessary parts of a façade, results in little material being brought in. The existing façade structure has to cope with the additional weight of the new cladding. Therefore, the connections to the main structure are very important. The thermal insulation effect, which can be achieved with a partial replacement, is often only basic. Thus, other means, such as the improvement of technical components and installations, have to be applied to optimise the total energy efficiency of the building.

6.4.9.4. Economic aspects
This concept combines reduced material consumption with a relatively high demand of labour. Thus, a good planning is essential to reduce construction costs. The interference with the interior is limited to the replacement of façade filling units. Maintenance of the refurbished façade tends to be simple. As the general layout and dimension of the façade does not change, it can be maintained in the accustomed way.

6.4.9.5. Applicability
The partial replacement of an existing façade demands the original structure to be of good quality. Therefore, post-beam curtain walls with reliable connections to the main structure are potential candidates. Existing window profiles can not be equipped with exterior insulating profiles, if they are exposed to rainwater. Hence, the partial replacement is particularly interesting for the technical improvement of the primary layer within a double façade. For example, if an existing façade is to be refurbished with an additional glass façade (strategies B), the inner layer can be improved by one of the above means, instead of being entirely replaced.

Figure 6.53
The ‘Post-and-Beam Refurbishment Adapter’ is mounted on top of existing mullions and transoms. Thus, it provides the standardised base for a new façade filling (Ebbert 2008)

Figure 6.54
Insulating profile on top of an original window inside a newly created double façade - Sparkasse Vorderpfalz, Ludwigshafen (GER)

Figure 6.55
Structural re-glazing of an original steel window frame, case study "Faculty of Civil Engineering” University of Technology, Delft (NL)
6.4.10. Strategy D: Interior Insulation
The interior insulation equips the existing façade with additional insulation and interior facing. Possible constructions have been described in chapter 2. Dependent on the insulation material (mineral wool, calcium silicate, or others), different means are necessary to prevent vapour penetration. Vapour condensing inside the structure can lead to severe damages. Placing the insulation on the inside of a façade changes the thermal behaviour dramatically. In a wall with exterior insulation the temperature range occurring inside the construction during one year is only 11K. It rises up to 60K if interior insulation is applied. In consequence, the structure is subject to a stronger movement due to thermal expansion, which causes stress in connections and the risk of cracks in adjacent walls. (Dittert 2008).

6.4.10.1. Architecture and function
Interior insulation is the method of choice for monument conservation. If the exterior impression of the building is of a high cultural value and therefore not to be changed, the necessary thermal insulation has to be mounted to the inside of the façade. Thus, the design freedom is limited, but the original design is preserved. Interior insulation is a technically difficult solution, as the transport of humidity inside the structure and possible condensation has to be kept in mind. Hence, the entire wall build-up functions as one system and cannot be altered easily in the future. Predominantly, the interior vapour tight layer must not be perforated. Therefore, if a façade is improved from the inside, this usually leads to a total interior refurbishment. In this case all potentially toxic material can easily be removed, and the structural fire safety can be improved.

6.4.10.2. Comfort
The interior insulation blocks the thermal mass of the façade. Thus, it tends to cause an unpleasant indoor climate and increases the risk of overheating. As the interior insulation demands the refurbishment of the interior, it is reasonable to retrofit the building services in the same time. Additional insulation on the façade wall demands existing radiators to be placed on a different position. A severe risk occurs, if old ducts are placed in the exterior walls. With interior insulation, the load bearing structure becomes colder in winter, which may lead to frost-damages of the ducts.
Figure 6.56
Characteristics of refurbishment strategy D: ‘Interior Insulation’
6.4.10.3. Material and energy
An interior insulation consumes only very little material. The connections to the existing structure are simple in terms of structural loads. Only, the detailing for vapour tightness demands thorough attention. The insulation capacity of this strategy is not perfect. Further means should be taken to optimise the energetic building performance. Although only little material is used, the deconstruction of the façade system will be just as labour intensive as its application. All materials have to be demolished separately. Only purely mineral constructions, such as calcium silicate plates with mineral plaster can be demolished together with the load bearing wall.

6.4.10.4. Economic aspects
An interior insulation is very labour intensive and imposes major changes of the interior. An extreme insulation thickness increases the problems with thermal bridges and a loss of usable space. Therefore, the overall performance of the building has to be considered rather than only the improvement of the façade.

6.4.10.5. Applicability
Interior insulation can usually not provide the perfect level of insulation. It holds the risk of several technical problems and a poorer indoor climate. Furthermore, usable space is lost. Therefore, it is mainly recommendable for buildings of a high socio-cultural value, whose exterior impression is to be preserved. As the interior finish needs to be attached to a planar wall, it is only suitable for load bearing perforated façades.

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Figure 6.57
Simplified temperature distribution dependent on the position of the thermal insulation (Dittert 2008)
**E1: Additional Insulated Interior Layer**

<table>
<thead>
<tr>
<th>Potentials</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preservation of exterior impression</td>
<td>Thermal bridges</td>
</tr>
<tr>
<td></td>
<td>Loss of space</td>
</tr>
<tr>
<td></td>
<td>Disturbance of interior</td>
</tr>
</tbody>
</table>

**Suitable for**
- Listed buildings of low standards
- Curtain walls

**Not suitable for**

**Case Studies**

**Best Practice Examples**
- Siemens Design Centre, Munich (GER)
- BMW Head Office, Munich (GER)

*Figure 6.58* Characteristics of refurbishment strategy E1: ‘Additional Insulated Interior Layer’
6.4.11. **Strategy E1: Additional Insulated Interior Layer**
The application of an additional insulated interior layer is a further
development of the interior insulation. In this case, an additional
façade is placed inside the original structure. The additional façade is
carried by the structural floors and supported by the dividing walls.
A special construction is the ‘box-in-a-box’ solution, which places an
insulated building unit inside an existing structure. Such a unit consists
of wall and floor elements, which provide the necessary insulation
and vapour barriers not only along the façade but also on the other
surfaces.

6.4.11.1. **Architecture and function**
The additional interior façade can improve the insulation of the
building while preserving its exterior impression. However, the interior
design is strongly affected by this interference and subject to thorough
planning. The future adaptability of this façade concept also depends
on the planning and design of the new components brought in.

6.4.11.2. **Comfort**
The additional glass layer and the depth of the cavity block natural
sunlight. The cavity, on the other hand, provides the protected space
for sun screens. The thermal comfort in winter does not tend to be
problematic, as the façade allows a good insulation. However, in
summer, the solar irradiation in combination with the loss of thermal
mass tends to create unpleasant conditions. Placing a new façade onto
the inside of an existing wall creates a certain space which can be used
for technical installations. Building services, such as new radiators or
decentralised HVAC units can be installed in this zone. Generally, an
interior insulation favours a fast heating and cooling system, which can
compensate the loss of thermal mass.

6.4.11.3. **Material and energy**
The interior addition reuses much of the original façade. The technical
demands for the interior façade are reduced, because it is protected
from outside weather conditions. Prefabrication of units reduces
construction time. Nevertheless, the extra load of the additional glass
has to be carried by the existing structure. The recycling capacity of
the additional façade is usually good, as it is a separated construction,
which can easily be removed from the building.

6.4.11.4. **Economic aspects**
The façade construction is rather difficult. Although many parts can be
prefabricated, the mounting demands a good deal of labour on site.
All connections to dividing walls and floors need to be insulated and
properly sealed. The new façade provides a relatively good thermal
insulation, which reduces energy demands. On the other hand, it
imposes more effort for maintenance and cleaning. Only if both layers
can be opened, the façade is fully serviceable from inside, otherwise
an exterior cleaning device has to be installed. Furthermore, the
additional façade layer occupies usable space, and the interference
with the interior during construction is significant. Hence, this solution is particularly interesting, if the interior is to be renovated anyway.

6.4.11.5. Applicability
The additional interior insulated façade can provide reasonable standards; but it also creates many problems, such as condensation and structural risks, a major interference with the interior, and a loss of usable space. Hence, it is most suitable for buildings with a protected exterior design, or those, which are meant to be preserved because of their cultural value. Among these, the addition of prefabricated façades units with their own carrying frames makes this concept not only suitable for load bearing walls, but also for skeleton façades and curtain walls.

If it is possible to improve the original structure, or if this structure provides a reasonable but not optimal quality, an interior façade layer can be added, which is not insulated. This interior layer usually consists of a single glass pane. In combination with the improved outer shell it creates an ‘exhaust façade’, in which the solar gains are extracted before they enter the room. The additional loads are supported by the floors or the carrying façade.

6.4.12.1. Architecture and function
Just as the other interior insulation strategies, this approach leaves the outer impression of the building generally unaltered. The additions and technical improvements have to deal with the original design. This concept therefore has to be combined with an interior renovation, which allows removing all potentially toxic material and delivering a new interior design and climate concept. Fire compartments are formed by each floor. The interior non-insulated façade is a specialised solution. Particularly if it is integrated into the climate concept, it is difficult to be adapted in the future.

6.4.12.2. Comfort
The façade receives a greater depth. This space reduces the daylight ratio, but also provides the room for sun blinds and technical installations. The acoustic separation between rooms can easily be improved. Even if the original façade connections were not sufficient, the additional interior shell can solve those details. The façade refurbishment can be combined with existing HVAC installations, as long as it is provided, that the façade cavity is well ventilated in summer, to extract solar gains. Therefore, the concept of an exhaust façade is best combined with mechanical ventilation, which extracts the exhaust air through the cavity. Incoming air then has to be provided from the corridor zone of the building. Heating and cooling is best achieved by radiation means such as climate ceilings or radiators. It may also be possible to use the space gained in the façade for decentralised HVAC units, which mechanically ventilate the cavity and use the solar irradiation to precondition incoming air.
Figure 6.59
Characteristics of refurbishment strategy E2: ‘Additional Non-Insulated Interior Layer’

<table>
<thead>
<tr>
<th>Potentials</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preservation of exterior impression</td>
<td>Thermal bridges</td>
</tr>
<tr>
<td>Elaborate ventilation concept</td>
<td>Loss of space</td>
</tr>
<tr>
<td></td>
<td>Disturbance of interior</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suitable for</th>
<th>Not suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listed buildings of good standards</td>
<td>Toxic material in original facade</td>
</tr>
<tr>
<td>Existing central ventilation</td>
<td></td>
</tr>
</tbody>
</table>

Case Studies

Best Practice Examples

Cecilienallee 5, Düsseldorf (GER)
6.4.12.3. Material and energy
This refurbishment strategy reuses most of the original structure and adds a relatively simple construction, which demands only little construction material. Unlike the insulated interior addition, this simpler construction of a single glass screen results in easier connections to surrounding elements and less structural weight. The new façade creates a reasonable improvement of insulation, simpler details, and less risk of condensation. Also, the recycling properties are better, because the addition is usually easily removable and does not contain laminated insulating elements.

6.4.12.4. Economic aspects
Bringing an additional façade layer into a room is very labour intensive. Although the non-insulated façade only needs a quality comparable to dividing walls, and is relatively fast to built, it does demand a refurbishment of the interior. Thus, this concept causes a big disturbance of the work staff and should rather take place in a vacant building. The operational costs of the façade are determined by the ventilation concept. An optimal management of technical devices can help to reduce operational hours.

6.4.12.5. Applicability
A non-insulated façade on the interior can only be an addition to an already reasonable façade. It provides the last bit of improvement necessary for the desired performance. Hence, it is suitable for buildings that are protected and which can be technically improved. Furthermore, those buildings are interesting, which are equipped with central ventilation that shall be reused. The best performance can be achieved, if the cavity functions as an exhaust façade.
6.5. The potentials of different refurbishment strategies – an overview

Each refurbishment strategy has its own technical performance and individual qualities. Every stakeholder of a project has individual preferences and weighs certain demands differently. Furthermore, each individual project shows different combinations of task and opens a variety of chances for synergetic effects. The previous sections have described the potentials and restrictions of the different refurbishment strategies. Hence, the following tables show the possible strategies in comparison and evaluate their various potentials. This evaluation is based on the assessment features presented in chapter 4 and on the ‘wheel of potentials’: ‘Architecture and function’ focuses on the interference of the refurbishment with the original design and the functional sustainability of each concept. It also covers the aspects of fire safety and toxic material. ‘Comfort’ shows the improvement of the building physical performance and the positive effect for the user. It also evaluates the possible combinations of the façade construction with different HVAC concepts. ‘Material and energy’ highlights the consumption of resources during the life cycle of the building. Furthermore, the ‘economic aspects’ cover the construction and maintenance effort, as well as the nuisance for the building user caused by the refurbishment process.

For each aspect a score is given on a four-level system which shows the possible improvement or the effort necessary to achieve a good result:

++ Easily possible
+ Possible
- Demands some effort
-- Difficult

Next to the rating system, the tables contain a small explanation of the necessary means and most common problems for each of the assessment aspects. Thus, a planner can use these tables for a very fast comparison between the individual list of demands and the potentials of possible refurbishment strategies. This comparison directly shows which options are worth to be further worked out in the planning process. In this sense, the following tables present the summary of results generated in this doctorate thesis.
Table 6.2
Overview of refurbishment strategies and their properties
(Part 1: Architecture and Function)

<table>
<thead>
<tr>
<th>Façade Replacement</th>
<th>Curtain wall</th>
<th>Double façade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A1</td>
<td>A2</td>
</tr>
<tr>
<td>Architecture and function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freedom of design</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Respecting the</td>
<td>Respecting the</td>
</tr>
<tr>
<td></td>
<td>original load bearing</td>
<td>original load bearing</td>
</tr>
<tr>
<td></td>
<td>structure (grid), any</td>
<td>structure (grid), any</td>
</tr>
<tr>
<td></td>
<td>new design is possible</td>
<td>new design is possible</td>
</tr>
<tr>
<td>Support qualities of original design</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Decision: replication</td>
<td>Decision: replication</td>
</tr>
<tr>
<td></td>
<td>or entire redesign</td>
<td>or entire redesign</td>
</tr>
<tr>
<td>Future design and technical adaptability</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Depends on design of new elements</td>
<td>Depends on design of new elements</td>
</tr>
<tr>
<td>Health and safety</td>
<td>Facilitate fire safety</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>New standards</td>
<td>New standards</td>
</tr>
<tr>
<td>Removal of toxic material</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Entire removal of material in the façade</td>
<td>Entire removal of material in the façade</td>
</tr>
<tr>
<td>Wrap-up</td>
<td>Addition of multi-storey façade</td>
<td>Addition of partitioned double façade</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td><strong>Original façade is not changed, different designs for climate skin possible</strong></td>
<td>Improvement of primary façade, secondary layer follows original grid</td>
<td>Secondary layer respects the original grid</td>
</tr>
<tr>
<td><strong>Showcase for initial building</strong></td>
<td>Blurring the impression of original façade</td>
<td>Creates new façade impression</td>
</tr>
<tr>
<td><strong>Exterior façade is defined, in the covered space, the original façade can be adapted</strong></td>
<td>Façade defines design and technical components at time of construction</td>
<td>Façade defines design and technical components at time of construction</td>
</tr>
<tr>
<td><strong>Floor-to-floor situation unchanged, the large covered space demands individual solution</strong></td>
<td>Rise of smoke in cavity, operable windows are problematic (sprinkler)</td>
<td>Fire and smoke spreading in cavity, attention on floor-to-floor connections</td>
</tr>
<tr>
<td><strong>Toxic material trapped in cavity</strong></td>
<td>Encapsulate or remove toxic material when inner leaf is improved</td>
<td>Encapsulate or remove toxic material when inner leaf is improved</td>
</tr>
</tbody>
</table>
### Exterior Upgrade

<table>
<thead>
<tr>
<th></th>
<th>EIFS</th>
<th>Ventilated cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Architecture and function

<table>
<thead>
<tr>
<th>Freedom of design</th>
<th>-</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window façade can</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>be coated with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plaster in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>different</td>
<td></td>
<td></td>
</tr>
<tr>
<td>colours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wide range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cladding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>materials,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adaptation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of geometry</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Support qualities of original design</th>
<th>-</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of uniform design</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Future design and technical adaptability

<table>
<thead>
<tr>
<th>--</th>
<th>++</th>
</tr>
</thead>
<tbody>
<tr>
<td>Façade provides quality at time of construction, has to be replaced for improvement</td>
<td>Adaptation of cladding, installations accessible</td>
</tr>
</tbody>
</table>

#### Health and safety

<table>
<thead>
<tr>
<th>Facilitate fire safety</th>
<th>+</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus: prevent fire spread in EIFS</td>
<td>Focus: prevent fire spread in façade cladding</td>
<td></td>
</tr>
</tbody>
</table>

#### Removal of toxic material

<table>
<thead>
<tr>
<th>+</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window replacement is only change to interior</td>
<td>Window replacement is only change to interior</td>
</tr>
<tr>
<td>Partial replacement</td>
<td>Interior Upgrade</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td>Interior insulation</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>D</td>
</tr>
<tr>
<td>Choice of materials and dimensions restricted by original structure</td>
<td>Design of interior finish, exterior preserved</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Exterior appearance unaltered</td>
<td>Exterior appearance unaltered</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Installations are independent of façade, cladding can be replaced</td>
<td>Façade provides quality at time of construction, has to be replaced for improvement</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>No changes to existing situation</td>
<td>Improvement of interior flashover barriers</td>
</tr>
<tr>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Sealants and filling panels removed, floor-to-floor connections unchanged</td>
<td>Removal of toxic material on inside of façade</td>
</tr>
</tbody>
</table>
Table 6.3
Overview of refurbishment strategies and their properties
(Part 2: Material and Energy)

<table>
<thead>
<tr>
<th>Façade Replacement</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtain wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double façade</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material and energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>Material consumption</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Material reuse</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Often large amount of removed material</td>
<td>Often large amount of removed material</td>
</tr>
<tr>
<td>Building process</td>
<td>Impact on structure</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Change to reduce dead weight (remove concrete units)</td>
<td>Extra loads either in roof or floor slabs</td>
</tr>
<tr>
<td></td>
<td>Connection to original building structure</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Depends on original structure, new connections needed</td>
<td>Horizontal and vertical loads brought into floor slabs</td>
</tr>
<tr>
<td>Thermal insulation</td>
<td>Improvement of insulation</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Solution for thermal bridges</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Optimal up-to date standards</td>
<td>Optimal up-to date standards</td>
</tr>
<tr>
<td>End of life</td>
<td>Recycling / reuse / re-refurbishment</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Depends on design of new façade</td>
<td>Depends on design of new façade</td>
</tr>
<tr>
<td>Wrap-up</td>
<td>Addition of multi storey façade</td>
<td>Addition of partitioned double façade</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>B1</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>B2</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Original structure unaltered / complex new structure</td>
<td>Original structure preserved / relatively simple addition</td>
<td>Original structure preserved / complex addition</td>
</tr>
<tr>
<td>B3</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Individual structure for climate skin</td>
<td>Extra load to be suspended</td>
<td>Extra loads brought into floor slabs</td>
</tr>
<tr>
<td>B4</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td>Roof connection</td>
<td>Connection to structure through roof</td>
<td>Horizontal and vertical loads brought into floor slabs</td>
</tr>
<tr>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Size and geometry of the climate skin predominates the buffer effect</td>
<td>Demands improvement of original façade</td>
<td>Demands improvement of original façade</td>
</tr>
<tr>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>New structure separated from original building</td>
<td>Depends on design of new façade</td>
<td></td>
</tr>
</tbody>
</table>

323
<table>
<thead>
<tr>
<th>Performance</th>
<th>EIFS</th>
<th>Ventilated cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C1</strong></td>
<td><strong>C2</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Material and energy

<table>
<thead>
<tr>
<th>Production</th>
<th>Material consumption</th>
<th>++</th>
<th>+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material reuse</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Minimum use of material (insulation, windows)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building process</th>
<th>Impact on structure</th>
<th>++</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light weight</td>
<td>Eccentric loads of cladding</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connection to original building structure</th>
<th>++</th>
<th>++</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demands carrying wall</td>
<td>Demands carrying wall</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal insulation</th>
<th>Improvement of insulation</th>
<th>++</th>
<th>++</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution for thermal bridges</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Special concern: Window connections</td>
<td>Special concern: structural cold-bridges</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>End of life</th>
<th>Recycling / reuse / re-refurbishment</th>
<th>--</th>
<th>++</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminated system</td>
<td>Modular components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial replacement</td>
<td>Interior Upgrade</td>
<td>Additional Interior Layer</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interior insulation</td>
<td>Interior façade insulated</td>
<td>Interior layer insulated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C3</th>
<th>D</th>
<th>E2</th>
<th>E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>++</td>
<td>++</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

- **Structure preserved**: Minimum use of material (insulation, windows)
- **Original structure preserved, complex addition**: Original structure preserved, relatively simple addition
- **Additional glass weight**: Additional glass weight
- **If necessary: improve original connections**
- **Depends on original façade structure**: Connecting walls, floors form thermal bridges
- **Special concerns: ventilation concept, thermal bridges**
- **Modular system, few material**: Laminated system
- **Easily separable façade leafs**

325
<table>
<thead>
<tr>
<th>Façade Replacement</th>
<th>Curtain wall</th>
<th>Double façade</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comfort</th>
<th>Use of natural daylight</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual comfort</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>New construction in</td>
<td>Double façade blocks day-light but provides space for light deflecting blinds</td>
</tr>
<tr>
<td></td>
<td>favour of optimal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>solution</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acoustic comfort</th>
<th>Sound-insulation to outside</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Depends on glass and</td>
<td>Depends on glass and</td>
</tr>
<tr>
<td></td>
<td>façade connections</td>
<td>façade connections,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>double layer block</td>
</tr>
<tr>
<td></td>
<td></td>
<td>exterior sources</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sound-insulation room-to-room</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Depends partly on</td>
<td>Sound transport in</td>
</tr>
<tr>
<td></td>
<td>original structure,</td>
<td>cavity, especially</td>
</tr>
<tr>
<td></td>
<td>new connections needed</td>
<td>with opening windows</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal comfort</th>
<th>Optimal, adjustable sun screen</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>New façade makes every system</td>
<td>Optimal position:</td>
</tr>
<tr>
<td></td>
<td>possible</td>
<td>cavity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prevent overheating</th>
<th>+</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depends on glazing ratio and</td>
<td>Demands ventilation</td>
</tr>
<tr>
<td></td>
<td>sun blinds</td>
<td>concept for cavity</td>
</tr>
<tr>
<td>Additional Exterior Layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrap-up</td>
<td>Addition of multi-storey façade</td>
<td>Addition of partitioned double façade</td>
</tr>
<tr>
<td>B1</td>
<td>B2</td>
<td>B3</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Roof structure potentially blocks daylight</td>
<td>Double façade blocks daylight but provides space for light deflecting blinds</td>
<td>Double façade blocks daylight but provides space for light deflecting blinds</td>
</tr>
<tr>
<td>-</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Outside noise is blocked / rain on roof and noise in atrium may disturb</td>
<td>Good insulation with 2nd glass layer</td>
<td>Good insulation with 2nd glass layer</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Sound reflection in covered atrium</td>
<td>Sound transport in cavity</td>
<td>Sound transport in cavity of corridor façade / box window OK</td>
</tr>
<tr>
<td>-</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>The roof structure and the façade must prevent overheating of atrium</td>
<td>Optimal position: cavity</td>
<td>Optimal position: cavity</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>-</td>
</tr>
<tr>
<td>Atrium tends to overheat</td>
<td>Stack effect leads to high temperature on upper floors</td>
<td>Demands ventilation concept for cavity</td>
</tr>
<tr>
<td>Comfort</td>
<td>Use of natural daylight</td>
<td>C1</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------</td>
<td>----</td>
</tr>
<tr>
<td>Visual comfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound-insulation to outside</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Acoustic comfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound-insulation room-to-room</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Thermal comfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal, adjustable sun screen</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Prevent overheating</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Partial replacement</td>
<td>Interior Upgrade</td>
<td>Additional Interior Layer</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td></td>
<td>Interior insulation</td>
<td>Interior façade insulated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C3</th>
<th>D</th>
<th>E2</th>
<th>E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Depends on original façade structure</td>
<td>Greater depth of façade, smaller windows due to added insulation</td>
<td>Greater depth of façade, extra glass leaf blocks daylight</td>
<td>Greater depth of façade, extra glass leaf blocks daylight</td>
</tr>
</tbody>
</table>

| +                   | +                | ++                        | +                        |
| Depends on glass quality | Improved by glass quality | Improvement by double glass layer | Improvement by double glass layer |

| -                   | +                | +                         | +                        |
| Depends on original façade connections | Original situation unchanged | Depends on original façade connections | Depends on original façade connections |

| -                   | -                | +                         | +                        |
| Optimal position: outside / beware of wind loads | Optimal position: outside / beware of wind loads | Optimal position: cavity | Blinds in cavity are protected from wind, absorbed heat must be ventilated off |

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Little thermal mass, demands efficient sun blinds</td>
<td>Loss of thermal mass</td>
<td>Demands ventilation concept for cavity</td>
<td>Demands exhaust façade concept</td>
</tr>
</tbody>
</table>
Table 6.5: Overview of refurbishment strategies and their properties (Part 4: Combination with HVAC)

<table>
<thead>
<tr>
<th>Façade Replacement</th>
<th>Curtain wall</th>
<th>Double façade</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td></td>
<td>A2</td>
</tr>
</tbody>
</table>

### Sensible combination with HVAC concepts

<table>
<thead>
<tr>
<th>Ventilation</th>
<th>Opening windows</th>
<th>Supported natural ventilation (mechanical extraction, windows)</th>
<th>Central mechanical ventilation</th>
<th>Decentralised mechanical ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
</tbody>
</table>

- New façade makes most ventilation concepts possible
- Individually controlled ventilation with heat recovery takes advantage of different temperatures in cavity and outside

<table>
<thead>
<tr>
<th>Heating / cooling</th>
<th>Radiator</th>
<th>Night cooling</th>
<th>Low temperature system</th>
<th>Convector heat exchanger</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

- Usually applied when interior is renewed, facilitates the installation of new components
- Cavity provides space for technical components

Variety of combinations with HVAC concepts: ++  —  +
### Additional Exterior Layer

<table>
<thead>
<tr>
<th>Wrap-up</th>
<th>Addition of multi storey façade</th>
<th>Addition of partitioned double façade</th>
<th>Addition of an insulated layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Diagram]</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
<td>![Diagram]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
</tr>
</thead>
<tbody>
<tr>
<td>++</td>
<td>--</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>--</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>0</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

- Windows open to buffer climate, infiltration loss is less important, risk of overheating
- Air velocity and different temperatures in cavity demand mechanically controlled airflow
- Controlled airflow from cavity or exterior
- If interior leaf is preserved, an exhaust façade is possible; if inner leaf is removed, the same concepts as a single layer replacement

<table>
<thead>
<tr>
<th>Existing system usually maintained</th>
<th>Decentralised conditioning of incoming air, takes advantage of different temperature levels in cavity and outside</th>
<th>Decentralised conditioning of incoming air with heat recovery</th>
<th>Original system can be preserved</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>--</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>

331
<table>
<thead>
<tr>
<th>Sensible combination with HVAC concepts</th>
<th>C1</th>
<th>C2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ventilation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opening windows</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Supported natural ventilation (mechanical extraction, windows)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Central mechanical ventilation</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Decentralised mechanical ventilation</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating / cooling</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiator</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Night cooling</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Low temperature system</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Convector heat exchanger</td>
<td>--</td>
<td>++</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety of combinations with HVAC concepts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

Existing system usually maintained, basic installation common
Existing system usually maintained, opening windows common, possibility to integrate HVAC components in cladding
Existing system usually maintained, integration of ducts in cladding possible
Existing system usually maintained, integration of ducts in cladding possible
<table>
<thead>
<tr>
<th>Partial replacement</th>
<th>Interior Upgrade</th>
<th>Additional Interior Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interior insulation</td>
<td>Interior façade insulated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C3</th>
<th>D</th>
<th>E2</th>
<th>E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>++</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Existing system usually maintained</td>
<td>Loss of thermal mass, basic solution common</td>
<td>Interior refurbishment facilitates retrofitting of technical components</td>
<td>Mechanically controlled exhaust façade, central heat-exchanger</td>
</tr>
</tbody>
</table>

| ++ | + | + | + |
| +  | - | - | - |
| +  | + | + | ++ |
| -  | - | ++ | - |
| Existing system usually maintained | Heating, cooling system independent of façade, no ducts allowed in the exterior walls (outside the thermal layer) | Cavity provides space for technical components | Heating, cooling system independent of façade |

| ++ | - | - | -- |
### Table 6.6
Overview of refurbishment strategies and their properties
(Part 4: Economic aspects)

<table>
<thead>
<tr>
<th>Façade Replacement</th>
<th>Curtain wall</th>
<th>Double façade</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Economy</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction cost</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>New construction with changes of interior</td>
<td>Complex construction with changes of interior</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interference with use</th>
<th>Construction time</th>
<th>Disturbance of interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alteration of all connections, building needs to be stripped, prefabrication saves time</td>
<td>Alteration of all connections, building needs to be stripped</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational cost</th>
<th>Maintenance cost façade (cleaning / repair)</th>
<th>Energy saving potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>New standards, single façade layer</td>
<td>New standards, more maintenance of double layer</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional benefits</th>
<th>Gain of space</th>
<th>Marketing potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>
### Additional Exterior Layer

<table>
<thead>
<tr>
<th>Wrap-up</th>
<th>Addition of multi storey façade</th>
<th>Addition of partitioned double façade</th>
<th>Addition of an insulated layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B2</td>
<td>-</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>B3</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>B4</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

- Construction costs to be allocated over adjacent façade, depends on building geometry
- Depends on upgrading demand for existing façade, demands sufficient load bearing structure
- Depends on upgrading demand for existing façade, demands sufficient load bearing structure
- Simple structure, high level of prefabrication, demands sufficient load bearing structure
- Complex structure for climate skin, original building unaltered
- Primary façade can be upgraded inside covered cavity
- Depends on connection details and level of prefabrication
- Fully mounted from outside, possibly removal of old window

- Reduction of façade surface depends on geometry
- Additional layer demands cleaning cradle
- Additional layer demands cleaning cradle
- Depends on façade detailing (single / double layer)
<table>
<thead>
<tr>
<th></th>
<th>EIFS</th>
<th>Ventilated cladding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>C1</strong></td>
<td><strong>C2</strong></td>
</tr>
<tr>
<td><strong>Economy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction cost</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Relatively cheap solution</td>
<td>Proven system</td>
</tr>
<tr>
<td>Interference with use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction time</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Very fast, replacement of windows and drilling cause disturbance</td>
<td>Replacement of windows and drilling cause disturbance</td>
</tr>
<tr>
<td>Disturbance of interior</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operational cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance cost façade</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>(cleaning / repair)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy saving potential</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Demands cleaning and painting in short intervals</td>
<td>Single layer, serviceable from inside</td>
</tr>
<tr>
<td><strong>Additional benefits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain of space</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Marketing potential</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

336
<table>
<thead>
<tr>
<th>Partial replacement</th>
<th>Interior insulation</th>
<th>Additional Interior Layer</th>
<th>Interior façade insulated</th>
<th>Interior layer insulated</th>
<th>non- insulated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C3</td>
<td>D</td>
<td>E2</td>
<td>E1</td>
</tr>
<tr>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Minimal material consumption</td>
<td>Minimal material consumption, labour intensive connection detailing</td>
<td>Labour intensive, connection detailing</td>
<td>Relatively simple construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>++</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td>Very fast, replacement of windows causes disturbance</td>
<td>No structural interference, all work from inside</td>
<td>Only interior work</td>
<td>Only interior work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>++</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Single layer, serviceable with existing means</td>
<td>Fully serviceable from inside</td>
<td>Ventilation components and cleaning of cavity</td>
<td>labour intensive</td>
<td></td>
<td></td>
</tr>
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<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
6.6. References

Feireiss, K., H. Binet, W. Pehnt and Ingenhoven Overdiek und Partner (2002). Ingenhoven, Overdiek und Partner - energies. Basel (CH), Berlin (GER), Birkhäuser.
7. Conclusions and Recommendations

This research project was aimed to verify, which refurbishment strategies are generally suitable for the most important types of office façades and how the decision-making process for one of these strategies can be facilitated. In order to do so, the most common façade types among those office buildings older than 30 years were identified. Refurbishment approaches in current practise were analysed and, based on these, assessment tools and improved strategies for façade refurbishment were developed. These strategies have been applied to five representative case studies and evaluated. Furthermore, two product orientated solutions have been developed for the most common façade types, which take into account the clients’ desire for a short building process with least disturbance of the interior.

This chapter highlights the most important findings of the research and recommends areas for further investigation. The first part answers the main research question by describing the findings of the market analysis and evaluation of different refurbishment strategies. The following part describes the influence of this work for practical application. The third section gives recommendations for further fields of research. The chapter concludes with an outlook onto the future development of office facades and their refurbishment.

7.1. Discussion of the research questions

7.1.1. Buildings in need for refurbishment
The research question imposed an analysis of the existing stock of office buildings in order to identify the most common types and their problems. A typology has been developed, which allows sorting all possible existing façade structures into five main categories and 22 subcategories with similar structural properties.

The research was focussed on the situation in North-Western Europe with spot checks in the Netherlands, the United Kingdom, and Germany because these areas are located within the same climate zone and façades have to fulfil comparable demands. The analysis showed how these demands were tackled in different cultures and in periods of different economic development. The building production reacts to this economic development with a delay of two to four years but then tends to overreact, which leads to an alternating oversupply or shortage of office space. The most valuable office locations – inner cities and best communicated zones in the proximity – have already been developed in the 1950s, 1960s and early 1970s. These buildings are the most promising for façade refurbishment. Their market volume in these three countries adds up to 500*10⁶ m².
The various façade types hold different shares of the national markets. The Dutch market, for example, includes many prefabricated structures. The UK and Germany prefer massive buildings. Generally, one can see that the average building stock in UK’s most valuable locations is older than in the other countries and presents a lower technical quality and grade of maintenance. Also, the form of technical building services differs. The British market, for example, does not see many exterior sun screens, but uses coated glass. Germany, on the other hand, often uses structural means for sun protection. It is the market with the largest share of exterior service platforms, which have been very fashionable until the early 1980s. The most common façade types are load bearing walls with or without additional insulation, which add up to more than 50% of the spot check. Curtain walls represent another quarter of the market volume; 10-15% of the existing façades are post- and-beam structures.

7.1.2. The most promising refurbishment strategies
The typical problems of the different constructions are similar for all assessed markets. However, the demands for the buildings and refurbishment intentions differ. Therefore, a very thorough assessment of the given situation and the clients’ interests is essential for a successful refurbishment planning. A checklist has been developed, which facilitates the analysis of a given building, highlights the potentials and challenges, and indicates promising refurbishment strategies. Thus, strategies have been found, which are predominantly interesting for specific façade constructions.

Load bearing façades, such as massive walls and the typical 1950s skeleton façades, usually provide sufficient load bearing capacity for a wide variety of solutions. In these cases, the best results, both with regards to technical and economical aspects, can be achieved by an exterior façade upgrade, which incorporates the replacement of window elements and the addition of insulation and façade cladding.

A totally different situation occurs with prefabricated constructions, such as to be found at the ‘University of Bielefeld’. Particularly unitised curtain walls are very complicated to refurbish. Usually the façade panels have been designed to the needs of the time of construction and contain insulation and finishing in one unit. Also, the fittings are dimensioned for this particular component. Therefore, replacement of the entire façade is often the best solution for these constructions, usually entailing major disturbance of the interior.

In some cases, the addition of a double façade can reduce the demands of the old layer and thus preserve it. The double façade principle in general is currently experiencing a lot of criticism for new constructions, because of its complex thermal behaviour and high expenses. However, in refurbishment it can find a new field of application. The original façade structure can be preserved. All façade
connections to interior finishings can remain unchanged; the building can be refurbished from the outside, while it is in use. Furthermore, the cavity can provide the space for new technical installations, which can thus also be renewed without interior disturbance.

7.1.3. Facilitating decision making
The great variety of existing façade types and an equally large range of refurbishment possibilities lead to an almost unmanageable number of theoretically possible combinations. This research has tidied up this confusion by evaluating the principal properties of each refurbishment strategy and creating a decision making tool which evaluates the different planning requirements. The properties desired of a refurbishment project strongly depend on the individual stakeholders. Therefore, a graphical tool has been used that shows the different potentials of each general refurbishment strategy in a circular scheme. The demands can be shown in the same scheme and thus easily compared with the proposed solution. In a later planning phase this ‘wheel of potentials’ can be used to compare different proposals for one object in more detail, which facilitates the evaluation of demands and their discussion. The general qualities of different refurbishment strategies and their applicability to different façade types have thus been worked out and presented in a matrix giving guidelines for the planning process. Naturally, the different strategies cannot be applied one-to-one, as every project shows different conditions. However, the matrix provides each refurbishment project with a few general approaches that can quickly lead to promising concepts in the early design phase.

7.2. Expected practical benefits
An office building has to fulfil three purposes. Firstly, it is an economical investment that has to be profitable for investors, owners and tenants. Secondly it is the built environment for many people working therein and living in the neighbourhood. Thirdly, it is also responsible for the sustainability of a society, due to its energy and material consumption, as well as its cultural value as a documentation of building history. The findings of this research can support all of these purposes.

7.2.1. Refurbish more
The market assessment and interviews with project stakeholders have shown that currently too many buildings are demolished due to prejudice. The knowledge of refurbishment possibilities is very limited both among planners, as well as with investors. This leads to a situation where many structurally sound buildings are demolished and replaced. Furthermore, if the decision was made to refurbish an office building, it is most often deconstructed down to its load bearing carcase and rebuilt from this level. As this treatment imposes a long construction period and demands the building to be vacant, it discourages many building owners even before they reconsider their real estate. The
analysis of refurbishment motivations has further shown that many clients would be willing to refurbish their buildings, if this could be done ‘fast, clean, and quiet’ – without the need to relocate staff.

This research has taken up this task and shown that there are further strategies beyond the common façade replacement or demolition of a building. It has put an emphasis on finding refurbishment strategies that are more cautious than a substantial deconstruction. The projects ‘Sparkasse Vorderpfalz’ in Ludwigshafen (GER), and ‘EnBW Administration Building’ in Esslingen (GER), exemplify that refurbishment during operation is possible and feasible. The tables and applicability tools direct the planning process towards the most promising solutions depending on individual demands. Furthermore, the presented concepts can fuel the creativity of project developers and planners, as long as the project stakeholders are willing to accept their existing building and care for its preservation.

On the contrary, the tendency is visible that the perception of people and the ‘public taste’ change in shorter periods than the actual life expectancy of an office building. This fact leads to ten year-old building falling vacant because their design is not considered sufficiently modern. Here, the refurbishment of the façade can give the building a new image and the client a new form of representation.

7.2.2. Build faster

Many office buildings, which are in need of refurbishment, can be found in densely populated areas. These locations usually restrict the building logistics and building method. Depending on the refurbishment strategy and façade type the building process has to be a combination of manual labour and off-site production. Older façades from the 1950s and 1960s are usually characterised by structural elements in the façade and hand-crafted details. Such building envelopes can often be refurbished with minimal interferences but based on much labour on site and a long building process. Prefabricated façades of the 1970s and 1980s, on the other hand, are often best refurbished by their replacement with new prefabricated units. This saves production time on site but leads to severe disturbance of the interior. The case studies presented in this research point out solutions, which keep either the construction time in general or at least the disturbance time for the building occupants as short as possible.

For example, the project ‘Sparkasse Vorderpfalz’ combined both principles: first, a secondary façade layer, composed of large units, was mounted from the outside, which caused only a short interference with public space and traffic. Later, the new cavity was used to upgrade the primary façade and building services independently of weather conditions. Thus, each office floor only needed to be vacated for eight working days. The ‘refurbishment window’ consequently wants to reduce the interference time to ‘one day per room’. Here, all the
ducting for heating cooling and electricity is mounted to the outside of the original façade. The new window unit is equipped with all necessary building services. It can be replaced just as fast as a normal window, but then also provides the heating, cooling, and air conditioning for a modern office room.

7.2.3. Prove feasibility
The refurbishment of an office building is a financial investment which has to prove its feasibility. The results of this research allow improving this feasibility at various points in the planning and building process. Each refurbishment project is an individual task. The dimensions, load bearing systems, the choice of materials, and the detailing differ in each project. So do location, its direct surroundings, the level of maintenance, and the user’s demands. This research could define a limited number of façade types with typical challenges. By being able to define the type of the original façade, it is faster and easier to find the typical problems and demands, and to identify the most promising refurbishment strategies.

The building envelope is only one part of the complex organism of a building. Therefore, insulation is only one means to improve the energy performance and comfort. Furthermore, building services and electric appliances are responsible for a large share of the energy consumption. The office layout and internal organisation of the building has a big influence on the feasibility of an office building on the one hand and on the sociological well-being of the user on the other. Only if the planner can look ‘beyond the façade’, it is possible to find the necessary synergetic effects that lead to an optimal design. In this respect, combined planning of the buildings function, the HVAC and the façade is very important. However, here lies a major drawback. Currently, many experts focus on their special field, which often leads to counteracting solutions that are inefficient and expensive. The refurbishment strategies developed in this thesis are always evaluated with respect to the building services, which makes it is easy to compare the technical installations in an existing building with the potentials of a possible façade refurbishment. It can be chosen for each project, which components are worth to be maintained, and which can best be renewed.

The same applies for the future performance of a building. A project does not end with the delivery of the finished building. The client faces maintenance costs and the user has to be provided with a liveable surrounding. An improved façade (and new building services) changes the performance of the building and the method of operation. Furthermore, the technical installations of today will be subject to revision in the future, and so will be the architectural design. Therefore, the strategies presented in this thesis take into account the operational phase of the building and the adaptability of the façade construction and building services. The life-cycle-cost approach looks at operational
costs, and thus calculates the economical break even point of an investment. This allows a more holistic comparison of concepts and puts the necessary emphasis on the sustainability of a project.

7.2.4. Plan for the people
Next to the economical sustainability, each refurbishment project has a strong socio-cultural aspect. The surfaces of buildings are essentially important for the quality of the public space. This public space is the calling card of a neighbourhood and represents the cultural and social life of its inhabitants. The designs of building elevations create the image of a neighbourhood and thus represent the cultural and social life of its inhabitants, and contribute to the authenticity and uniqueness of a location, the so-called ‘genius loci’.

Walking through a neighbourhood of poorly maintained buildings one can often experience the depressive atmosphere, which results from the feeling that no-one cares about the buildings, the neighbourhood, and thus the people living therein. Such latent dissatisfaction is seen as the cause of social problem problems which become visible in dilapidation of entire streets and in vandalism. Thus, the public space is segregated; certain zones develop, which people are frightened to use. In this respect, the quality of the building envelopes has a strong influence on the social life of people in neighbourhood. The refurbishment of particular buildings can not change an entire neighbourhood at once, but it can spark off a development towards its improvement. However, this refurbishment has to keep more aspects in mind than only the retrofitting of the façade. Many projects hold the chance to supply an added value to the public space, if the building is interwoven with its surrounding. For example, the ground floor of the ‘Sparkasse Vorderpfalz’ building used to be a dark zone with entrances to an underground car park, which prevented people from approaching the building. After refurbishment, the first floor forms an illuminated area which now functions as a covered arcade that connects a public park and a renatured river.

Furthermore, a façade is responsible for the exterior expression of a building itself and the public image of the building’s owner. In this sense, most clients desire that the façade expresses the building’s improvement. Even if the façade can generally be optimised by minor maintenance, it has to be made visible that it has been improved. For listed façades and protected designs, this means that the original façade is to be repaired, cleaned, and improved to express the owners respect for the cultural heritage. Buildings, which are not listed, are most commonly requested to receive an entirely new façade. However, this research has shown that many further options are possible, which reduce the impact on the building and step into a dialogue with the original building design. Even those façades that appear entirely outdated often provide forgotten design qualities and can be considered as valuable representatives of certain eras of social and economical development. For example, the redesign proposals for
the ‘CITG’ building in Delft deliver three promising solutions for such design dialogue with an original concrete façade.

A façade is responsible for exterior impression of the building, but also for the comfort this building can provide to the interior. People often spend their entire working day inside a building. Hence, the design goal has to be to provide a healthy and comfortable surrounding. Many older facades can not provide this quality. Here, the refurbishment supports the wellbeing of people by providing the necessary protective shell. Furthermore, there is much more known about harmful substances today than thirty years ago. During refurbishment, these toxic materials, such as asbestos plates and PCBs in sealants, can be removed. The same applies to the technical building services. While mechanical ventilation and non-opening façades are a major cause for the ‘Sick Building Syndrome’, an improved building envelope can solve these mistakes of the past.

The building process in itself tends to be very stressful for the users of a building. Either the occupants have to be relocated or the refurbishment takes place while the building is in use. In either case, it is essential that every person concerned is well informed about the planning and building progress. Refurbishment during operation has to avoid excessive noise and dirt production. The realisation of the project ‘Sparkasse Vorderpfalz’ has proven that the best strategies appear to be those that can be realised with a minimum need for drilling and grinding. The product developments presented in this thesis focus on this topic and show how it is possible to upgrade the most common façade types with minimum disturbance.

7.3. Research recommendations

Based on the presented work a number of relevant topics become apparent which will be needed for future office refurbishment planning. This research has highlighted the refurbishment market of office and administration building. These buildings only make out approximately 20% of the Western European building stock. 40% of the stock is made up for by single family homes and approximately one quarter is accounted for by multi-family-houses. Especially these are very interesting to be evaluated in a similar approach, which takes into account their typical forms of structures and the organisation of the construction process. Particularly in these cases, solutions are needed, which can be applied while the residents stay in the building. Here the integration of residents in the planning process is of major importance.

The Life Cycle Cost Assessment used in this thesis covers construction costs, operational cost, rental costs, and relocation expenses. However, there are further costs, which influence the feasibility of a project. Especially when comparing different refurbishment concepts, it is very important to take the replacement intervals of components
into account. It can, for example, be useful to replace components before the end of their technical life-span, if their replacement at a later stage would impose additional costs. Furthermore, it would be very interesting to see, to which extend the refurbishment influences the productivity of the working staff. Much research is currently being done in the field of indoor comfort. Thermodynamic simulation tools are able to predict the comfort level in a room. From here it should only be a small step to combine these results with cost estimations and predict the financial benefit of happier staff.

The cost assessment only makes out one share of its total Life-Cycle performance. Therefore, not only the economical pay-back should be estimated, but also the ecological amortisation time. Such calculation contains the total energy balance of a project from construction through its operational life up to deconstruction and reuse. Much research is currently being done on this topic. However, the architects practice is urgently lacking an easy to handle, but reliable tool which estimates the ecological sustainability of a project. Such a tool must be commonly understandable in order to facilitate the communication between project partners.

7.4. **Prospects of office refurbishment and façade planning**

7.4.1. **Green building**
Today, mainly those buildings are refurbished that are in valuable locations, function as landmarks, are used by the owner, or listed as monuments. For many other buildings, refurbishment is often not considered feasible. However, the sustainability aspect of a project is increasingly been seen as a marketing argument. The current political support raises the sensibility for this topic. The Dutch government, for example has decided to only rent offices with a good energy rating. Many real-estate companies consider only those building to be marketable in the future that can call themselves ‘green building’ and that score high in sustainability labelling. A refurbished building has best chances to score high in these, because it reuses a large share of the original building and adds only the necessary material. Provided, the added construction fulfills the sustainability demands too, there will be a huge market for refurbished buildings in the near future.

7.4.2. **Passive house**
Residential buildings are currently requested to achieve a ‘passive house standard’, which means that the optimal indoor temperature can be achieved without a heating or air conditioning system. The maximum heating energy demand must be 15kWh/m² (Feist 2009). It has to be questioned to which extend this standard can be applied to office buildings: Firstly, the biggest effect on thermal insulation can already be achieved by replacing windows and insulating the roof. Excessive insulation of the façade bears the risk of overheating in summer, as offices have very high internal heat loads and often a relatively large
amount of glass in the building envelope. Thus, the cooling loads often
outrival the heating demand and the static calculations of energy
demands, needed for building application, deliver misleading results.
Effective solar protection and efficient cooling is often more important
in office buildings than thermal insulation alone.

Secondly, the high demand for electric power in an office building
cannot be gained by renewable energy on the same plot. Thirdly, the
desired tightness of the building can also become problematic. Existing
office buildings have never been designed to be fully airtight. Sealing
increases the risk of poorer air quality. If the air exchange rate is
reduced, the concentration of potentially present hazardous materials
in the ambient air rises. This aspect does not only apply to the ‘classic’
built-related toxins, but to any material used in buildings. For
refurbishment of office buildings this means that the static evaluation
of the passive house standard is not applicable. Only the combination
of different means such as improved insulation, efficient building
services, efficient appliances, optimised controls, and the use of
renewable energy can lead to optimum performance. Therefore,
the simulation of the building performance and the interactions of
different components will be increasingly important for the planning
of an office building.

7.4.3. Integration of technologies
The façade industry has shown major developments over the
past years, such as the integration of building services into the
façade and interactive building envelopes. The future will see more
technical innovations occurring at shorter intervals. The field of
façade refurbishment will for example benefit from new materials,
which provide the desired function with less weight and volume.
Vacuum insulation panels and vacuum glass help to reduce the dead
load. Synthetic materials will replace traditional materials such as
glass or concrete. The technical building services will see far more
computerisation. Buildings will get smarter by automatisation, but
also more individualised. Users will for example not accept a centrally
controlled air conditioning in a building any more while they can have
four different temperature zones in their cars. Hence, the tendency
clearly goes towards individualised building services, which function
on decentralised components integrated into the building envelope.

7.4.4. The effect on the way we build today
The entire concept of office work is subject to constant changing.
Today’s buildings, as well as the refurbished ones will have to able to
cope with these demands. For some of the existing office buildings
there will be no future with the same function. For these, new
meanings have to be found, which demands a large deal of creativity
and courageous decision making among planners and developers. The
buildings which are to be offices in the future will have to provide a
maximum of flexibility in floor lay-out, façade design, and building
services.
Furthermore, the future will also see entirely new concepts of building and contracting. For example, it will be more common to lease office space and services. Developers will not only erect a building; but they will also be responsible for its operation for a long period of time. The client will be able to order: ‘20 years of functional, healthy, representative office space for low rental rates and low operational cost’ instead of ‘a building’ It will be possible to quickly adjust the building to changing needs and to upgrade or downgrade the technical infrastructure of an office room. Consequently, buildings of a higher quality will be planned and the focus will shift from construction cost and ‘current standards’ towards operational costs and high adaptability – sustainability in the original sense. New buildings will be designed to be redesigned. After all, today’s new buildings are the refurbishment candidates of the future.

7.5. References

A. Appendix A
Best practice examples of office refurbishment

A.1. Dorma Head Office
A.2. Stadtsparkasse Düsseldorf
A.3. Refurbishment concept ‘3X’
A.4. LUWOGE Null Heizkosten Haus
A.5. Mannesmann Tower
A.6. Police Station Chemnitz South
A.7. BP Solar Skin
A.8. KfW Head Office
A.9. Westraven Gebouw
A.10. Münchener Rückversicherung
A.11. BMW Headquarters
A.12. Bertolt Brecht School
A.13. TU Delft Onderzoeksinstituut OTB
A.14. Deutsche Bank, Frankfurt
A.16. Mobimo Building, Zürich
A.17. Former Consulate General of the USA, Cecilienallee 5
A.18. Federal Ministry BMVEL Bonn
A.19. Nürnberger Hypothekenbank
A.20. References
A.1.  Dorma Head office

Owner:  Dorma GmbH
User:  Dorma GmbH
Main function:  Office
Location:  Ennepeetal, Germany
Storeys:  Original: 6, new: 8
GFA:  7,940 m²
Year of completion:  1968
Architect:  
Year of refurbishment:  2002-2004
Architect refurbishment:  KSP Engel Zimmermann
Refurbishment strategy:  B1 – Multi-storey double façade
Façade Type after refurbishment:  4.1.2
Main motivation for refurbishment:  Technical improvement and creation of a corporate ID

A.1.1.  Initial Situation
The initial building had six floors. With its height of 25m it already was a landmark in its surrounding. The façade was characterised by prefabricated concrete elements and service platforms.

A.1.2.  Façade Technology
During refurbishment the building has been entirely remodelled. The concrete units are removed. The primary façade has been equipped
with new opening windows and an exterior insulation system. The building has received three additional floors, which are realised as a steel-glass construction. From this structure also, the secondary façade is suspended, which surrounds the entire building. This façade layer consists of a structural glazing, which forms a multi-storey façade. Glass panes of the same dimensions are mounted at different heights. Thus openings occur, which permit a permanent, but uncontrolled ventilation of the cavity.

A.1.3. Architectural Design
The original building was designed for large open plan offices. Current standards demand natural daylight for all work spaces. Therefore, all floors are partially cut out to allow more daylight to enter the building. This cut-out marks the entrance and links the original structure to the additional floors. Heightening the building makes it more impressive as a landmark. The load bearing structure of the addition is a deliberate reminiscence to the company’s logo (Holl et al. 2005).

A.1.4. Technical installations
The technical installations take certain advantage of the double façade. Ventilation is achieved by opening windows in the primary façade layer and a central mechanical exhaust. Only when the windows are opened, the air is mechanically extracted from the room. Thus, every user controls their individual ventilation rate. It is made sure, that the air always flows from the cavity to the room. Thus, pre-conditioned air can be used in winter. In summer, the air exchange rate of the cavity is considered high enough to prevent excessive heat intake. Convectors units along the façade provide heating for all rooms. A cooling function is only integrated in the rooms facing south-east and south-west.

A.1.5. Economics
The façade refurbishment was part of the remodelling of the entire building. Hence, the building was vacated and rebuilt from the primary structure. This has yielded a building with up-to date standards. The additional floors provide extra usable space and a roof terrace.
A.2.  **Stadtsparkasse Düsseldorf**

Owner: Stadtsparkasse Düsseldorf  
User: Stadtsparkasse Düsseldorf  
Main function: Office  
Location: Düsseldorf, GER  
Storeys: old: 4+15; new: 4+17  
GFA: 35,000  
Year of completion: 1964  
Architect: Sieverts, Pfennig, Kraemer  
Year of refurbishment: 2001  
Architect refurbishment: Ingenhoven Overdiek & Partner  
Façade Type original: 5.4.1  
Refurbishment strategy: A2 – Replacement with a double façade (corridor)  
Façade Type after refurbishment: 5.3.2  
Main motivation for refurbishment: Technically outdated, legal reason (A replacement building would not have been allowed the same height.)

A.2.1.  **Initial Situation**
The initial building was equipped with a curtain wall façade / stick-system. After 40 years, this structure did not comply with current demands.

A.2.2.  **Façade Technology**
The entire façade was removed. Furthermore, the building height was increased by two floors. These floors provide a roof terrace, which is protected by a glass wall. This single glass wall is an extension of the secondary layer of the double façade used for the regular office floors below. The replaced building skin is realised as a corridor façade. The outer layer is single glazed. The primary façade provides the insulation.

A.2.3.  **Architectural Design**
The ‘new’ headquarters of Sparkasse aimed to represent a new form of bank-architecture, which meant that the refurbished building had to appear new. The building was supposed to ‘communicate transparency and openness both inside and outside’ (Feireiss et al. 2002). Thus, it received an all glazed façade both for the tower building, as well as for the low-rise part. The double façade makes it possible to supply users with optimised day lighting and individual (part-natural) ventilation.

A.2.4.  **Technical installations**
The offices are mechanically ventilated by façade integrated units. Furthermore, the inner façade layer can be opened to the cavity for alternative natural ventilation. The façade cavity also provides the protected space for daylight reflecting sun blinds.
A.2.5. Economics

The façade refurbishment was part of the remodelling of the entire building, which took place while the building was empty. At an early stage it was considered to replace the building completely. But, during the planning phase it turned out that a new building would not be allowed to have the same height as the original one. Thus, the potential to maximise usable space became the main argument for refurbishment instead of replacement.
A.3. Refurbishment concept '3X'

Owner: 
User: 
Main function: Double façade with integrated building services for refurbishment Concept

Location: 
Storeys: 
GFA: 
Year of completion: 
Architect: 
Year of refurbishment: 2000
Architect refurbishment: Evers Ingenieurgesellschaft, Octatube

Façade Type original: 
Refurbishment strategy: B2 – Addition of multi-storey façade with integrated building services

Façade Type after refurbishment: 
Main motivation for refurbishment: Improve insulation and building services without interference with interior

Figure A.8 Ventilation principle in winter, using solar preconditioned air from the cavity
A.3.1. Initial Situation
The initial building is characterised by outdated insulation and technical building services. It provides sufficient structural capacity for an additional façade layer. The interior and building operation should not be disturbed by the refurbishment.

A.3.2. Façade Technology
The ‘3x’-concept proposes to install a double façade as multi-storey climate skin. This glass screen protects the existing façade and gives the building a new look. The space inside the cavity is used to install decentralised building services, the necessary supply ducts, and daylight deflecting sun blinds.

A.3.3. Architectural Design
The ‘3x’-concept only represents a technical solution. The design is subject to individual planning. Nevertheless, the refurbished building is always equipped with a more-or-less transparent double façade.

A.3.4. Technical Installations
The ventilation concept takes advantage of the solar gain inside the cavity. A rotating valve can either take supply air from the cavity or from the outside. In winter, the solar gains in the façade can thus be used. The exhaust air is led outside. In summer, fresh air is taken from outside; used air is brought to the cavity, where the natural updraft supports the ventilator power. A heat-recovery within the decentralised ventilation unit regains thermal energy from exhaust air. An additional air-water heat exchanger inside the room conditions the incoming air. The system can also be run in recirculation mode. Thus, the room can quickly be heated or chilled.

A.3.5. Economics
By placing all technical equipment inside the cavity, the office interior and operation is only minimally disturbed. This reduces construction time on site and aims to save the relocation cost for staff. In operation, the concept takes advantage of solar gains in the double façade. Efficient, individually controlled ventilation units with heat recovery aim to reduce the need for heating and cooling. Being installed in the cavity, these units can be maintained without disturbing the interior (Evers 2000).

A.3.6. Further Information
The ‘3x’-concept was the base for the refurbishment concept for ‘Sparkasse Vorderpfalz’, which is one of the case studies evaluated in this dissertation.

All images courtesy of Rudolf Evers.
A.4. **LUWOGE Null Heizkosten Haus**

Owner: Ludwigshafener Wohnungsbau-Gesellschaft  
User: Rental  
Main function: Residential  
Location: Ludwigshafen / Rhein, GER  
Storeys: 4  
GFA:  
Year of completion: 1968  
Architect:  
Year of refurbishment: 1998  
Architect refurbishment: Luwoge Consult  
Façade Type original: 3.1.1  
Refurbishment strategy: C1 – Exterior insulation finishing system (EIFS) with integrated building services ducts  
Façade Type after refurbishment: 4.1.1  
Main motivation for refurbishment: Outdated building physics and high heating demand

A.4.1. **Initial Situation**
Luwoge is a real estate company that belongs to BASF (chemical company) and owns approximately 8,000 flats. The presented multiple dwelling building was built in 1968 and contains 16 apartments. It represents a typical housing block of the late 1960s and 1970s, constructed in brickwork and on-site concrete. The building was still in original state without any additional insulation.

A.4.2. **Façade Technology**
The refurbishment concept aims to show the maximum potential of the building materials produced by BASF. It wants to proof, that it is possible to reduce the heating demand of an existing building to almost

![Figure A.11](image-url)

Impression of the refurbished façade
zero. The façade is refurbished by applying an exterior insulation finishing system (EIFS) consisting of Polystyrene and synthetic plaster. The existing windows are replaced with new frames and triple glass.

A.4.3. Architectural Design
The refurbished building has to be a representation object. Therefore it shows the technical components applied in the façade. The additional balconies (on separate foundations) contribute to the quality of the rental flats.

A.4.4. Technical installations
The building was refurbished while it was in use. Therefore, all new technical ducts and electric cables are placed outside the actual apartments. The ducts are mounted to the exterior walls and later wrapped up in the EIFS. A central mechanical ventilation system with heat recovery reduces the energy consumption. The energy still necessary is produced by solar collectors and PV cells on the flat roof and in the façade. The electric power is fed to the public network. Under normal conditions, the internal loads and solar irradiation fulfil the heating demand. Only in extremely cold weather an additional heating is needed. Instead of a hot water heating system, the building uses heating glass, which brings in the necessary heat load by electrically heating the window panes.

![Figure A.12](image.png)
Refurbishment concept

A.4.5. Economics
After the refurbishment the building consumes less than 20 kWh/m²a of final energy. The building users take advantage of a higher comfort and very low utility costs (Luwoge Consult 2007).

All images by LUWOGE.
A.5. **Mannesmann Tower**

Owner: Vodafone GmbH  
User: Vodafone GmbH  
Main function: Office  
Location: Düsseldorf, Germany  
Storeys: 23  
GFA:  
Year of completion: 1956  
Architect: Paul Schneider Esleben  
Year of refurbishment: 2002  
Architect refurbishment: RKW Rhode Kellermann Wawrowsky  
Façade Type original: 5.3.1  
Refurbishment strategy: A1 – Replacement of a unitised curtain wall  
Façade Type after refurbishment: 5.3.1  
Main motivation for refurbishment: Technical deficiencies and fire safety demands

*Figure A.13*  
Elevation after refurbishment
A.5.1. Initial Situation
The initial building is one of the first post-war high rise buildings in Germany. Therefore, the façade is subject to monumental protection. Nevertheless, the original post frame aluminium façade caused several problems such as draft, condensation, a high energy demand and excessive heat intake in summer. Also the central air conditioning and the fire protection concept did not comply with current demands.

A.5.2. Façade Technology
Complying with the monumental protection rules, the façade is replaced with a new unitised aluminium façade. This façade has the same dimension, shape and colour as the original, but provides current standards in thermal and sound insulation, as well as fire resistance. The new façade is replaced successively from top to bottom. The ground floor façade is only improved optically, as there is no insulated glass available in the dimension of the original glass panes (2.60/7.40).

A.5.3. Technical installations
The entire building services are renewed. The building is equipped with central mechanical air conditioning. Chill ceilings add on to the thermal comfort.

Figure A.14
Façade during refurbishment, the upper floors are new

Figure A.15
Initial Situation [TU Dortmund 2008]
A.6. **Police Station Chemnitz South**

Owner: Federal state of Saxony  
User: Saxony police  
Main function: Office  
Location: Chemnitz, Germany  
Storeys: 4  
GFA:  
Year of completion: 1980s  
Architect: GDR state department  
Year of refurbishment: 2008  
Architect refurbishment: Schulz & Schulz Architekten, Leipzig  
Façade Type original: 3.1.1  
Refurbishment strategy: C2 – Ventilated cladding  
Façade Type after refurbishment: 4.1.1  
Main motivation for refurbishment: Technically and optically outdated, severe building physical deficiencies

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A.6.1. **Initial Situation**
The initial building was constructed in brickwork. Students and trainees took this building as a practise example in the 1980s. This fact together with a lack of high-quality building material in the former GDR has resulted in severe structural problems and a limited capacity. Also, the building design had originally not been the point of focus and consequently was not accepted today. The original façade was built from 36.5 cm brickwork without exterior coating or cladding. The windows were equipped with single-glass.

A.6.2. **Façade Technology**
The refurbishment focussed on the improvement of insulation and prevention of future damage to the structure (condensation, driving rain). Also, the design was to be renewed. The architects designed a ventilated cladding with aluminium-sandwich-plates (Alucobond) mounted on top of a supporting structure. The cavity was insulated and the windows replaced.
A.6.3. Architectural Design
The new façade design wants to create the impression of a new building. The choice of colours refers to the colour-code of the Saxony police. The detailing of the façade cladding achieves a very planar impression without shadow gaps or offsets. The design won the ‘Deutscher Fassadenpreis 2009’.

A.6.4. Technical installations
The building is naturally ventilated by opening windows. The southwestern façade is equipped with exterior, individually controlled Venetian blinds.

All images courtesy of Schulz & Schulz Architekten.
A.7. BP Solar Skin

Owner: University of Trondheim NTNU
User: University of Trondheim NTNU
Main function: Office
Location: Trondheim, NOR
Storeys: 5
GFA: 
Year of completion: 1970s
Architect: 
Year of refurbishment: 2001
Architect refurbishment: Faculties of architecture and building technology at NTNU
Façade Type original: 3.1.1
Refurbishment strategy: B2 – Addition of a climate skin
Façade Type after refurbishment: 3.1.2
Main motivation for refurbishment: Test mock-up for building integrated photovoltaic

A.7.1. Initial Situation
The façade design was initiated by BP Norway, who gave Trondheim University the research commission to investigate the possibilities of PV integration in façades. The building, on which the façade is applied, is a standard office building of the 1970s with a load bearing façade made of prefabricated concrete elements. The main research goals were to investigate the effect of the façade on the indoor climate and energy performance of the building, as well as the potential of the façade-integrated PV-cells (Aschehou et al. 2003).

Figure A.21
Initial Situation

Figure A.22
Elevation after Refurbishment
A.7.2. Façade Technology
The new façade structure is mounted onto a steel structure. It leaves a cavity of 80cm between the secondary glass screen and the original façade. The original façade is left unaltered. The original windows stay in place, no additional insulation is placed. The double façade functions as a multi-storey climate-skin. It is closed on the sides. Flaps on top and bottom allow controlling the airflow in the cavity.

A.7.3. Architectural Design
The façade design places the solar cells only in front of the massive parapets. This permits an optimal view, but also reaches a certain sun-screen effect.

![Figure A.23](image1)
Façade construction principle

A.7.4. Technical installations
The façade has a surface of 455 m². 192m² of this are covered with PV modules, which have a net surface of 102m² (Aschelouf and Bell 2003). The ventilation of the cavity can be controlled by opening windows on top and bottom of the secondary façade. The office rooms are naturally ventilated by opening windows to the cavity.

A.7.5. Research results
The prototype façade produced 7.200 kWh of electric power within one year, which equals 75% of the theoretical maximum. The heating demand for the building was reduced by 7-8% without additional means on the initial façade. The research report does not state any building physical problems, such as condensation on the secondary façade. The offices on the top floor of the building experienced summer periods of overheating. The report suggests improving the summer situation by opening the offices to a corridor on a northern side of the building. Thanks to the stack effect in the façade, cooler air from the northern side could thus be drawn through the rooms.

All images by (Aschelouf et al. 2003).
A.8. KfW Head office

Owner: Kreditanstalt für Wiederaufbau
User: Kreditanstalt für Wiederaufbau
Main function: Office
Location: Frankfurt, GER
Storeys: max. 14
GFA:
Year of completion: 1968
Architect:
Year of refurbishment: 2007
Architect refurbishment: RKW Rhode Kellermann Wawrowsky
Façade Type original: 3.1.2
Refurbishment strategy: A1 – Replacement of curtain wall
Façade Type after refurbishment: 4.1.1
Main motivation for refurbishment: Fire regulation

A.8.1. Initial Situation
The initial building was an on-site concrete structure, composed of four building volumes of different heights. The demand for improved fire safety initiated the refurbishment planning. The building owner, KfW, is a federal owned bank with – among others – has the task to give grants for sustainable building refurbishment. Hence, their own building was to be a best-practise example.
A.8.2. Façade Technology
The building was substantially refurbished. It received a new façade, interior design and technical installations. The new façade consists of highly insulated windows and additional insulation on the outside of the parapets. The facing is realised with a ventilated cladding. This cladding also creates an individually controllable sun-screen. The design aim was to create a sun protection device, which can be individually controlled, and which can be operated in any wind condition even in high-rise buildings. The solution is a movable glass pane combined with an expanded metal plate. In the ‘zero position’ the panes are placed in front of the parapets. When shading is needed, they lower and fold outwards. Thus, optimal shading is achieved, while the user can still enjoy a good view.

A.8.3. Architectural Design
The vertical posts of the new façade give the buildings a more slender appearance. This effect is amplified by the glass walls, which provide the wind shields for the roof terraces.

A.8.4. Technical installations
The offices are naturally ventilated, supported by controlled exhaust ventilation. Every building volume is equipped with a vertical shaft. A fan in this shaft creates an under pressure. By opening a window, fresh air is let inside. Used air is thus extracted through the corridors. The same system is used to support the cooling of the building. At night time, flaps open in the upper part of the windows. Cool air is drawn inside the room and above the suspended ceiling. Here it passes the concrete structure. During daytime, the chilled mass then absorbs excessive heat loads. Furthermore, the building uses rain water for adiabatic cooling and grey water of wash basins for flushing toilets. Overall these means reduce the sewage water produced by 89% (RKW 2009). The building performance was monitored within the research program ‘EnSan – Energetische Sanierung’ supported by the German Federal Ministry of Economics and Technology. This monitoring proved a reduction of primary energy consumption from 215kWh/m²a to 94kWh/m²a (BINE Informationsdienst 2009).
A.9. Westraven Gebouw

Owner: Rijksgebouwendienst,
Ministerie van VROM
Rijkswaterstraat
Office
Location: Utrecht, NL
19
GFA: 53,000 incl. new additions
Year of completion: 1975
Architect: Architectenbureau Cepezed,
Delft, NL
Year of refurbishment: 2007
Architect refurbishment:
Façade Type original: 5.1.2
Refurbishment strategy: A2 – Replacement of a curtain
wall with a double façade
Façade Type after refurbishment: 5.1.2
Main motivation for refurbishment: Technically and optically
outdated, presence of asbestos

A.9.1. Initial Situation
The ‘Westraven Building’ is a landmark located along the central Dutch
highway A12. The building was erected in the early 1970s. Before
refurbishment, it was characterised by unaccepted looks, technical
deficiencies in the façade and an outdated HVAC concept. Users
complained about the poor indoor air quality and the non-operable
windows. The air conditioning ducts were placed in the parapet
elements. As these also contained asbestos, the refurbishment was
strongly indicated.

A.9.2. Façade Technology
The new façade structure takes advantage of the parapet-window
construction principle. The original façade (windows and prefabricated
parapets) is removed. Instead, a double façade is installed, which
consists of pre-fabricated gangways that carry new window units. On
the northern façade, the outer shell is realised as a closed glass-shield,
which protects against the noise emitted from the adjacent highway.
The other three elevations are equipped with a textile façade. A Teflon-
coated glass-fibre mesh functions as windbreaker. Thus, it is possible
to open the windows even on the upper floors. Furthermore, the mesh
provides the sun-screen. Only the balustrades of this secondary façade
are glazed in order to provide the building user with a proper view.

Figure A.30
Elevation after Refurbishment
photo copyright Jannes Linders,
Rotterdam, NL

Figure A.31
Façade construction principle
(Cepezed 2009)
A.9.3. Architectural Design
The new façade changes the original horizontal emphasis to a planar design, which presents the high-rise as one cubic form. The goal was to let the building appear as if it was new.

A.9.4. Technical installations
The textile façade makes it possible to naturally ventilate all office rooms. Nevertheless, central mechanical ventilation is installed to guarantee the necessary air exchange rate. The top floor is equipped with heating and cooling circuits. Additionally, convectors in front of the façade serve as heating devices.

A.9.5. Economics
Installing the new façade and technical installations demanded the building to be entirely vacated. Especially the multi-storey atria, which serve as informal meeting places in a buffer climate, have been a big interference with the load bearing structure.
A.10. München Rückversicherung

Owner: München Rückversicherung
User: München Rückversicherung
Main function: Office
Location: Munich, GER
Storeys: 5
GFA: 53,000 incl. new additions
Year of completion: 1973
Architect: Baumschlager Eberle, Vaduz, LI
Year of refurbishment: 2001
Façade Type original: 5.1.1
Refurbishment strategy: A2 – replacement with corridor façade
Façade Type after refurbishment: 5.4.2
Main motivation for refurbishment: Change of existing building to appear the same as extension

A.10.1. Initial Situation
The initial building is a concrete framework structure from the early 1970s. The façade construction is formed by a structural concrete parapet. This parapet is clad with a prefabricated concrete unit, which also carries the window elements.

A.10.2. Façade Technology
During the refurbishment the old façade cladding is removed. The massive parapets are cut back to the possible minimum and supported with additional reinforcement. A new, non-load bearing façade is mounted to the outside edge of the parapet. The new façade consists of a unitised aluminium façade as the inner layer and a secondary façade layer functioning as corridor façade. The outer layer is supported by solid stone brackets. The secondary glazing is formed by single glass panes, which are placed into the stone bracket without additional profiles. All panes are overlapping each other leaving a small gap for ventilation. The corridor façade serves as a screen to protect the sun blinds against wind and to reduce noise immissions.

A.10.3. Architectural Design
Next to the refurbished building an extension has been erected. The refurbished façade gives both building parts the same impression. Thus, the original building has been substantially refurbished. A change of design was desired. Furthermore, the interior has been remodelled entirely.

A.10.4. Technical installations
The double façade functions as a noise shield. Thus, it is possible to ventilate the office naturally by opening windows. Nevertheless, central mechanical ventilation is installed to supply the necessary air
exchange if the windows are closed. Heating and cooling are achieved by floor heating in the elevated floor.

A.10.5. Economics
The refurbishment had a strong influence on the building structure. The façade parapets have been reduced and reinforced. Also, in the interior zones several openings were cut into the concrete floors. While the building was empty, these means could relatively easily be applied. The street elevations, on the contrary, demanded elaborated building logistics. The narrow street could not be blocked by construction work. Thus, the façade was prefabricated and delivered as floor-high units. The stone brackets were placed on site. The secondary glazing could be fitted in short time by simply sliding the panes into the glazing grooves.
A.11. BMW Headquarters

Owner: BMWAG
User: BMW
Main function: Office
Location: Munich, GER
Storeys: 22 (99.5m)
GFA: 72,000
Year of completion: 1972
Architect: Karl Schwanzer, Vienna (A)
Year of refurbishment: 2003-2006
Architect refurbishment: ASP Schweger Assoziierte Gesamtplanung GmbH, Hamburg, GER

Façade Type original: 4.2.1
Refurbishment strategy: C1 – Interior addition of a new façade
Façade Type after refurbishment: 4.2.1
Main motivation for refurbishment: Improvement of thermal performance and fire safety in monument

A.11.1. Initial Situation
The initial building structure was very modern when it was erected in 1973. The building soon became an icon and was listed in 1999. The hanging reinforced concrete structure is supported by the ‘spine’ in the core of the building. The floors were assembled on the ground and later elevated. The original façade was constructed of cast aluminium panels that span floor high. These panels create the outer appearance of the tower. The actual thermal layer was formed by an insulated façade and window units, which were fitted against the aluminium panels from the inside.

A.11.2. Façade Technology
The building has been substantially refurbished. The interior, the technical installations and parts of the façade are renewed. As the building is listed, the exterior aluminium panes of the façade are left in place. New façade units have been mounted against these panels from the inside. These units take in the same inclination of 9° as the original façade. But, they provide an up-to-date thermal insulation and are equipped with high potential solar glass. The glazing aimed to provide a maximum of daylight transmittance in combination with a maximum of sun protection, as no exterior devices were allowed. The used glass achieves a g-value of 35% and a daylight transmittance of 63% (Schollglas 2006). Of the 2,300 glass panes, 864 have been realised as opening windows. These can mechanically be opened parallel outwards. Additionally, interior Venetian blinds have been installed.
These provide glare protection and daylight control. A computerised control system coordinates the daylight deflection performance of these blinds.

A.11.3. Architectural Design
The looks of the building could not be changed. Therefore, the entire refurbishment has taken place from the inside. Furthermore, it was desired to achieve a new indoor quality by renewing all installations and finishings. The massive concrete top floor has been taken out and replaced by a 40mm high computer floor (Intelligente Architektur 2001).

A.11.4. Technical installations
The opening windows allow individual natural ventilation. Additionally, the basic ventilation needs and air conditioning are supplied by mechanical ventilation. The opening windows also function as smoke exhaust and thus eliminate the need for such mechanical installations.

A.11.5. Economics
The building has been refurbished entirely from the inside. To do so, the building was vacated during the time of construction. The empty building allowed creating an almost new technical standard and optimal user comfort. Using opening windows and insulating the façade significantly reduced the need for mechanical ventilation components. Thus, 2/3 of the original technical space could be transferred to usable floor space. Altogether, the refurbishment of the tower and the neighbouring museum demanded an investment of approximately 100m € (Schollglas 2006).
A.12. Bertolt Brecht School

Owner: Municipality of Dresden
User: Bertolt Brecht School
Main function: School
Location: Dresden, GER
Storeys: 3
GFA: old 1,900, new 2,400
Year of completion: 1960s
Architect: IBUS, Berlin, GER
Year of refurbishment: 1993-1995
Façade Type original: 3.1.1
Façade Type after refurbishment: 4.1.1
Main motivation for refurbishment: Change of existing building to appear the same as extension

A.12.1. Initial Situation
The building is one of the so-called ‘typical schools’, built with the modular prefabricated concept (Plattenbau) of the former German Democratic Republic. In Dresden alone, there are approximately 180 school buildings of the same type. The original building consists of two rectangular east-west aligned blocks connected by three stair cases, which form two interior courtyards. The façade construction is based on load bearing prefabricated wall units with windows.

A.12.2. Façade Technology
The building envelope is thermally improved by replacing the windows and adding an exterior insulation and finishing system (EIFS) of 120 mm. The main modification has been the transformation of the courtyards to covered atria. Thus, the building gains an additional floor area of approximately 400m² in an intermediate climate, which can be used on special occasions.

A.12.3. Architectural Design
The exterior impression of the building has not been changed much. The EIFS reproduces the original impression of a massive parapet with windows in a strong grid. The refurbishment of the interior and the atrium has led to a general improvement of the spatial quality.

A.12.4. Technical installations
The technical installation concept takes advantage of the new building layout with protected atria. The buffer climate is used to reduce heating demands. In winter, fans in the atrium walls are used to transport the preconditioned atrium air to the classrooms. The fans are linked to sensors in the opening windows of the classrooms and the atrium.

Figure A.40 Elevation after Refurbishment (Bertolt-Brecht-Gymnasium 2009)
Thus, they only run, if windows are opened to prevent an overpressure in the building. In summer the airflow is reversed. Fresh air is drawn through the rooms and led out via the atrium. The natural updraft in the atrium supports the airflow. Fan power is only needed if this stack effect is not strong enough. Also at night time the airflow is used to cool down the thermal mass with cold outside air.

There is no further cooling system installed. The existing heating system remains in the building. Only malfunctioning parts are replaced and a new control system is installed, which allows an optimal operation. The atria have received only a basic installation of local hot air convectors. The outer façades are equipped with exterior Venetian blinds that are controlled individually for each class room. The atrium roof has received an interior canvas shading system to prevent overheating. This system has turned out to be sufficient, as the monitoring showed that the only days with unpleasantly extreme temperatures occur during the summer holidays.

A.12.5. Economics
The entire refurbishment project was intended to be very cost effective. The EIFS is a very cheap solution for an exterior façade. Most technical components have been preserved. Closing the atrium has not only activated additional floor space, but also reduced the building surface significantly. The Annex 36 documentation reveals that the heating energy consumption of the building could be reduced from 283 kWh/m² to 69 kWh/m².
**A.13. TU Delft Onderzoeksinstituut OTB**

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**A.13.1. Initial Situation**

The initial building was designed by van den Broek and Bakema Architects. Its facade was equipped with prefabricated floor-high concrete units. These contained a close parapet zone and a concrete framework supporting the window elements. While the parapet zone provides some interior insulation, the windows were not insulated.
A.13.2. Façade Technology
The main facades have been refurbished by adding an exterior insulated facade. The original prefabricated concrete units have been kept in place. Only the non-insulated windows have been removed. Thus, the original structure is still recognisable both from the outside, as well as from the inside. The closed façades on the narrow sides have been equipped with an exterior insulation and finishing system (EIFS).

A.13.3. Architectural Design
Although the building was no listed monument, it was desired to maintain its appearance as a reference to the work of van den Broek and Bakema. The horizontal structure is marked by enamelled glass, just like the original, only, with different colour. The original concrete structure is very present on the inside. From the outside, the new façade creates a certain depth. The original structure is recognisable, but does not stand out. It demands a closer look to understand the façade structure, which evokes curiosity to dive into the building’s history.

A.13.4. Technical installations
The building is equipped with controlled natural ventilation. Mechanical openings control the air inlet. Used air is extracted by a mechanical exhaust. Radiators provide heating, just as in the original concept.

A.13.5. Economics
When the building was refurbished, it was only 50% occupied. Therefore, the users could relocate to one wing, while the other was refurbished. Thus, also the interior could be renewed quickly. The façade concept would also allow a ‘refurbishment in use’. But, in this case this was not desired. It was mainly chosen for this solution in order to provide the necessary insulation and deal with the original architecture.
A.14. Deutsche Bank, Frankfurt

Owner: Deutsche Bank AG
User: Deutsche Bank AG
Main function: Office
Location: Frankfurt (GER)
Storeys: 38-40
GFA: 60,000 m², Façade: 40,000 m²
Year of completion: 1979–1984
Architect: Walter Hanig, Heinz Scheid, Johannes Schmidt
Year of refurbishment: 2008-2010
Architect refurbishment: Mario Bellini
Façade Type original: 5.3.1
Refurbishment strategy: A1 – Replacement with a single-layered curtain wall
Façade Type after refurbishment: 5.3.1
Main motivation for refurbishment: Energy demand and unpleasant indoor climate

A.14.1. Initial Situation
The initial building was equipped with a curtain wall, which was fully closed and contained highly reflective solar glazing. Opaque zones were supplied with insulation and a ventilated cladding in the same appearance as the curtain wall Central mechanical air conditioning provided ventilation and cooling. Heating was supplied from radiators along the façade. The tasks for refurbishment have been to reduce the energy demand significantly and to improve the indoor climate. Building users did not accept the system of central air conditioning any more.

A.14.2. Façade Technology
The entire façade is replaced. The areas of ventilated cladding are equipped with additional insulation and a new glass rain screen. The new curtain wall contains triple glass, which is made of an exterior laminated glass pane, a centre pane and an inner pane. A reflective coating on the inside of the laminated glass provides the solar protection. Furthermore, interior Venetian blinds adjust the individual glare protection and deflect natural daylight into the room. Every second façade unit is realised as a parallel action window that can open outwards.

A.14.3. Architectural Design
The building is substantially refurbished. Nevertheless, the new façade intends to preserve the original appearance. It will preserve the original geometry and receive a similar reflective coating. The major difference will be the parallel opening windows.
A.14.4. Technical installations
The technical building services are completely renewed. The central mechanical system is removed. The office rooms along the façade are naturally ventilated by opening windows. Climate ceilings are used for cooling. Furthermore, concrete-core activation is built into the new top floors. This will cover the base load for cooling and heating.

A.14.5. Economics
In order to bring in all the new technical appliances and to replace the façade, the building was entirely vacated. The office staff has been relocated to different buildings around the city of Frankfurt. During operation, the refurbished building aims to achieve major savings. The heating demand is estimated to be reduced by 67%, the electricity demand by 55%, and the overall energy consumption by at least 50% (F.A.Z. 2009).

Owner: Consortium Safire
User: Ministry of Finance
Main function: Office
Location: The Hague (NL)
Storeys: 5
GFA: 66,000 m²
Year of completion: 1975
Architect: J. Vegter and M. Bolten
Year of refurbishment: 2007 – 2008
Architect refurbishment: Meyer and Van Schooten Architects, DEGW and Peutz
Façade Type original: 2.1.2
Refurbishment strategy: B3 – Replacement of primary façade and addition of a second layer, B1 – cover of a courtyard
Façade Type after refurbishment: 2.1.2
Main motivation for refurbishment: Complaints about the HVAC installations (Senter November 2009), poor insulation

A.15.1. Initial Situation
The ministry of finance building in The Hague is a famous example of Dutch brutalism. It is characterised by the strong horizontal gesture of balconies, which serve for façade cleaning and sun protection. This design has given the building a relatively closed exterior impression. The inside of the building opens to two courtyards. The original façade structure consisted of prefabricated concrete elements resting on a concrete framework. The window units were made of simple steel profiles and equipped with single glass. Consequently, the refurbishment aims to improve the insulation and technical building services. Furthermore, it has to preserve the design qualities of a cultural-historically relevant building.

A.15.2. Façade Technology
The original concrete parapets are preserved. Only the filling façade elements are replaced with new insulated windows. Additionally, a single glass layer is mounted between the parapets, close to edge of the balconies. The corridor façade thus created, acts as a buffer zone between the exterior and interior. The original concrete beams, which penetrate the primary façade, form thermal bridges, but the temperature inside the cavity is higher than outside, which prevents the risk of condensation. Furthermore, the double façade plays an important role in controlling the indoor climate and provides the sound protection from the busy surrounding roads.

Figure A.50
Elevation after refurbishment, photo: Imre Csany

Figure A.51
Impression inside a new winter garden, photo Imre Csany
The prominent corner situation, which houses a staircase, has been covered with glass. Thus, it forms two winter gardens on top of each other, each two storeys high. These generate additional usable space. The original interior courtyards have also been treated. One court has been opened to the street to create a public square. The other courtyard has been covered with a transparent roof. Thus, it forms an atrium, which houses the reception and a library.

A.15.3. Architectural Design
The building has been substantially refurbished. Nevertheless, the refurbishment design aims to preserve the brutalism character as the main architectural quality of the building. The new concept plays with intermediate climates and buffer zones. Opening the ground floor the public street embeds the office complex within the urban fabric. The glazed atrium and winter gardens give the building a more open and welcoming appearance.

A.15.4. Technical installations
The building is fully mechanically ventilated. The double façade is integrated in the technical concept. There are two air ducts installed inside the cavity, hidden behind the concrete parapets. Dependent on solar irradiation, the incoming air can be taken from outside or use the thermal gains inside the cavity. The heating and cooling system is based on climate ceilings. With reduced heating demands it is possible to use the ceiling for heating too. The low temperature system takes advantage of underground storage of thermal energy in aquifers.

A.15.5. Economics
The refurbishment achieves a strong reduction of energy demand by insulation and renewed technical building services. The low temperature heating and cooling system permits to supply 100% of heating and cooling energy from renewable sources.
A.16. Mobimo Building, Zürich (CH)

Owner: Mobimo AG
User: Bluewin
Main function: Office
Location: Zürich (CH)
Storeys: Original: 12, after refurbishment: 15

GFA:
Year of completion: 1973 – 1974
Architect: Farner and Grunder, Zürich (CH)
Year of refurbishment: 1999 – 2001
Architect refurbishment: Rolf Läuppi and Heinz Zimmermann
Façade Type original: 2.2.1
Refurbishment strategy: B3 – Replacement of primary façade, addition of second layer
Façade Type after refurbishment: Very economical floor layout, difficult inner city plot

A.16.1. Initial Situation
The original building rests on a steel structure with columns in the façade and in the centre of the building. The floors, cores and the stiffening walls on the narrow sides are made of on-site concrete. The building provides a very practical rectangular floor plan of optimal width, with very small core zones, and exterior emergency staircases. A new construction could not have been realised more efficiently. Furthermore, the location on a major traffic junction would have complicated demolition and new construction. The major deficiencies lay in the façade and building services. The original façade had exterior steel columns. The filling elements were attached to their inside edge. The load bearing columns and the steel rain shields showed signs of corrosion. All sealants between infill and structure leaked. The exterior Venetian blinds had been damaged by the wind. Furthermore, the assessment yielded asbestos reinforced components in the façade. Therefore, it was decided to replace the entire façade.

A.16.2. Façade Technology
The building is located on a very noisy and windy location. It has been decided to add three storeys on top of the original structure. For these reasons, a double façade has been chosen. The secondary layer is realised as a multi-storey climate skin, which spans the full height of the building. It is suspended from the new construction on the roof and realised in structural glazing. Horizontal loads are brought directly into the load bearing original columns. Steel gratings provide the horizontal stiffening and serve for maintenance. The cavity in front of the old part of the building is 1.10m wide. As the new floors are wider, the cavity is reduced to 70 cm. The primary façades have been replaced by

Figure A.54 Elevation after refurbishment

Figure A.55 Inside the cavity with daylight deflecting louvers
floor-high windows. The narrow façades, which are structural concrete walls, are insulated with 20 cm of mineral wool and also covered by the glass screen.

A.16.3. Architectural Design
It was the desire to give the building a new overall appearance. The addition of three storeys makes the proportions more slender. The new primary façades shows the dimension of the original building and makes the addition visible. The second façade layer visually holds these building parts together and creates the remote image of one cubical building.

A.16.4. Technical installations
The building is mechanically ventilated and air conditioned. The system uses the double façade as adjustable buffer climate and solar collector. The cavity is equipped with openings on top and bottom. In hot weather conditions these are opened and the stack effect extracts excessive solar gains from the cavity. In winter, the two cavities can be connected. The south façade is opened at the bottom. Air ducts and fans on the top floor transport the warm air to the northern cavity. Thus the entire building is surrounded by a ‘cushion’ of warm air. At the bottom of the north façade, the warm air is taken from the cavity and led past a cross-flow heat exchanger to precondition the incoming air for the mechanical ventilation.

Much effort has been put on the sun- and glare protection devices, which are placed in the cavity. The north façade only demands glare protection for the adjacent work spaces. This is achieved by textile screens. The east and west façades without workspaces are also equipped with screens. These shade the primary façades. Solar gains can be ventilated from the cavity. The south façade has to provide sun and glare protection. This is realised with daylight deflecting Venetian blinds. These specially formed ‘Retroflex’ blinds reflect most of the daylight back towards the sun, even when they are not fully closed. Thus, they facilitate a good view.

A.16.5. Economics
During planning phase many thermo-dynamic simulations have been realised to optimise the façade layout, material choice, ventilation concept, and sun protection. The focus lay on optimising the daylight deflecting blinds. The tested variants showed that, compared to normal Venetian blinds, the daylight deflecting blinds can reduce the cooling demand by 60%, due to less need for artificial lighting. On the other hand, more energy is needed for heating. As heat generation is easier and cheaper than cooling, an overall saving of 30% on heating, cooling, electric lighting can be reached. In comparison to the original situation, the refurbished building consumes only 50% of the total energy.

All images courtesy of Heinz Zimmermann, Zürich.
A.17. Former Consulate General of the USA, Cecilienallee 5

Owner: Grundstücksgesellschaft
Cecilienallee 5
User: Rental
Main function: Office
Location: Düsseldorf, GER
Storeys: 4
GFA: 
Year of completion: 1953
Architect: Skidmore Owings Merrill (SOM), New York, USA
Year of refurbishment: 1998
Architect refurbishment: Ingenhoven, Overdiek & Partner, Düsseldorf, GER
Façade Type original: 3.2.1
Refurbishment strategy: E2 – Interior insulation and exhaust façade
Façade Type after refurbishment: 5.2.2
Main motivation for refurbishment: Functional and technical deficiencies, monumental protection

A.17.1. Initial Situation
The building was designed as the US Consulate General in Düsseldorf by SOM in the early 1950s (DBZ 1957). The load bearing structure consists of a steel framework with concrete floors cast on site. The façade is characterised by the visible floors and columns. The filling elements are made of steel profiles and opening windows. The parapets are built up in gas concrete and clad with natural stone. Interior Venetian blinds originally served as sun protection. The building is a listed monument.
A.17.2. Façade Technology
As the exterior impression was not to be altered, the architects
developed an exhaust façade using the original façade as exterior leaf.
The original façade is equipped with insulated glass and technically
and optically maintained. To improve the energetic performance and
sound insulation, a second façade leaf is added to the inside of the
original façade. This layer consists of sliding elements of single glass.
Thus, an exhaust façade is created. The sun-blinds are located inside
the cavity, which allows discharging solar heat gains.

A.17.3. Architectural Design
The building is a listed monument. Therefore, it has not been possible
to change the exterior impression. The improved façade resembles
very much the original state.

A.17.4. Technical installations
The offices are mechanically ventilated. The façade functions as
an exhaust façade in summer. By opening the inner façade leaf, the
thermal updraft in the cavity extracts used air from the room. Radiators
in the interior parapet cladding provide heating.
A.18. Federal Ministry BMVEL Bonn

Owner: Government of Germany
User: Federal Ministry of Food, Agriculture and Consumer Protection
Main function: Office
Location: Bonn, GER
Storeys: 13
GFA: 
Year of completion: 1968
Architect: 
Year of refurbishment: 1997
Architect refurbishment: Ingenhoven Overdiek, Düsseldorf, GER
Façade Type original: 3.1.1
Refurbishment strategy: B3 – Addition of ‘cold-warm-façade’
Façade Type after refurbishment: 4.1.2
Main motivation for refurbishment: Technical improvement

A.18.1. Initial Situation
The initial building provided an on-site concrete construction with structural parapets in the façade. The massive parapets were decorated with natural stone plates, but without additional insulation.

A.18.2. Façade Technology
The refurbishment concept left the façade parapets in place. The exterior cladding and the old windows were removed. Instead, wood frame windows were installed. The parapets received an exterior insulation. The new façade cladding consists of printed glass panes. The space in front of the windows is supplied with a secondary glazing, which forms an opening box window.

A.18.3. Architectural Design
While most of the building interior stays unchanged, the new façade cladding gives the building an entirely new identity. The secondary glazing is also placed in front of the structural façade columns. Thus, a horizontal rhythm is imposed, which is emphasised when the façade is opened. The double façade also extends above the roof level and creates a protected roof terrace.
A.18.4. Technical installations
The double façade functions as a protection for the sun blinds in the cavity and wants to allow opening windows even on higher floors. The necessary insulation is achieved by the primary façade. Therefore it is not necessary to fully seal the box windows. By opening the secondary façade overheating can be prevented. The building is naturally ventilated by opening windows. No mechanical ventilation or cooling is needed. The original radiators have been maintained. Both the inside of the façade and the concrete ceiling are passed by circulating air. Thus, the thermal mass of the building is activated.

A.18.5. Economics
The refurbishment concept aimed to reduce the intervention to a minimum. The heating distribution system has been preserved. Also, most of the interior has not been changed. Only some asbestos reinforced panels were removed. This kept construction time inside the building short.
Nürnberger Hypothekenbank

Owner: Nürnberger Hypothekenbank
User: Nürnberger Hypothekenbank
Main function: Office
Location: Düsseldorf, GER
Storeys: 6
GFA: 2,000
Year of completion: 1970
Architect: 
Year of refurbishment: 1998
Architect refurbishment: Petzinka Pink & Partner
Façade Type original: 5.4.1
Refurbishment strategy: A1 – Replacement with a unitised façade
Façade Type after refurbishment: 5.3.1
Main motivation for refurbishment: Functional and technical deficiencies – reactivation

Figure A.67
Initial Situation

Figure A.68
Sections and elevation of unitised façade
A.19.1. Initial Situation
The initial building provided a concrete framework with structural parapets and binding girders in the façade layer. The façade itself was designed as a curtain wall with additional cladding on the parapets. The building layout and technical performance did not meet the desired standard, which caused a high vacancy rate.

A.19.2. Façade Technology
In order to increase the allowed load bearing capacity of the floors, the refurbishment has to focus on the reduction of weight. The building was completely stripped and restructured. The load bearing parapets and girders in the façade were removed. Instead the floor was equipped with additional reinforcement. The new façade is made of pre-fabricated units based on an aluminium framework. Window units and opaque elements of equal width alternate. While the windows are floor high opening aluminium windows, the opaque parts create a solar façade. The insulation is adjusted for an optimal heat protection in summer. On top of the coloured insulation, the façade provides a ventilated cavity of 50mm clad with a single glass pane. This construction functions as heat trap in winter. The solar irradiation heats up the exterior of the insulation level to 60°C, which serves as dynamic insulation and reduces heat loss (Busmann et al. 2004).

A.19.3. Architectural Design
The new façade is meant to give the building a completely new impression. The chosen colour refers to the corporate ID of the owner. The strict grid is a modern interpretation of the surrounding 1950s skeleton buildings.

A.19.4. Technical installations
The offices are naturally ventilated by opening the façade. A cooling device is not installed. Heating is provided by convector units integrated in the interior parapet cladding. An exterior textile sun- and glare screen is mounted in front of the floor slabs. Its cladding also covers the distance between the façade units. Furthermore, this zone provides the space for installation ducts, which can be easily accessed and maintained from outside without disturbing the interior (Busmann et al. 2004).

A.19.5. Economics
The refurbishment solution focuses on the reduction of operational costs. The very high insulation level reduces heating demands. Demolishing the girders allows a better use of daylight. The maximised load bearing capacity of the floors and the easily accessible technical installations make the building very adaptable to different functions.

All photos by Tomas Riehle / arturimage; all drawings by Petzinka Pink Architekten Düsseldorf.
A.20. References


TU Dortmund (2008) "Architekturdatenbank NRW."
## Building inventory

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<tr>
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<tbody>
<tr>
<td>Address</td>
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### Contacts

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### General facts

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<tr>
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<tr>
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<td>solitaire / block / ... /</td>
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<td>Number of Floors below ground</td>
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<td>Gross Volume</td>
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<td>Persons in the building</td>
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### Documentation

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<th>Floor plans</th>
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<tr>
<td>Facade details</td>
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<td>HVAC concept</td>
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<td>Expertise toxic material</td>
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<td>Fire expertise</td>
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### Owner Interview

- Motivation for Refurbishment
- Qualities of the building
- Users' complaints
- Desires for the refurbished building
- Worries
- Organisational restrictions
- Time restrictions
- Financial frame

### Building

#### Architectural design

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<td>public transport / car access / green / complaints</td>
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<td>noise / pollutant</td>
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#### Structure

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<td>material / dimension</td>
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<td>material / dimension</td>
<td></td>
</tr>
<tr>
<td>material / dimension</td>
<td></td>
</tr>
<tr>
<td>Technical Installation</td>
<td>Comment</td>
</tr>
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<td>------------------------</td>
<td>-----------------------------------------------</td>
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</tr>
<tr>
<td>Cooling</td>
<td>machine / state of maintenance</td>
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<td>Heat / Cold distribution</td>
<td>water / air</td>
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<td>central / de-central</td>
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<td>Heat recovery</td>
<td>central / de-central / efficiency / age</td>
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<td>Evacuation route on balconies</td>
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<tr>
<td>Maintenance cost facade</td>
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### Zone 1

**Description / Location**

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<td>Accessibility floor</td>
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<td></td>
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<tr>
<td>Suspended ceiling</td>
<td>height / material / quality</td>
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<td>Accessibility ceiling</td>
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**Artificial Lighting**

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**Electrical Installation**

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<td>Facade grid</td>
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<td>Offset to structural grid</td>
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<td></td>
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<tr>
<td>Year of glass</td>
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<tr>
<td>Insulation of opaque parts</td>
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<td>U-value / g-value window</td>
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<tr>
<td>U-value opaque part</td>
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<td>Thermal bridges</td>
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<td>Vapour seals</td>
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<td>Connection to dividing walls</td>
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<td>Connection to floor / ceiling</td>
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Summary

Re-face
Refurbishment Strategies for the
Technical Improvement of Office Facades

Two thirds of all office real estate in Europe is older than 30 years. While the load bearing structure of a building can last for a century, the interior design is renovated at relatively short intervals. Practice has shown, however, that at the age of twenty to thirty years the facades and climate installations of a building do no longer fulfil today’s demands. They are out-of-date on technical, optical and comfort matters. Particularly these building components hold the potential to improve the energy performance of a building significantly. The façade of a building is also responsible for its exterior appearance and thus the public perception of it, as well as for the interior climate and the well-being of the occupant. Consequently, more and more office buildings come into consideration for refurbishment.

However, currently the building economy is lacking innovative refurbishment strategies for office facades. On the one hand, most of the current renovation projects tend to substantially refurbish a building, which causes major interference with the building’s interior and the load bearing structure, and consequently a major investment. On the other hand, only little is known about the various façade types, which have been built in different eras. This leads to certain reluctance in initiating a refurbishment project. The market is obviously lacking an overview of practical refurbishment strategies and their applicability to different existing façade typologies. The present thesis intends to fill this gap of knowledge. After an introduction (chapter 1) and overview of the 'state of the art' of façade refurbishment (chapter 2), this research project is set up in four steps.

In the first place, chapter 3 evaluates the existing stock of office facades in Western Europe. It defines the typical office facades and sorts them into 22 categories, which are characterised by structural features and similar refurbishment challenges. With this typology at hand, the distribution of these office facades is evaluated in different locations in the Netherlands, the United Kingdom, and in Germany. The local market analysis shows that the three countries, although being in the same climate zone, have developed very different office façades. Thus, an overview is created, which estimates the amount of façades of one typology for certain locations and eras. The common refurbishment tasks become evident.

The following step (chapter 4) elaborates the demands and restrictions of façade refurbishment planning. In order to compare different concepts for one given building with each other, this chapter also evaluates existing assessment methods and generates appropriate
tools for the special task of refurbishment. These tools compare the quantifiable features energy consumption and life-cycle-cost, as well as quality aspects such as the construction process and the interference with the function of an office, and possible improvement of indoor comfort. For these 'soft skills' an evaluation tool is developed, which facilitates the comparative rating and graphical visualisation.

Chapter 5 takes in the central part of the research and intensively assessing five case studies that can stand representative for the most common façade types. Among these cases there are office buildings in the Netherlands and Germany, as well as the campus of Bielefeld University. In these studies, the typical problems of each façade typology come to light. For each case, different refurbishment concepts are developed and evaluated in order to define the most promising solution. These concepts look at the building in general and at the façade construction in detail.

Furthermore, two product developments are part of this research, which propose solutions for the most common façade types. For the typical post-and-beam façade, an adapter profile has been developed, which permits upgrading existing façades of different manufacturers with new standardised products. It brings the façade to an up-to-date insulation level without alteration of connections to dividing walls and interior finishings. The second product development looks at the typical load bearing facades with window units. The concept proposes to replace the windows and renew the building services within the façade. By combining these features in new façade components it is possible to renew the building envelope and installations entirely from the outside with minimal disturbance of the interior. The system is highly modular, which allows future adaptations.

In the fourth step (chapter 6) the results of the case studies and further assessed best-practice examples are combined. This thesis thus gives an overview of the common existing façade types and their typical challenges. The possible refurbishment strategies are evaluated in terms of architecture, function, comfort, investment, material consumption, and energy saving potential. It is possible to choose those refurbishment strategies that are most promising for the various refurbishment tasks. This analysis results in a matrix, which presents the features of each refurbishment concept and relates the concepts to the different existing types of façades. Thus, it will be of use for architects and specialist consultants in the early planning stage to clarify the building task and to identify the first refurbishment concepts. This work is also intended to provide decision makers, such as owners and investors with the necessary background knowledge of the topic. The façade industry can gain insight into the market for office refurbishment and can find inspiration for future product developments.
With these goals in mind, this thesis aims to structure the complex task of façade refurbishment and visualise its possibilities. Thus, it wants to motivate real estate stakeholders to step into the planning and initiate more buildings to be refurbished. The presented refurbishment strategies permit reducing the energy consumption of an existing building, while the life-cycle costs are reduced. At the same time, they give the chance to improve the comfort of the inhabitants and the quality of the urban environment. In this sense, the refurbishment of office façades takes its share in improving the sustainability of the building stock.

Thiemo Ebbert
Samenvatting

Re-face
Renovatie strategieën voor het technisch verbeteren van kantoorgevels

Tweedere de van de kantoorgebouwen in Europa zijn ouder dan 30 jaar. Draagconstructies van deze gebouwen kunnen een eeuw meegaan, interieurs worden vaker vernieuwd. Uit de praktijk is gebleken dat bij een gebouw van tussen de 20 en 30 jaar de gevels en de klimaatinstallaties niet meer voldoen aan de hedendaagse standaard. Ze zijn versleten, qua techniek, qua uitstraling en qua comfort. Deze gebouwonderdelen bepalen in grote mate het energieverbruik van een gebouw, maar de gevel heeft nog meerdere functies, zij bepaalt de uitstraling van een gebouw en daarmee tevens het beeld dat het publiek van de eigenaar heeft. Daarnaast beïnvloedt de gevel ook het binnenklimaat en het welzijn van de gebruiker. Bijgevolg komen steeds meer kantoorgebouwen in aanmerking voor renovatie. Helaas bezit de bouw op dit moment nog weinig strategieëns voor innovatieve renovatie van kantoorgevels. Aan de ene kant neigen de meeste renovatieprojecten ertoe gebouwen compleet op te knappen, wat vaak gevolgen heeft voor het interieur en de draagconstructie en wat daardoor grote kosten met zich meebrengt. Aan de andere kant zien we dat er weinig kennis is van de verschillende geveltypes die in de afgelopen decennia zijn toegepast, wat tot een zekere wezer in leidt om met een renovatieproject te starten. Duidelijk mag zijn dat de markt een overzicht mist met praktische renovatiestrategieën en hun toepasbaarheid op verschillende bestaande geveltypologieën.

Deze thesis beoogt dit geman aan kennis op te vullen. Om tot bruikbare antwoorden te komen is het rapport in vier delen opgedeeld. Na een introductie (hoofdstuk 1) en overzicht van de stand van zaken (hoofdstuk 2) wordt in hoofdstuk 3 de bestaande kantoorvoorraad in West Europa geëvalueerd. Typische kantoorgevels worden gedefinieerd en geordend in 22 categorieën die worden gekarakteriseerd door constructieve elementen alsmede door bepaalde renovatie-uitdagingen. Met behulp van deze typologien wordt de spreiding van deze kantoorgevels geëvalueerd in Nederland, het Verenigd Koninkrijk en in Duitsland. De lokale markt-analyse laat zien dat in deze drie landen met een identiek klimaat zeer verschillende kantoorgevels zijn ontwikkeld. Aldus is een overzicht gemaakt dat een inschatting geeft van het aantal gevels van één type voor bepaalde locaties en tijdsvakken. De overeenkomende renovatietaken worden duidelijk.

Hoofdstuk 4 belicht de verschillende eisen rondom kantoorgevels en de renovatie daarvan. Om verschillende renovatie-concepten met elkaar te vergelijken, worden kwantificeerbare onderdelen tegenover elkaar uitgezet, zoals de energiekosten en de life cycle costs. In dit hoofdstuk wordt tevens een evaluatie-tool ontwikkeld voor kwaliteitsaspecten.
Hierbij moet u bijvoorbeeld denken aan de invloed van het bouwproces op het functioneren van een kantoorgebouw, alsmede de mogelijkheid van comfortverbetering. Deze aspecten worden gewaardeerd en grafisch gepresenteerd.

In de derde stap van het onderzoek (hoofdstuk 5) wordt gefocust op de meest voorkomende geveltypes door vijf representatieve case-studies te beoordelen. Deze case-studies omvatten kantoren in Nederland en Duitsland alsmede de campus van de universiteit van Bielefeld. Door deze studies komen de typische problemen van iedere geveltypologie aan het licht. Voor elke case zijn verschillende renovatieconcepten ontwikkeld en geëvalueerd om zo de meest belovende oplossing te definiëren. Deze concepten richten zich in het algemeen op het gehele gebouw en in detail op de gevels.

Verder zijn twee produktontwikkelingen onderdeel van dit onderzoek, dat oplossingen aanlevert voor de meest voorkomende geveltypes. Voor de typische vleesgevelsystemen is een adapterprofiel ontwikkeld waarmee bestaande gevels van verschillende leveranciers kunnen worden opgewaardeerd met nieuwe gestandaardiseerde producten. De isolatiewaarde van gevels wordt hiermee verbeterd tot een hedendaags niveau zonder dat hiervoor de aansluitingen met binnenwanden aangepast hoeven te worden. Het tweede produkt dat tijdens dit onderzoek is ontwikkeld richt zich op typische dragende gevels met een raam. Het concept stelt voor om het raam te vervangen in combinatie met de gebouwinstallaties. Door deze twee onderdelen te combineren in nieuwe gevelcomponenten wordt het mogelijk zowel de gevel als de installaties te vervangen vanaf de buitenkant en zo de overlast binnen het gebouw tot een minimum te beperken. Het systeem is zeer modulair waardoor toekomstige aanpassingen mogelijk zijn.

In de laatste stap (hoofdstuk 6) wordt het resultaat van de case-studies en verder beoordeelde voorbeelden uit de praktijk gecombineerd. Op deze manier geeft deze thesis een overzicht van typische bestaande geveltypes en hun specifieke uitdagingen. De mogelijke renovatierichtlijnen worden geëvalueerd vanuit architectonisch oogpunt, vanuit de functie, het comfort, investering, materiaalgebruik en mogelijke energiebesparing. Het is mogelijk de beste strategie te kiezen die het meest belovend zijn voor de verschillende renovatietaken. Deze analyse resulteert in een matrix die de eigenschappen toont van elk renovatieconcept en legt daarbij een verband met bestaande geveltypes. Het is dus van praktisch nut voor architecten en specialist consultants in een vroeg stadium van het ontwerpproces om het renovatieconcept te bepalen. Dit werk is ook bedoeld om beleidsmakers zoals eigenaars en investeerders met de nodige achtergrondkennis van het onderwerp te voorzien. De gevelindustrie kan inzicht krijgen in de markt voor kantoorrenovatie en hieruit inspiratie halen voor toekomstige produktontwikkelingen.
Met deze doelstellingen voor ogen is in deze thesis de renovatie van kantoorgevels gestructureerd en gevisualiseerd. Het vereenvoudigd hiermee de opstelling van een plan van aanpak en een stappenplan. De drempel voor gevelrenovatie wordt verlaagd en meer renovatieprojecten zullen een kans van slagen hebben. De voorgestelde renovatieconcepten maken het mogelijk de energieprestatie te verbeteren terwijl de life cycle costs omlaag zullen gaan. Tegelijkertijd verbeterd het comfort voor de gebruikers en de kwaliteit van de omgeving. Gevelrenovatie levert zo zijn bijdrage aan de verduurzaming van de huidige kantoorvoorraad en mede de maatschappij.

Thiemo Ebert
Zusammenfassung

Re-face
Sanierungsstrategien für die technische Aufwertung von Bürofassaden


Bei der Suche nach neuen Sanierungskonzepten gilt es, den Blick auf Fassade und technische Gebäudeausrüstung zu lenken. Während das Tragwerk bis zu hundert Jahre und länger seine Funktion erfüllen kann, wird der Innenausbau in der Regel mit jedem Mieterwechsel erneuert. Die Praxis hat gezeigt, dass ausgerechnet die Fassade und TGA nach 20 bis 30 Jahren nicht mehr in der Lage sind, den heutigen Anforderungen zu entsprechen.

Darüber hinaus lässt sich feststellen, dass überraschend wenig Wissen über die verschiedenen Bürofassadentypen der vergangenen Dekaden vorliegt, welches nötig ist, um innovative und pragmatische Sanierungsstrategien zu entwickeln. In der vorliegenden Arbeit werden unterschiedliche Sanierungsstrategien entwickelt und bewertet, sowie deren Anwendbarkeit auf unterschiedlichen Bestandsfassaden evaluiert. Nach einer Einleitung (Kapitel 1) und einer Übersicht der aktuellen Situation des Sanierungsmarktes (Kapitel 2) geht die Arbeit in vier Schritten vor.

Im folgenden Schritt (Kapitel 4) werden die Anforderungen an die Planung einer Fassadensanierung erarbeitet. Um unterschiedliche Sanierungsstrategien miteinander vergleichen zu können, werden zum einen quantifizierbare Aspekte wie Energieeinsparung und Lebenszykluskosten betrachtet. Zum anderen wird in diesem Kapitel ein Vergleichstool entwickelt, mit dem die qualitativen Eigenschaften wie Bauprozess und Einfluss auf Funktion, Gebäudenutzung und mögliche Komfortverbesserung bewertet und graphisch dargestellt werden können.

Mit Hilfe dieser Methodik werden in Kapitel 5 die typischen Fassadenkonstruktionen näher betrachtet. Dazu werden fünf Fallbeispiele für Bürogebäude in den Niederlanden und in Deutschland, sowie die Universität Bielefeld, umfassend analysiert. Für jedes Gebäude werden mehrere Strategien der Fassadensanierung mit individueller Schwerpunktsetzung erarbeitet. Die möglichen Lösungen betrachten sowohl das Gebäude im Ganzen, als auch die Fassadenkonstruktion im Detail, sowie die Kombination mit unterschiedlichen TGA-Prinzipien.


Thieme Ebbert
Resumen

Re-face
Estrategias de renovación para el mejoramiento de la eficiencia de fachadas de oficinas

Dos tercios de todos los inmuebles de oficinas en Europa tienen más de 30 años de antigüedad. Mientras que la estructura de un edificio puede durar al menos cien años, el diseño interior es renovado en períodos más cortos de tiempo. Sin embargo, la práctica ha demostrado, que las fachadas y instalaciones técnicas de más de veinte o treinta años ya no satisfacen las demandas de la actualidad. Estos están desactualizados en aspectos técnicos, ópticos y de comodidad. Particularmente estos componentes tienen el potencial para mejorar significativamente la eficiencia energética del edificio. La fachada del edificio es la responsable del ambiente interno y del bienestar de sus ocupantes, así como de la apariencia externa y por lo tanto de la percepción pública con respecto a su dueño. En consecuencia, más y más edificios comerciales entran en consideración para su rehabilitación. Sin embargo, la actual industria de la construcción carece de rehabilitaciones innovadoras estratégicas para fachadas de oficina. Por un lado, la mayoría de los actuales proyectos de renovación tienden a rehabilitar considerablemente al edificio, lo cual causa una mayor interferencia con el interior de este y de su estructura de carga, lo que conlleva a una mayor inversión. Por otro lado, poco se conoce sobre los varios tipos de fachadas que han sido construidos en diferentes áreas. Esto produce cierto desinterés para iniciar un proyecto de rehabilitación. El mercado carece obviamente de una perspectiva general de rehabilitación práctica, estratégica y de su aplicabilidad a las diferentes topologías de fachadas existentes.

La presente tesis intenta llenar esta falta de conocimiento. Con el fin de llegar a respuestas útiles, este proyecto de investigación es formulado en cuatro pasos. En primer lugar (capítulo 3), se evalúa la existente variedad de fachadas de oficina en Europa Occidental. Las fachadas típicas son definidas y ordenadas en 22 categorías, las cuales son caracterizadas por peculiaridades estructurales y retos similares de rehabilitación. Con esta topología en mano, la distribución de estas fachadas de oficina es evaluada en diferentes lugares en los Países Bajos, en el Reino Unido y en Alemania. El análisis del mercado local muestra que los tres países, a pesar de encontrarse en la misma zona climática, han desarrollado fachadas de oficina muy diferentes. Esto lleva a crear una perspectiva general, la cual estima la cantidad de fachadas de una topología para ciertos lugares y áreas. Las tareas comunes de rehabilitación se vuelven evidentes.
En el próximo paso (capítulo 4) se elaboran los requisitos para la planificación de una rehabilitación de la fachada. Para poder comparar las diferentes estrategias de rehabilitación se contemplan los aspectos cuantificables, tales como el ahorro de energía y el costo del ciclo de vida. En este capítulo se desarrolla una herramienta comparativa, con la cual se evalúan las características cualitativas, como son el proceso de construcción y la influencia de su función, el uso del edificio y posibles mejoramientos de la comodidad. Estas características se las puede presentar gráficamente.

El tercer paso de la investigación (capítulo 5) destaca a los tipos de fachadas más comunes gracias a evaluaciones intensivas desarrolladas en cinco estudios de casos representativos. Entre estos se encuentran edificios comunitarios en los Países Bajos y Alemania así como el campus de la universidad de Bielefeld. En estos estudios surgieron a la luz los típicos problemas de cada topología de fachada. Para cada caso se desarrollaron y evaluaron diferentes conceptos de rehabilitación para definir la solución más prometedora. Estos conceptos vieron al edificio en general y a la construcción de la fachada en detalle.

Además dos desarrollos de producto son parte de esta investigación, los cuales proponen soluciones para los tipos de fachada más comunes. Para las típicas fachadas ligera de montantes y travesaños, un perfil adaptable ha sido desarrollado, el cual permite modernizar las fachadas existentes de diferentes manufacturas con nuevos productos estandarizados. Esto da a la fachada una actualización de su nivel de aislamiento sin la alteración de conexiones que dividen paredes y acabados interiores. El segundo desarrollo del producto toma en cuenta las típicas fachadas pesadas con ventanas. El concepto propone reemplazar las ventanas y renovar los servicios del edificio dentro de la fachada. Combinando estas características en nuevos componentes de fachada es posible renovar la apariencia del edificio y las instalaciones completamente desde el exterior molestando mínimamente el interior. El sistema es altamente modular, lo que permite futuras adaptaciones.

En el capítulo 6 se combinan los resultados de los casos estudiados y además de los mejores casos prácticos evaluados. Por lo tanto, esta tesis da una perspectiva general del tipo de fachadas existentes y de sus típicos desafíos. Las posibles estrategias de rehabilitación son evaluadas en términos de arquitectura, función, comodidad, inversión, consumo de material y potencial de ahorro de energía. Es posible elegir las estrategias de rehabilitación que sean más prometedoras para las diferentes tareas de rehabilitación. Este análisis resulta en una matriz, la cual presenta las características de cada concepto de rehabilitación y relaciona los conceptos a los diferentes tipos de fachadas existentes. Por lo tanto, será usado por arquitectos y asesores especiales en la etapa temprana de planeamiento para aclarar las tareas de construcción y encontrar los primeros conceptos de rehabilitación.
Este trabajo también intenta proveer un proceso de decisión con el conocimiento de fondo acerca del tema, tanto para los dueños como para los inversores. La industria de la fachada puede entender mejor el mercado de rehabilitación de oficinas y puede encontrar inspiración para futuros proyectos de desarrollo.

Con estas metas en mente, esta tesis tiene como objetivo dar comienzo a un mayor número de proyectos de rehabilitación, lo cual mejora la calidad del stock existente de edificios, su rendimiento energético y la comodidad del personal de oficina. En este sentido la rehabilitación de fachadas de oficinas contribuye a la sostenibilidad del stock de edificios y así a la de la sociedad.

Thiemo Ebbert
List of publications


Curriculum Vitae

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