Refurbishment solutions for post-war housing blocks

New façades, new buildings

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Technical University of Delft,
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Master track Building Technology

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In November 2010, I started this master thesis within the chair of Future Façade Design, Building Technology. This chair is part of the faculty of Architecture on the Technical University Delft. The topic for this master thesis is related to a PhD-research done by Thaleia Konstantinou. The assignment is formulated by the faculty of Architecture, department Future Façade design, Building Technology.

I want to say ‘thank you very much’ to everybody who assisted me during my study. I want to thank my parents who supported me a lot along my study. My gratitude goes out to Marcello Bilow, Regina Bokel and Thaleia Konstantinou who helped me during this master thesis. Also the people of ‘Rochdale’ who provided information about the case study building.

This master thesis is about the energy use of the ageing (post-war) residential buildings and how the energy consumption of these buildings can be reduced. A way to do this is to refurbish the buildings in such a way they will be energy efficient again. The focus of the refurbishment will be on the façade of the building and how different adjustments will react on the energy use and the indoor climate of the dwelling.

The first part of the thesis will focus on the theoretical research about the housing stock in the Netherlands, comfort demands in the housing sector, the energy consumption in the housing and building sector and previous refurbishment projects will be analysed.

The second part of the thesis will consist of the refurbishment of a case study building. On this building different refurbishment solutions will be tested. In the end the results of the testing will be discussed and evaluated.

The use of energy in the world is directly related to the human behaviour. More people will use more energy. If the subject is about energy use or energy efficiency most of the time it is also about climate change in the world. Nowadays everybody is aware of energy use and that it is important to reduce the energy consumption all over the world.

A lot of energy is used by the building sector especially the older buildings without strict building regulations for energy efficiency. In the Netherlands there are a lot of old buildings that are still in use. These buildings are consuming a lot of energy because of the lack of efficiency of these buildings. This way a lot of energy is wasted and lost.

In most areas in Europe the state of the art of the building sector is the same as in the Netherlands. So the energy consumption of buildings is a common problem, not only the Netherlands but also in Europe. That is why some researches will not only focus on the Dutch housing market but also is related on European scale.

The housing sector consumes a great amount of energy and most of this energy is wasted because a lot of old buildings are in a bad state. Nowadays new built buildings are required to answer the building regulations for the building sector, but the buildings out of the post-war period do not answer these building regulations. The buildings out of the post-war period remain out-dated and are consuming a lot of energy while this is a big amount of the total residential buildings in the Netherlands and Europe.

Initiatives to address the problems of energy efficiency are not new. They have been developed for decades if not centuries, especially intensified when the oil crisis of the 1970s hit the capitalist economies hard.

What changed more recently is the growing sense of the globalization of the problem and its perception. Issues such as climate change, energy security, economic uncertainty, and poverty have all come to their summits and all achieved global status, demanding immediate, adequate and comprehensive responses. Housing offers a major possibility for action. Dwellings belong to the longest lived parts of a city’s infrastructure and that is why these buildings needs to be improved in their energy efficiency.

Nevertheless energy efficiency in the housing sector is more than a technical problem. The sort, quality and the variety of dwellings define for a great part the identity of a city or neighbourhoods. Citizens identify themselves, or are being identified with their housing situation. Quality of housing, and its surrounding, has influence on the quality of life of the inhabitants, but also on the costs of living. This makes the matter more complicated for subsidized housing, where the costs for the individual tenant should be affordable, with acceptable costs for the house owner. So despite the technical high potential in energy savings, other aspects make the matter more complicated than it looks at the first sight.

Edwin Tensen
June 2011
Summary

The first part of this master thesis consists of the theoretical background and the second part contains the research part together with the conclusions.

The main objective of this master thesis is to find a solution to make the ageing building stock energy efficient again. The façade is not only important in its appearance, but is also important for the energy use, comfort and indoor climate. That is why the focus of this thesis will be on the façade. This way the energy efficiency, indoor climate and comfort of the building can be improved.

A lot of energy is wasted because of ageing buildings in the Netherlands and in Europe. These ageing buildings are not energy efficient. Newly built buildings are built with the new and energy efficient building requirements, but the ageing building stock does not meet these requirements. The ageing buildings are a substantial part of the total building stock. This is a reason to focus on the ageing building stock and improve the energy efficiency. This way the energy efficiency of the total building stock can be improved.

Approximately 1% of new dwellings is added to the existing building stock each year. This makes it clear the existing building stocks exceeds the newly build buildings by far. During the post-war period (1945 – 1972) a lot of new buildings are added to the existing building stock. In this period the building method was not that good and there were a lot of complaints because of several problems. Not only technical problems like: draft, moisture, mold and bad insulation but also on the social aspect. In the beginning the social problems were not there but this changed during the years. The building method was based on producing a lot of dwellings on a fast and cheap way.

Nowadays everybody is aware of energy use and wasting energy is not good for the environment. Reducing the energy consumption in different objects like buildings, cars and electrical devices is an important issue nowadays. Another reason to reduce the waste of energy is the agreement according to the Kyoto-protocol. The Netherlands should reduce the energy consumption with at least 20% in the year 2020 compared to the year 1990. There are new agreements of a reduction of 30% in the year 2020.

To deal with the energy reduction for the building sector the Dutch government introduced energy labels for buildings. The better the label, the more energy efficient the building will be. A lot of dwellings out of the post-war period are labelled D, E or F. On a scale from A till G this is not very good. The most energy for a dwelling is used for space heating (56%) and hot water (26%). If those two energy consumers can be reduced, a lot of energy will be saved.

Already a lot of buildings are refurbished in the Netherlands. All these buildings are refurbished with their own approach. Each building developer has its own focus and strategy how it can be refurbished. Some refurbishments projects are focusing on energy reduction. Other projects are focused on sound reduction, bigger floor plans, extra dwellings or the indoor climate.

Each project must meet a certain level of comfort and requirements. These requirements are given in the book for Dutch building codes. There is also the indoor climate comfort which has to be taken into account for a refurbishment project. Out of the theoretical background different energy concepts are developed. These concepts are based on the way a building can be refurbished. In total eight different concepts are developed which can be used for a case study building. Within these concepts a lot of different options can be used to refurbish a building, not only in materials that can be used but also as a combination of different concepts.

The next step is to test the different refurbishment concepts on a case study building. This case study building is located in the city Zaandam. The building is a typical building out of the post-war period (1963). It is a gallery flat and there are ideas to refurbish the building, but there are no final plans for it right now. The dwellings are labelled D, E and F. The energy efficiency of the building can be improved. In the building there are typical problems like moisture, mold, draft, noise and the energy consumption.

The case study building is used to test different refurbishment concepts. Different solutions are made up within these concepts. The solutions differ in such a way that different simulations can be done for one concept. Out of these simulations the energy consumption of the dwelling can be calculated. This way each concept and solutions has got its own energy consumption. Together with other criteria like indoor comfort, execution, generic solution, improvement critical connections, impact on the residents and façade possibilities a decision can be made how to refurbish the building.
Out of the calculations it becomes clear that a lot of energy can be saved by only improving the insulation value of the façade elements. An energy reduction of about 33.5% can be reached by improving the insulation value. Besides the façade refurbishment some investigation is done to additional installation for the building. The second highest energy consumer of the building is the energy that is used to get hot water. If there will be decided to use a solar collector on top of the building an energy reduction of about 44.6% can be reached. This can be a collective solar collector. This way no individual interventions are needed in the dwellings.

Because the building is built with several façade elements, it is not possible to replace each element. Some elements are prefabricated and therefore these elements only can be improved with an extra insulation layer. It is hard to replace those elements because they are anchored to the structure. Other façade elements can be replaced for better insulated (prefabricated) façade elements. This way the critical connections of the building also can be improved. To gain extra floor area for the dwellings there is decided to close of the loggia with a thermal layer, which is very beneficial for the energy reduction of the building. Closing of the loggia improves the critical connections of the building because three low insulated façade elements will be closed off to the outside.

To give the people a certain level of comfort in the dwelling it is beneficial to create extra floor area and give the people an outside space also. That is why there is chosen to give the building an external structure which can act as a balcony and an outside area of the dwelling. This way the people will have more floor area and the amount of overheating hours during summertime also can be reduced.

With these interventions, together with extra insulation on top of the roof, the new energy labels for the building can be label A instead of D, E or F. For the corner dwellings extra research will be necessary because these dwellings do have other characteristics like a cavity wall. For now it is uncertain if the wall is insulated. If there is lack of insulation these walls must have an extra insulation layer to reach energy label A.

In the end there can be concluded that is possible to refurbish post-war building on such a way the building can be energy efficient again. It depends on the owners of the building how this refurbishment can take place and if the investments can be earned back with the extra rent of the dwellings.

The refurbishment concepts that are given in this master thesis are solutions that can be used for post-war residential building. The solutions can be used for gallery flats as well as for porch flats. There are still enough buildings in the Netherlands (and Europe) which needs to be refurbished to be energy efficient again. Energy plays an important role in the life of human beings. The use of energy should therefore be in everybody’s attention. The greenhouse gas emission like CO2 contributes to the climate change so it is important to reduce these gases. This thesis shows it is possible to meet the new appointments of the governments to reduce the energy consumption with 30% in the year 2020.
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Introduction

Background, why this master thesis?
The use of energy in the world is directly related to the human behaviour. More people will use more energy. If the subject is about energy use or energy efficiency most of the time it is also about climate change in the world. Nowadays everybody is aware of energy use and that it is important to know that the energy use has to be reduced.

A lot of energy is used by the building sector, about 37% of the final energy consumption, especially the older buildings without strict building regulations for energy efficiency. New built buildings do have these regulations and are consuming less energy than ageing buildings. In the future the regulations will be even better and this means also the energy efficiency of the new buildings will be better. The energy efficiency of the old buildings is not that good, but still it is a big amount of the total building stock. The existing residential stock exceeds the number of newly built dwellings by far. Approximately 1% new residential buildings are added to the existing building stock.

That is why the focus should be on the existing building and not that much on the new built buildings. These buildings are already energy efficient. Also the question for new buildings cannot catch up with the amount of new built buildings. So making old buildings energy efficient will be good in environmental aspects, but will also be better for the amount of dwellings. This means it is not always better to demolish residential building but to refurbish these buildings in such a way they can act as new buildings again.

The topic of this master thesis is about refurbishment of ageing building stock and how these buildings can be made energy efficient with the new building regulations. The focus of making the building energy efficient will be on the façade related with the energy consumption. The façade is not only important in its appearance, but is also important for the energy use, comfort and indoor climate.

Main objectives
The main objective for this graduation project is to find a strategy to refurbish a housing block in such a way the building will be energy efficient with a comfortable indoor climate. To accomplish this the influences of different refurbishment strategies or solutions will be investigated and how these solutions are related to the energy consumption and the indoor climate of the building. A comparison will be made between the old and new building.

By different strategies there can be thought about different options to refurbish a building. For example what are you going to do with the façade, remove it in total or just remove the old windows for new ones etc. This way you can think about different strategies and how they act and what the profit will be of the modification. Also the materials and façade method will be investigated, what is possible and feasible (prefab, casting etc.)?

The refurbishment will focus on the façade of the building, as it is the part of the building that plays a key role not only in the form and appearance of the building, but also in its performance, in terms of energy use and indoor climate.

The first part of the thesis will look into the state of the art of energetic refurbishment. Namely, data such as energy demand of housing sector, related regulations, innovative materials and good practice examples will be collected and analysed.

The design part will be based on a case study residential building. After examining the current situation of the building fabric and environmental performance, refurbishment solutions to upgrade the façade will be proposed and evaluated.

Sub objectives
- Analysis comfort demands, energy use and building stock
- Analysis of previous refurbishment projects
- Façade techniques that can be used
- Develop different refurbishment strategies
- Finding a case study building
- Test the strategies on a Case Study building
- Additional installations to make the building energy efficient
- Use of new and innovative materials
- Results per strategy (calculation comfort & energy use)
- Optimize chosen strategy
- Drawings final design
- 3d impressions of the design
Final objectives
- Give an overview of existing refurbishment projects with used products, technologies, strategy, the new energy performance and the climate design
- Test different strategies on a case study building
- Calculation energy and comfort indoor climate
- Optimise refurbishment strategy
- Evaluation of the refurbishment on the case study
- Evaluation in terms of energy performance
- Technical drawings of the building
- Conclusion, evaluation/discussion and recommendation

Results
At the end of this master thesis different subjects has to be accomplished. During the first part of the thesis an overview will be given about different refurbishment projects. In these projects there will pointed out parts that will be necessary for the case study building. For the refurbishment project/case study there can be looked at the way they did it, the strategy that is been used, which materials are used, what is the energy-use/performance in the old and new situation, used products and technologies.

Different strategies will be tested on the case study building to see what the influence of these strategies will have on the indoor climate and energy performance. With these strategies the feasibility must be taken into account and what can be done with the residents during the refurbishments.

The chosen strategy will be worked out in detail and will be improved in performance in terms of energy use and indoor comfort, material use and feasibility, how the façade will be constructed.

The indoor comfort is an important part of the thesis, so it is required to have a look at the requirements of the building regulations for housing in the Netherlands and use these regulations to refurbish the case study building.

In the end a comparison will be made between the old and the new performance of the building. This comparison can be done in different kind of way. A simulation program can be used to see how the adjustments can improve the indoor climate and the energy use of the building.

Boundary conditions (what and what not)
The evaluation of the performance of the existing dwellings is based on the energy consumption, the physical condition of façade and the internal conditions. Accordingly, the evaluation of the proposed strategies will take into account the above parameters, combined with the materials that can be used and the architectural effect.

The issue of the embedded energy of the façade, both existing and retrofitted, will not be investigated in the present research. It is a broad subject and requires a different methodology. The present study will focus on the potential savings on energy consumption.

The socio-economical parameters (eg. what is the added value to the dwelling after the refurbishment or will the same occupants stay), even thought well known and understood, will not be fully analysed for the different solutions.

Starting points
The starting point for this master thesis will be a case study building from the post-war period which needs to be refurbished. It will not provide the best practice examples but energetic viable solutions for mass implementation that can be easily and fast constructed.

Preconditions
The preconditions of this thesis will come out of the theoretical background. Out of the comfort demands for housing, requirements will be made. These requirements are the demands for the refurbishment strategies. The requirements for the case study building will tell how the proposed strategies should act and which demands it should meet.

Assumptions
The strategies will be proposed on the assumption that the owners and the occupants are willing to refurbish in order to extend the life-circle of the building and achieve better quality housing and savings on energy consumption.
Research questions
For the master thesis it is necessary to think about some questions that must be answered. If all the questions have got an answer the problem statement of this master thesis can be explained and will give an insight about possible solutions to solve the formulated problem.

Main question
How can a housing block out of the post-war period be refurbished in such a way the building can be transformed in a resource-efficient and environmentally healthy building if the focus is on the façade, the indoor climate and energy consumption?

Sub questions
- How is the housing stock developed in the Netherlands nowadays and in the past?
- Why refurbishment?
- What is the energy consumption of the building sector nowadays?
- What are the comfort/building requirements for housing in the Netherlands?
- What are the shortcomings in comfort of housing block from the post-war period?
- Which existing products and technologies are being used for refurbishment to reduce energy consumption?
- What innovative materials are used or can be used to refurbish a building?
- What kind of refurbishment strategies are been used nowadays and which one can be used for a case study building?
- How can you implement the refurbishment strategies on to a case study building?
- What are the comfort and energy performances of these solutions?
- How do these solutions perform in terms of other refurbishment aspects like execution, building technology, and architecture?
- How can different solutions can be evaluated and discussed to compare them with each other?
- What is the best overall solution?

Research approach & methodology
To start the master thesis on a right way it is necessary to have an idea about how to organize the stuff and what kind of method will be used to bring the master thesis to a good end. There has to be structure which can be followed during the graduation project. This structure can give a clear overview about the methodology of the master thesis

Research parts
The first part of the thesis will be a research of the theoretical background about some topics, shown underneath. After the theoretical background some sub questions can be answered. In the end of the master thesis the main question can be answered. During the first part the analysis will answer some of these questions. Out of the analysis a problem description will be given. The problem description will point out the bottlenecks of the thesis and were the next steps will lead in to and why these steps must be taken.

- Housing stock and energy consumption in the building sector
- Comfort demands housing and building regulations
- Previous refurbishment projects
- Innovative/new materials for refurbishment projects
- Façade technologies for refurbishment
- Different refurbishment strategies
- Strategies on case study building
- Testing strategies
- Optimise chosen strategy
- Evaluation of strategy
- Additional installations for the refurbishment
- Construction/execution of the refurbishment
- Bottlenecks of the housing blocks; technical aspects
- Strategies vs. energy use
**Methodology - Research method**

The methodology is partly explained in the schedule as seen in the figure below. To explain the methodology better per chapter will be explained were the chapter is about and why this chapter is needed to answer some questions.

*Methodology and steps that will be taken during the research*
Introduction
This chapter will explain shortly were the master thesis is about. It is an introduction why this master thesis is made and in short what the problem are for the energy consumption in the ageing building stock in the Netherlands (& Europe). Further will be explained the methodology that will be followed during this master thesis and what kind of questions needs to be answered in the end.

Theoretical background
The theoretical background will be a chapter about data such as the housing stock in the Netherlands nowadays and how this is related to the energy consumption in the building sector. There will be given an explanation why typical buildings are chosen to focus on and why that kind buildings out of a particular period. There will be shown some typical construction methods out of the post-war period and what the technical bottlenecks are in the buildings out of that period.
The other part will consist of the comfort demands and building regulations for residential buildings in the Netherlands. This will be necessary because there has to be a starting point for the requirements for the case study building.

Previous refurbishment projects
This chapter will show different refurbishment projects that are already done in the Netherlands. With these projects insight will be given about some subjects to learn about previous interventions of refurbishment projects. In these analyses the following subjects will pointed out: strategy, façade construction, structure, energy use and comfort (old vs. new), climate design, product and materials, people and costs.
With these subjects insight will be given about how the project is realized and what will be beneficial is in terms of energy efficiency and comfort.

Problem description
Out of the theoretical background there will be made a conclusion and a summary of the problems that come out of the analyses. This will be described in this chapter. This way a short overview is given about some particular problems which can be used in the next step for this master thesis.
There will be pointed out what the next step will be and how these problems can help to lead in to the next step of this master thesis.

Requirements
This chapter will describe what the requirements will be for the case study building. The requirements will be related to the building regulations in the Netherlands, but also the comfort demands for housing. The energy efficiency will be determined; this way a list of requirements can be written down and can be followed during the master thesis to check if the case study building will meet the right requirements.

Refurbishment strategies for case study building
This chapter will describe different strategies to refurbish a building. If a case study building is found the strategies will be explained which can be used for the case study building. There are different possibilities to refurbish a building and every possibility will have some advantages and disadvantages. These advantages and disadvantages will be thought about and in the end some strategies will be explained and why these strategies will be used.
Planning
In the appendix a planning is added which will be followed for this master thesis. But this planning will develop during the master thesis.

Relevance of the master thesis
Socially / Scientific / Innovative
The social relevance of the thesis is people who are involved in a refurbishment project. Not only the contractor and architect are involved in such a project, but also the residents of the building. Another point is the energy reduction that can be accomplished without demolishing a building and give it a new change to stay longer in the area. This way the surrounding area also gets the opportunity to get refresh without changing a lot in the area. Also the comfort of the housing from the post-war period will be improved, this way people will have better quality housing.
Scientifically, the research is related both with building technology and climate design. The proposed strategies will be calculated for the energy performance and indoor climate. Each design will have its own advantages and disadvantages.
The innovative part of this thesis will be the different strategies that will be tested on a case study building. These strategies will give insight about how you can refurbish a building in an efficient way with the energy use and indoor climate related to it. It will provide insight about the technical aspects that comes together with refurbishing an ageing building.

Relationship with other research projects
This master thesis is directly related with the PhD-research done by Thaleia Konstantinou. She is doing a PhD-research on the Technical University in Delft at the faculty of architecture, department building technology. This PhD-research is about ‘Façade refurbishment strategies for the technical improvement and energy-efficiency of multi-residential buildings’.

Who will have benefit out of this master thesis?
The people who will have benefit out of this master thesis can be architects and façade builders.
First the architects because they can see what kind of refurbishment options there are and what kind of techniques can be used to design a ‘new’ building. There are different kinds of strategies which can be used to refurbish a building so the report will show some strategies and what went right or wrong in specific examples. There will be shown why refurbishment is necessary, the benefit for the neighbourhood but also for the residents that are living in the area. Also the improvement of energy use and architecture for the building can be an interesting topic for the architect to think and read about.
For the façade builder the points are more or less the same. Some additional points can be the façade techniques that can be used, how the indoor climate reacts on the façade in compared with the energy use. Also some new ideas can be developed by reading the possibilities to refurbish a residential building and an insight can be given about the materials that can be used.
Theoretical background
Theoretical background

The theoretical background is about the research part of this master thesis. The subjects that will be pointed out in this chapter will be an investigation about the development of the housing stock in the Netherlands, the energy use in the building sector, focusing on the residential buildings and comfort demands for housing will be explained and why this period of building will be used to work out. In the end the technical bottlenecks of the typical buildings will be analysed.

Housing stock in the Netherlands

The current housing stock counts 6.9 million dwellings. More than half (55%) of the houses are sale, over one third (35%) is social rent housing and one tenth is private rent housing. Over three quarters (78%) is built after the Second World War, over two thirds (71%) was built as a single family home and about one third (29%) are stacked (multi-family apartments). After the Second World War a lot of dwellings were destroyed in the Netherlands. In total 87,000 dwellings were destroyed, 43,000 heavily damaged and 300,000 slightly damaged. One out of five dwellings did not remain intact after the war. Reconstruction of new dwellings was thus necessary and huge. Not only the damaged houses are restored in the period after the war, also a lot of new houses were built that period, the post-war period, as shown in figure 1.

The demand for new dwellings was high because of the growth of the population, from 8.8 million in 1940 till 12.9 million peoples in 1970, that means from 2.3 million households in 1947 till 3.6 million households in 1971. The demand for new dwellings was not only necessary in the cities, but also in the rural areas the question for new dwellings was there.

In the period of 1945-1965 the areas has to catch up with the question for new dwellings. In this period new houses were build fast and against a low costs. During this period almost 2 million were added to the existing (pre-war) building stock of 1.5 million dwellings.

The housing stock nowadays increases with almost 1% each year which are about 70,000 dwellings. This is not enough compared to the demand for new dwellings by people that want to live in new houses or are moving out.

To get insight about the current building stock research is done about the residential buildings in the Netherlands. This is done for dwellings build in different periods. This way an overview is given in the current building stock and in which period the dwellings are built.

The graphs on the right show the developments in the Netherlands in the years from 1920 till 2009. Figure 1 show the amount of dwellings which are built and demolished in the Netherlands. During the Second World War there was a negative balance because houses were destroyed during this period. After the 1950’s a lot of new houses are build till the 80’s and 90’s the amount of houses increases fast.

Figure 2 shows the development of households and figure 3 the amount of people per household.

1 Thomsen A.; ‘Levensloop - van woningen’, in: Uittrede rede (7); TU Delft, 2006
2 Tienstra N.S.A.; Wegwijzer wederopbouw - toekomst voor wederopbouw wijken; Molenberg Repro b.v., Overijsel, 2009
The last decades the amount of people and households increases in such away a linear development can be recognized. This is shown in the figures 2 & 3. The figures represents the increasing amount of households and the average amount of people who lives in one dwelling.

The amount of people increases during the time. It will be necessary to build more houses. Also the average amount of persons per dwelling results in the necessity of new development for new dwellings.

Due the fact people want to have bigger spaces to live in it is also necessary to increase the amount of housing. In the Netherlands different types of dwellings are built during the years.

In figure 4 the different types of dwellings are presented. The townhouses represent 32% of the total amount. Second, in terms of percentages, are the multi-storey residential buildings with 27% of the total sector.

Figure 5 shows the amount of gas each house is consuming from different periods. The graph shows houses that are built in the period till 1981 uses a lot more energy than the houses built after 1982. The difference between the houses built before 1981 and after 1982 can be found in the different types of dwellings and the comfort demands of the people.

After 1982 more single family houses were built which consumes a lot of more energy. This is caused by the fact these houses have a bigger volume. Single family have more façades area which are connected to the outside air.

**Energy label Netherlands**

In the Netherlands buildings can be classified in different energy labels. These energy labels represent the energy efficiency of a building. Since January 2008 this label is required for people who want to rent or sell their house.

The label is classified in the grades A till G and with the colours from green till red (fig. 6). Class A, green, means the building is energy efficient and the classification G, red, means a lot of things can be done to make the building energy efficient. The energy label is developed to make it interesting to make energy efficient buildings. This will be a solution to counter the climate change in the world & the Netherlands.

The label is based on the insulation value of the floor, walls, windows and roof of the building. Also the installations for heating, hot water, ventilation and sustainable techniques are taken into account.

The label only says something about the energy efficiency of the building and not about the amount of used energy by the residents because this is user independent.

Another option to rate a dwelling is with an Energy Performance Coefficient (EPC). The EPC is based on the building characteristics, installations and user behaviour.

The difference between the energy label and EPC: the energy label does not involve user behaviour and the EPC calculation method does involve the user behaviour.

Not every building in the Netherlands is labelled, because it is not required for everybody to label their house. It only has to be labelled when people want to sell or rent their house. This way other people can see if the building will be energy efficient or not.

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The Dutch government introduced the energy label to make it one of the cleanest countries in Europe on energy use. They want to bring the energy reduction from 1% each year to 2% each year and bring the use of renewable energy up to 20% in the year 2020. These interventions have the purpose to reduce the greenhouse gasses by 30% in the year 2030 compared with the year 1990. Within the European context the countries will do some efforts to succeed the Kyoto Protocol this way.

The graph (fig. 7) on the right shows dwellings in the Netherlands with the energy labels. The dwellings are divided in different periods. It becomes clear the housing built in the period in between 1951 and 1974, and a bit of the period 1975 and 1990, are not labelled very well. Most of the building are labelled D or lower.

Energy use and consumption

Nowadays everybody is aware of the use of energy and the energy consumption of all kind of products. Not only cars and electrical devices, but also in the building sector the energy consumption plays a big role. New buildings got regulations which they have to deal with to be sure the building will answer the demands of the building codes. These regulations were not that strict for buildings that are already built. This means the ageing building will consume more energy than the new buildings.

This chapter shows how the energy consumption is divided on different scales. First of all the greenhouse gas emission will be discussed. Greenhouse gases are gases in the atmosphere which increases the temperature of the earth. Greenhouse gases contribute to global warming. Figure 8 shows that about 60,4% of the greenhouse gases comes from the energy use (excluding transport) in Europe.

Figure 9 shows the energy consumption per sector. The building sector (residential and service building) consumption in the EU was 37% of the final energy use, bigger than industry (28%) and transport (32%). This means the building sector is largely responsible for climate change so it is necessary to increase the energy performance of the building sector to reduce the energy consumption of the buildings. The energy use of the residential building sector in the EU is 26% of the final energy consumption; the household sector is one of the biggest energy consumers in the building sector, but this differs in every country.
The energy consumption for an average household is shown in figure 10. More than the half of the energy (57%) is used for space heating. The energy use for water heating (25%) is also a big amount of the total energy consumption. Cooking (7%) and electric appliances (11%) are the other categories for the final energy consumption in a dwelling.

The energy consumption for dwellings is changed during the time. The older the dwellings are the higher the energy demand of the dwellings will be.

Table 1 shows the apartment characteristics in the Netherlands. The table shows the average energy demand of apartments and social housing apartments. Before the 1930s the average demand is about 100 kWh/m² each year. The energy demand decreases in time. In the period from the year 1931 till 1980 the average use is about 86 kWh/m² each year for the apartments and social apartments. Nowadays the average energy demand is about 50 kWh/m² for apartments and 62 kWh/m² for social housing apartments.²

Table 1 - Apartment characteristics in the Netherlands ²

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Post-war building / Industrial building (1940-1972)

During the Second World War no new dwellings are built, but a lot of dwellings are destroyed. After the Second World War architects, urbanists and engineers used this period to develop new building methods in the Netherlands. In this period it was necessary to create new residential areas where people can live in a ‘good’ environment. High production of dwellings was priority by the developers.

After the Second World War there was a problem with the households in the Netherlands. After 1945 a lot of people getting married, the amount of people was growing fast. During the war no new dwellings were built for 6 à 7 years and a lot of dwellings were damaged or destroyed.

In 1950 around 50,000 new dwellings were built, this was not enough and the building speed must be increased. Between 1945 and 1972 the target was to build more dwellings each year. In the building law a lot of new regulations were developed to increase the standardisation and industrialization of the building production.

Architects and landlords were convinced to choose for industrial production methods. This way the building speed could be increased. There was a shortage on professional workers on the building site. The building techniques were made that simple also people who were not professional workers could help to build dwellings. This way the shortage of professional workers was solved.

In 1955 around 500,000 post war dwelling were produced. The production speed increased every year. In 1962 the millionth post-war dwelling was build and the total amount in the Netherlands was on that moment 3 million households. The early 70’s reached the building production its summit in the Netherlands with more than 150,000 dwellings each year.

Porch and gallery flats

Characteristic of the post-war housing was the creation of modern residential areas with a high percentage of multi-storey dwellings in three or four storeys. Two types of building were built a lot during the post-war period. One of these are porch flats without a lift. Six to eight houses are connected to a staircase with storage space on the ground floor. The second type are flats accessed by galleries.

The three or four storey high gallery flats could be entered by a staircase without an elevator. This was the first time the Netherlands high-rise building came into the country. Higher buildings with galleries were achieved with a lift.

Stacked houses

These types of dwelling were very similar to the porch flats. The house had a central hall, where the living room and two bedrooms were placed. The toilet, kitchen and bathroom placed close together because the simpler layout of ventilation channels and water drains. Disadvantage in these plans was that the bathroom not directly could be entered from the central hall, but only through the kitchen.

The building method of these stacked houses consists of: non-insulated cavity walls, brick masonry walls, stone walls with a bracket or in-situ concrete for inside cavity and brick masonry on the outside wall. Wooden frames are placed as an independent element in the façade or are part of a storey high prefabricated wooden façade element.

Load-bearing interior walls were made of stone: till 1960 float stone, after that cinder stone, gypsum blocks or aerated concrete blocks were used. Figure 11 & 12 are showing some typical detailing out of this period.

Systematic building method

To increase the building speed of new dwellings a systematic building method was introduced in the 1960s. There were two types of systematic building: stacked building and casting on site. Systematic building increased the building speed and the amount of construction workers decreased on the building site. The new building system ensures the building time was only one third of the old building system.

\[1\] van Boom P., Maessen W.H., Noy D.J., Raadschelder J.G.M.; Jellema B - Woningbouw; ThiemeMeulenhoff, Utrecht/Zutphen, 2005 (15)
**Criticism on the post-war housing**

Around 1970 the critics about the realized post war buildings were coming up. The scale of the residential areas was too large; the individual people could not recognize themselves in the massiveness of the buildings.

There were also critics on technical aspects of the buildings. The rapidly realized houses were noisy, drafty and poorly insulated. Moisture problems arose due thermal bridges.

In the winter this results in low surface temperatures where condensation can occur. In a continuous high relative humidity there can exist mold, this has got as a negative effect on the health of the residents. This phenomenon occurs in balconies, galleries, lintels, beams and roof edges.

During the sixties the minimum requirements for housing increased. The living area increased by approximately 15%. After the discovery of gas in Slochteren in the early sixties, the Netherlands were supplied by a gas network. The dwellings had central heating system with radiators in all living spaces the ventilation in households improved because of the new regulations for residential buildings.²

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² van Boom P., Maessen W.H., Noy D.J., Raadschelder J.G.M.; Jellema B - Woningbouw; ThiemeMeulenhoff, Utrecht/Zutphen, 2005 (15)
Gallery and porch flats

During the post-war period several types of residential building are built in the Netherlands. All these building have a particular way of construction. Two typical residential building types out of that period are the gallery flats and the porch flats. Because of the amount of gallery flats and porch flats built in the Netherlands in the post-war period this is a reason to make a choice between these types of building.

Porch flats represents 83,000 dwellings in the Dutch building stock in the period 1966 – 1975 which is about 1,3% of the total building stock. The gallery flats are representing 127,000 dwellings in the Dutch building stock in the same period (1966-1975) which is about 2% of the total building stock in the Netherlands.\(^1\)

Graph 2 shows the housing type that are built in the Netherlands. Different kind of construction methods are shown in the graph. There can be concluded that the gallery flat is one of the most common housing type out of the post-war period (1965-1966-1967) for non-traditional building methods in the Netherlands.\(^2\)

The graph also shows the building method that is used for the different types of buildings. The most common way of construction is in-situ or with prefabricated elements. In-situ and prefabrication are used for different kind of building types (gallery, porch and single-family).

In total 50,883 buildings out of the period from 1965 till 1967 are analysed and shown in graph 2. The in-situ method has got a total of 23,222 buildings. In total 19,208 (82,7%) gallery flats are built with the in-situ method. The prefabrication method is used for 20,664 residential buildings. In total 12,747 (60,7%) gallery flats are build with the prefabricated elements.\(^2\)

<table>
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<th>montagebouw</th>
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</tr>
</tbody>
</table>

Graph 2 - Shows the building method compared with the type of dwelling in the period 1965 - 1967\(^2\)

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2. Priemus H., Elk van R.S.F.J.; 'Niet-traditionele woningbouwmethoden in Nederland', in: SBR (39); Rotterdam, 1970
Comfort demands housing

In the Netherlands there are building requirements for the building sector. These requirements are made to ensure the building has a certain level of comfort and energy efficiency. These rules for comfort are divided in different subjects like ventilation, energy, acoustics, day light and fire safety. The rules are written down in a book for Dutch building codes.

Below the most important topics for the building regulations will be explained and some demands will be given to get an insight which values the housing sector have to deal with. Only the aspects that are relevant for this research will be explained. The values that are given in the building regulations are minimum values for the housing sector. That means the value that is given can be designed better for a better comfort.¹

Comfort demands for dwellings are divided in several topics as mentioned before. A lot of these topics and their requirements can be found in the building regulations book. One topic that is not described is the comfort demands for indoor temperature. The indoor temperature is user independent, because everybody reacts different on changes in temperature. For this topic is used a concept design for indoor climate comfort of residential building.

Ventilation

The fresh air supply or the ventilation of a building is a very important aspect when the healthiness of the residents is discussed. A healthy building is good for the people who are living in it. The ventilation of a house can be done by natural or mechanical ventilation.

Natural ventilation can be, for example, realized by opening a window in the façade. Opening a window gives the feeling that there is contact with the outside. For windows that can be opened the following requirements must be taken into account:
- A ventilation rate less then 1,5 á 2 (because of draft)
- The fresh air must be heated up till at least 18°C
- The space cannot be deeper than 5 till 6 meter, or twice the height
- Not affected by sound or smell from traffic or industry

With natural ventilation facilities in the façade not every space can be ventilated. For these spaces mechanical ventilation is required. Most of the time bathrooms and kitchens will be mechanical ventilated. To achieve this ventilation grills with ducts are necessary. These ducts are going to a ventilator unit.

The minimum ventilation rate of a living room and bed room must be at least 0,9 dm³/s per m² with a minimum of 7 dm³/s. For a kitchen 21 dm³/s is the minimum, a toilet 7 dm³/s and bathroom 14 dm³/s ventilation of fresh air is required. The air velocity inside a room cannot be bigger as 0,2 m/s otherwise the people will feel draft.

The space that has to be ventilated must have the possibility to adjust the amount of fresh air with a supply that can regulate the ventilation rate. This supply must have the possibility to change it in between 0 - 25% of the total. Position '0’ means that not more than 10% will penetrate the supply. The fresh air that is brought in to the space has to be at least 50% from the fresh air outside.²

Rules for dwellings and residential buildings

The standard: NEN 1087 provides ventilation requirements for ventilation and summer cooling. In summary, this means the following for the requirements:
- Living room : same total ventilation other rooms, minimum of 75 m³ / h, up to 150 m³ / h;
- Other Rooms : 3,6 m³/m²*h, at least 25 m³ / h;
- Studio apartment : 4,7 m³/m²*h, at least 75 m³ / h;
- Kitchen <10 m² : 75 m³ / h;
- >10 m² : 100 m³ / h (mechanical);
- Open kitchen at home : 150 m³ / h (mechanical);
- Open kitchen in dwelling unit : 3,6 m³/m².h, at least 50 m³ / h, up to 100 m³ / h (mechanical);
- Bathing, wash & dry room : 50 m³ / h;
- Storage, basement, attic : 3,6 m³/m².h;
- Common stairwell or hallway : single ventilation;
- Garbage storage : 360 m³ / h;
- Elevator : 3,6 m³ / h per person;

In high-rise (apartments) and houses with windows in one façade is just mechanical exhaustion or mechanical supply and exhaust needed. The NEN standards provide minimum requirements. Usually higher demands are used because of the comfort acceptance in practice.³

¹ http://www.bouwbesluitonline.nl/ (visited 6/12/2010)
² van Overveld M.; Praktijkboek Bouwbesluit 2003; VROM, Den Haag, 2005
³ Dictaat Technische installaties - eisen binnenklimaat;
Acoustics
The comfort demands for acoustics is a topic for refurbishment to take it into account. The acoustics of a building is important because it has got influence on the comfort of a dwelling. If a dwelling is too noisy people will complain about the noise that can be heard in the dwelling. There are two types of sound where you have to deal with: contact noise and air noise.

To reduce the amount of sound on the inside of the building there are some regulations how a façade should act under certain conditions. For the noise that can come from the neighbours there are also some requirements for the minimum sound insulation. Especially in stacked housing this can be an important point because it is possible that dwellings are connected to four other dwellings.

The value of the maximum amount of sound in dB(A) that is accepted in a house depends on the location of the building. The regulations for a building which has to deal with road-, rail-, or industrial noise counts a maximum of 35 dB(A) inside the space is accepted conform the regulations. For a building which has to deal with air plane noise other regulations are used but will not be taken in account for this research.

For the contact noise and air noise there are other regulations for sound insulation. Contact noise means the noise that comes from direct contact to floors and walls which can penetrate through the wall to the other spaces/apartments in a building. Air noise is the sound that people or instruments makes and can be heard in other rooms or apartments.

For the contact noise or air noise there is made a graph with standard values in it. These standards are given in a standard curve. In the building regulations a value is given how the sound insulation should perform compared with the standard curve. An example of this standard curve is showed in figure 13.

In the NEN5077:2006 European standard is made up for contact noise. There is a standard out of the building regulations which says the standard has to be +5 dB better than the standard curve. According the NEN5077:2006 this will be 54 dB(A). This means 54 dB(A) is the sound level in the room where the sound is pressure measured.

For new buildings, and to get extra comfort in the room, better insulation is recommended. The level of sound in the room will be 49 dB(A) so that will be +10 dB better than the standard curve. This means the lower the value, according the NEN5077:2006 the better the sound insulation will be.

For the noise through the air the difference between the standard curve and the building regulations will be 0 dB. This means a difference of 52 dB will be the minimum sound insulation between the transmitting and receiving area according the NEN5077:2006. Compared with the contact noise the difference is; the higher the value, according the NEN5077:2006, the better the sound insulation will be.

Daylight
Daylight plays an important role in the mood of the people. More daylight will give a better feeling compared to less daylight. Enough daylight will help in the way people feel in a space where they stay.

The regulations says the minimum percentage of openings in the façade has to be at least 10% of the (occupied) floor area with a minimum of 0,5 m². Most of the times this will be not the main problem by refurbishment projects because the façade will act for the same function behind it. Only when the floor plans will be changed the regulations will be taken into account.

Fire safety
Fire safety will not be taken in to account because the thesis is about the energy use and indoor comfort. Of course in the end the façade has to meet the fire safety requirements, but for this part extra research is necessary.

Energy efficiency
The shell (floors, façades, roof) of a building plays an important role in the energy consumption of it. How better the insulation value, the lower the energy consumption. To reduce the energy consumption in the Netherlands the Energy Performance Coefficient (EPC) is introduced. The EPC is based on the building characteristics, installations and user behaviour. This way an assessment of the building can be given and this tells how energy efficient the building is. A lower EPC value means a better energy efficiency of the building. Nowadays the EPC is 0,8 but after January 2011 the EPC-value for the housing sector will be 0,6 and in January 2015 the EPC-value has to be 0,4 or less.

In the new standard NEN7120 the new calculation method is explained how the EPC can be determined. It is for now not sure if the standard will be ready on time (January 2011), but there are some new developments in the software for the EPC calculations.

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4 ISOVER: Theorie en praktijk over contactgeluidisolatie met verend opgelegde dekvloeren, 2007 (14-22)
Insulation values
For the façades, roof and floor demands are made up were the building has to deal with. For the façade of a dwelling the
minimum requirement is $R_c = 2.5 \text{ m}^2 \cdot \text{K}/\text{W}$. For doors and windows a U-value of $4.2 \text{ W/m}^2 \cdot \text{K}$ will be
enough according the building regulations. These values are the minimum requirements a building has to deal with. These values are the first step to make an energy
efficient building, but to make it even better energy efficient better values are desirable. This means the higher the $R_c$-value
of the closed parts of the façade will be and the lower the U-value of the glass will be, the better the energy efficiency of the
building will be in the end.

Thermal comfort
During summertime the building is the Netherlands will be heated up by the sun. Most of the times the indoor temperature
can be that high extra cooling can be necessary. During wintertime the temperatures can be that low extra heating will be
needed to get a sufficient indoor temperature. Extra heating can be provided by mechanical systems.
A system to heat up a space can exist of an air or a water system. Most of the times a water system is used in residential build-
ing because of the smaller installations and pipes that can be used. Examples of water systems are: radiators, convectors
and floor heating. Good thermal insulation and accumulative capacity of the building can reduce the heating requirements.
As mentioned before, the temperature can be that high in a building extra cooling will be necessary. Especially in office
buildings and hospitals the temperature cannot be too high. In these buildings mechanical cooling is necessary.
Most of the time (old) residential buildings do not have mechanical cooling because the investments are too high. This way
only natural cooling is possible by opening a window. Efficient sun shading, thermal insulation and accumulative capacity of
the building can reduce the need for cooling load.

There are no specific requirements for the inside temperature of residential building. Thermal comfort is determined by
four different variables (air temperature, radiation temperature, humidity and air speed). These four variables determine
the PMV (Predicted Mean Vote) of professor P. Ole Fanger according NEN-ISO 7730. The PMV is a method to determine the
indoor comfort of a building. The ideal indoor comfort is achieved when the PMV = 0. The satisfaction of the people then
is the highest. Only 5% of the people will have complains about the indoor comfort. This 5% is expressed in PPD (Predicted
percentage of dissatisfied).
In general, the indoor thermal comfort is sufficient when $-0.5 < \text{PMV} < 0.5$ is, the maximum number of dissatisfied people
will then have a PPD of 10%. The PMV is used on a scale from $-3$ (extreme cold, PPD: 99.9%) to $+3$ (extreme hot, PPD: 99.9%).
With the previous theory in mind a program of requirements for inside temperatures can be made up.
In this program of requirements operative temperatures are given with a range between $-0.5 < \text{PMV} < +0.5$ and the absolute
maximum and minimum temperatures are determined. The operative temperatures may not exceed the temperatures more
than 5% of the time during occupation. For the minimum and maximum temperatures counts 1% of the time the tempera-
tures may not be exceeded. These operative temperatures often are translated to design temperatures. The design tempera-
tures are related to extreme outside conditions such as $-7^\circ\text{C}$ (winter) and $28^\circ\text{C}$ (summer).
The values for the temperatures are shown in table 2.\(^5\)

Previous refurbishment projects

In the Netherlands already enough (post-war) housing blocks are refurbished. To develop a refurbishment concept for the case study building it is wise to get insight about refurbishment projects which already are finished. After some research several projects are found and analysed on different subjects. These subjects have been chosen to get a clear view about the projects and to compare the different projects with each other. The subjects were the projects has been analysed on are described underneath. After the explanation of the different subjects the chosen projects will be discussed. In the end there will be looked if there is a systematic approach between the different kind of projects.

**Strategy**
The first part of the analysis will explain the main strategy of the refurbishment project. This means the main idea of refurbishment will be discussed. The interventions that is done to the building will be analysed. Out of these analysis a used refurbishment strategy will be the output. The strategy will be discussed and will provide insight of the project and how several problems are solved.

**Façade construction**
The façade construction of the project will be discussed. The façade is, in most of the times, refurbished. This done different in each project. The old and new situation of the façade will be discussed and what is changed compared to the old situation. This also contains how the new façade is attached to the building and what the new requirements are for the façade.

**Structure**
The structure of the building will be analysed. Not only the amount of floors will be mentioned, but also the types of floors (if available) will be analysed. The other parts of structure will also be analysed and which type of structure in the building is used. This way insight can be given about the used building method and what is changed in the new situation. It is, for example, possible that there is added some extra floors on top of the building to create other spaces in the building. This way developer can gain more money out of the refurbished building.

**Energy use and comfort (old vs. new)**
After the refurbishment of the building the efficiency in terms of energy consumption and the comfort of the indoor climate will be improved. The old buildings are labelled with a value for the energy and after the refurbishment there will be another energy label for the building. There will be discussed how these improvements are done in the specific project.

**Climate design**
Climate installations can give the building better energy efficiency because they can provide energy on an efficient way. It is possible that some installations are added to the building. Per project it could be nice to see if this is done in such a way the installations helps to increase the energy efficiency and what kind of installations are used in the project. The overall climate design will be taken in account to see how this is solved in the different projects.

**Products & Materials**
In every refurbishment project a lot of materials are used to improve the building in several ways. This could be in appearance of the building but also in the performance of the building. Products and materials can analysed and this way an overview of different possible materials and products can be given.

**People**
In every project it is interesting to look after the people who are involved in the project and who has got benefit out of the refurbishment of the housing block. There are several parties who have interests in the refurbishment. It could be interesting for a municipality, a project developer and an architect but also for the residents of the building. Who gains benefit out of the refurbishment of the old building and how to deal with the different parties. For instance how do you deal with the residents of the building and what do you do with them in terms of leaving the building during the execution or let them stay inside their own houses?

**Costs**
The costs will be discussed. There will be mentioned what the total cost are of the refurbishment. The costs per dwelling and per m² is interesting to investigate. This way a comparison between the different projects can be made. Also the investment in relation with the energy reduction will be investigated.
Torenflat, Zeist (1973)

In 1973 a housing block with 484 apartments is build in the city of Zeist. The building stands on the ‘Laan van Vollenhove’ and has got 20 stories. The routing through the old building is a corridor on the inside. On the outside of the façade balcony floors are going around the whole building and can be used as a fire escape route.

When the building was ready for use in 1974 there were immediately some technical problems with the building. These problems came out of some critical details of the structure. The balconies of the building were connected to the structure without any insulation in between it, so this was a thermal bridge from the outside of the building to the inside the structure. Other points of attention were the wooden frames with single glazing. This caused moisture and mold in the carpets and curtains.

In the dark corridors of the building people left their garbage there, put out their cigarettes and dogs were pooping. The mutation rate was relatively high: thirty percent of the apartments got a new tenant every year.

The new owner of the building ‘Woningcorporatie SGBB’ decided to refurbish the old building and to get rid of all the problems. They realised a new function next to the building, a care institution. The total costs of the buying and renovation of the building in the end was about 90 million Euros.

The project has finished in the year 2010.

(All the Information comes from ‘de Bouwwereld’ and an interview with Paul de Roos, Architect)

Strategy

The idea of the architect, Frowijn de Roos architects, was to get rid of the stacked expression of the building. The new façade is therefore a shift of surfaces in vertical and horizontal direction, with a shade of nineteen colours, from dark red to white enamelled glass. The colour red refers to innovation. The dark gray area changes this picture (figure 1).

The first idea of the architect was to do more interventions in the building like move all the people out and change the floor plans of the apartments. This way different kind of apartments can be realized and different kind of people can be attracted.

The architect saw that this was not feasible because more than 1,000 people are living inside the building and it was very hard to move out all of these people and find another place to live. In early stage was decided to refurbish the building while it will be still occupied.

After analysing the building the architect realised it was too expensive to replace the old not-insulated balconies for new insulated elements. To lose the thermal bridges in the façades and improve the water barrier the existing structure has to be packed in. There was decided to put a new insulated and watertight ‘jacket’ around the building. Thereby the dwellings extended towards the new façade and the balconies changed into a loggias.

By this intervention the fire escapes are gone, but this is solved by a central management system of smoke detectors in combination with fire separations in the corridors.

Besides a new façade for the building the inside of the building is also renewed. The corridors are renewed and painted in light colours. This was the first part of the building that was changed. To do this as the first part of the refurbishment the contractor was able to convince the residents. It was very hard to convince the people that they really wanted to refurbish the building and this way the residents could be convinced.

Façade construction

The façade is hanged in front of the old structure. The old balconies stayed, but do not function as balconies anymore, but as loggias for the apartments. The new façade is the new thermal layer between inside and outside. So the climate changes on the inside of the building.

The new façade elements are prefabricated. In total 15,000m$^2$ of façade is renewed. Per standard dwelling about 2 elements of 200 kilogram are used. The elements are made of aluminium profiles, styles and rules, in between insulated glass panels or cassettes are placed. The cassettes have a structure with a glass, polyurethane foam insulation and an aluminium plate.

The façade constructor used two mobile cranes on top of the roof to install the elements. During the renovation the workmen were tight on the building like mountaineering.
The façade elements are mounted on the existing holes in the concrete of the balconies. The holes were already there in the concrete because of the old 1,2 metre high fence. In these holes L-profiles are attached by bolted connections through the floors. The façade elements can be attached on the L-profiles (fig.2). During one day, six elements placed on the building. Rubber strips in between the elements take care of a three times water tightness. Per day about 200m² has been placed. The connection between the elements is done by big steel bolts on parapet level.  

The elements are specially designed and developed for this project, the elements are 2,78 meter high and are provided with adjustable facilities in height and longitudinal direction. To prevent rotation of the insulated elements they are connected by three points. Maintenance of the façade elements can be done with the installation that is placed on the roof of the building.

**Structure**
The building is 60 metres high 27 metres width and 105 metres long. The structure of the building is made out of in-situ concrete. During the execution of the building the safety factor was that good, the extra weight of the new façade elements did not influence the foundations and the shell. There were no extra interventions needed. The foundation of the building is not made out of piles, but out of a clump of concrete with a thickness of 3 metres and which sticks 3 metres out of the building.

**Energy use and comfort (old vs. new)**
The energy use and comfort are improved by this project because the new façade is hanged in front of the old structure, but also the extra insulation on top of the building. This way problems, like thermal bridges and bad insulated façade are solved. 

The energy label of the old building was rated, for the old building, on label F. After the refurbishment the building was rated on label C. Only the façade takes care of this improvement of the energy efficiency of the building. The architect had the idea to use PV-cells on the façade elements, but because of the costs this was saved on the bill. This intervention means that the CO₂ emission of the building will be reduced by 290 tonnes a year. After the first energy bills an average of about €350,- per dwelling is saved compared to the old bills.

**Climate design**
For this project no extra installations are used to reduce the energy consumption of the building. The lower part of the old façade, 70 centimetres, is not removed. This way the old radiators from the collective heating system could stay intact. The heating of the building is done by block heating, on the top of the building two old boilers are replaced for two High Efficiency Boilers. The tricky part of this building was the ventilation for the apartments. Because the houses were orientated one direction it was necessary to ventilate through the middle corridor inside the building. The living rooms can be ventilated directly through the new façade cause of the ventilation supplies in the façade element. The adjacent bedrooms can be ventilated indirectly, even when the windows are closed. Because of the extension of some walls from the old walls to the new façade it was necessary to give them a fire resistance cladding.
Products & Materials
Each façade element for the living room or bedroom is made of five aluminium posts. Steel reinforcement is used to ensure the required fire resistance. In 15,000m² façade a total of 200 tonnes of aluminium is used and 100 km of rubber strips. In the façades different types of windows are placed, this is done because of the use of the loggia’s. People can open the windows and this way they can sit ‘outside’ their apartment.
The maintenance of the building is reduced to a minimum. This is done by choosing for an aluminium façade (partly recycled) and glass. The new skin makes loggia’s out of the balconies so the life in the outdoor space is extended during the year.

People
In 2005 the housing cooperation ‘Woningcorporatie SGBB’ made a feasibility study about the residents of the building. Approximately 1000 people of 40 nationalities lives in the flat. During the renovation the building stayed occupied. This discussion was made almost in the beginning because it was not realistic to move all the people out of the building during the renovation. The residents only had to stay one day at home to let the construction people work on the connection of the old wooden frames on to the new façades, including applying the window sill.
The residents were not convinced about the refurbishment plans of the contractors because in the past there were made loose promises to the people. The contractors said they would refurbish the building, but is was taking very long before they started. People thought: “Seeing is believing”. The residents seem pleased with the refurbishment: the mutation rate fell from thirty to less than fourteen percent now.

Costs
The value of the old building, before it was refurbished, was still € 20,000,000,-. This is one of the reasons the building is refurbished and not demolished. Another point was the local interests. If you demolish 484 apartments you will never be able to gain profit out of the new build houses for the reason this amount of apartments will never be put back on the same area again.
The municipality will also get less money from the government because the amount of houses and people in the municipality will decrease. If there was decided to demolish the old building not only €20,000,000,- will be lost, but also the extract costs of the houses (about € 20,000,- each) will be gone.
In the beginning the decision was made to let the people stay in their apartment because of the cost that it will bring to move all the people out. That is way is chosen to use the old holes in the concrete slabs and a prefabricated aluminium façade. This way less drilling was necessary and the are not disturbed.
The total costs of the refurbishment was about €42,000,000,-.
The total costs of the façade was about €8,000,000,-.
The costs per dwelling is about €85,000,-

Principal: SGBB project, Zeist
Design: Frowijn de Roos architecten, Zeist
General Contractor: PHB - Hardonk Paul Construction, Zeist
Façade Builder: Aluminum Kremers, Tilburg
Profiles: Schüco aluminum and Kremers
Leeuw van Vlaanderen, Amsterdam (1958)

The residential building ‘De Leeuw van Vlaanderen’ in Amsterdam adjacent to the highway A10-west is built in 1958. The building is designed by architect J.P. Kloos. In 2005 the building is totally refurbished into a ‘new’ building. Before the refurbishment the building the masonry façade was polluted and the balconies on the highway side were hardly used. There were 72 social (rent)-dwellings in the building before it was refurbished.

The building stands in between the highway A10, less than 4 metres next to it, and a neighbourhood on the other side. The building served as a sound barrier between the highway and the neighbourhood.

Originally the building stands on a wide avenue. But since the Coentunnel (1966) opened in Amsterdam-West, the amount of cars passing the building was increasing every day. Nowadays 180,000 cars passing the building every day. The busy road not only ensures a division of the Bos en Lommer district, but also problems for the residents such as traffic noise and smell. Refurbishment was necessary to make the building liveable again.¹

Strategy

The Amsterdam housing block, ‘De Leeuw van Vlaanderen’, is that close to the A10, demolishing this building and build a new one on this location was not allowed because of noise and particulate pollution. Therefore there is chosen for a major refurbishment of the building, complete with the placement of an elevator, two additional floors and new galleries. Another reason to not demolish the building was that the underlying buildings will need extra sound insulation because the building functions as a sound barrier in between them.

Architect, Dirk van Gestel (Heren5 Architecten) had the idea to keep the existing entrances to the building on the ‘Leeuw van Vlaanderenstraat’ and to place the routing of the building on the highway side. This way the balconies of the apartments can be placed on the side of the neighbourhood.

The refurbishment of the building was done by stripping the whole building and placing a whole new façade on to it. On the highway side of the building a new façade was placed against the concrete structure. Two meter in front of the building a glass façade was placed. This way a sound barrier, wind barrier and watertight façade is created in between the façades of the apartments and the highway. The space in between the façades is used for a gallery. This gallery is used for the entrances of the houses.

On the other side of the building is chosen for a façade with an expression of stone. The idea was to give an example to the rest of the area near the building to make the surrounding area also better again.

On the top of the building two extra floors are added. To make all the apartments accessible, elevators are added to the building. The storage spaces on the ground floor are replaced for apartments, so this way the activity on street level is increased and gives more social control.

Façade construction

For the building is chosen to make different interventions for the façade. It depends on the orientation of the façade which strategy is been used. On the side of the highway is chosen to make a double skin façade with a gallery in between. On the side of the neighbourhood is the old façade has been removed and new façade elements are placed in the old concrete structure.

The gallery on the highway side takes care of the sound reduction on the inner façade, but also acts like a wind and water barrier. The inner façade is placed directly on the concrete structure and has got a Rc-value of 2,5 m²*K/W. The curtain wall is made of laminated glass 10/10/2 mm, 6000 m² in total, from floor to ceiling with only the horizontal gallery edges on the outside are visible.

¹ Barendz M.A., Vervest B.C.H.; ‘Bouwen met staal - Renovatie woongebouw Leeuw van Vlaanderen Amsterdam’; in: Staalframebouw, ()
In between the inner façade and the curtain wall there is space for a gallery where people can enter their dwelling. In between the façades there is also space for voids so people will have more daylight inside the gallery and their houses. The façade on the side of the neighbourhood is made of stone panels. The old brick masonry is removed in total. Total demolishing of the façade will cost more money than improve the existing façade, but is also gives a lot more opportunities to do something with the new façade. The existing structure was there so it can be filled in with a total new façade. A new traditional façade out of brick or stone would be too heavy for the structure so is chosen for a system of steel frame elements of C and U-rails and aluminium sheet piling. The system of façade elements is a wind and water tight construction, provide adequate insulation (Rc = 2,5 m² °K/W) and takes care of the thermal bridges. The relatively rigid elements, thin stone slabs used as a finishing layer. The profiling of the steel plates makes sure there is a stable background and through the channels ventilation and drainage is possible. Per plate six dots’ glue were sufficient enough to attach the 20 mm thick stone plate on the profiled element. By applying more glue per plate is a surplus is created to improve the safety. Most windows in the façade do have large reveals with an aluminium framework.

**Structure**

The structure of the building is made of concrete and the building is 180 metres long and about 13 metres wide. On top of the building are placed two extra floors. The old foundation and structure of the building, which consists of 4 layers of floors and concrete piles, was strong enough to catch up the extra vertical loads from the extra floors on top of the building. For the extra wind load that comes out of the extra height of the building 150 piles extra were needed in the foundation.

The existing floor to floor height was about 2.90 metres so it was no problem to increase the acoustical demands for the apartments.

**Energy use and comfort (old vs. new)**

Because of the position of the building, next to a highway, a lot of sound is coming on to the façade. To reduce the sound on the façades of the apartments an extra layer is placed in front of the building. The sound from the highway is about 77 dB(A), the demands for housing have a maximum of 35 dB(A) for the inside. By placing a glass façade the sound pressure was reduced. It is reduced that much it was necessary to increase the sound insulation of the separating walls and floors of the apartments, otherwise the neighbours will hear each other.

The building is refurbished according the minimum requirements of the building code. The energy efficiency of the building has not been taken into account and there are no calculations about the energy reduction.

**Climate design**

For the side of the highway a façade is chosen that can reduce the sound on the inner façade of the double skin, but also to reduce the polluted air from the highway. Normally the gallery will also provide the exhausting of smoke and heat during a fire, but placing grills in the façade will decrease the reduction of sound and polluted air on the inner façade. Because of the dimensions of the area where the smoke has to be taken out it was necessary to use ‘push’ ventilation in the gallery. This means if smoke is detected a ventilation system will be activated and will take care of the exhaustion of the smoke in such a way escaping the building will be still safe. This system normally is used in traffic tunnels and parking lots. The normal ventilation of the gallery is done by taking air from the neighbourhood side and brings it into the gallery.
**Products & Materials**

The materials that are used for this building are not the same for every façade. The façade that is orientated to the highway consists of laminated glass 10/10/2 mm from floor to ceiling with only the horizontal gallery edges which are visible on the outside. The vertical connections of rubber profiles are there to prevent the glass falling on the highway in case of emergencies. Also deeper grooves are used to create better connections. The floor in the gallery is made out of wooden beams, bankirai. The inner façade is made of strips of stone and a profiling of the different windows.

Because of the building speed there is chosen for a steel frame for the extra floors on top. This way a stiff structure can be realized and less stability facilities are required. The extra floors on top of the building are raised 0,60 metre because the old roof was not strong enough to function as floor. The space was also necessary because of the pipes and ducts that running through the space in between.

The neighbourhood side has got a stone look. A traditional façade constructed of brick or stone would be too heavy and too expensive. The solution is a system of steel frame elements of C and U-rails and aluminium sheet piling covered with stone plates of 20 mm thickness.

The relatively rigid elements, thin stone slabs are used as a finishing layer. Chosen is for ‘Anruchter’ dolomite in a green colour with three different finishes. The profiling of the steel plates makes sure there is a stable background and through the channels ventilation and drainage is possible.

**People**

During the refurbishment of the building the residents had to move out of the building. The whole façade was stripped of the building and only the concrete structure was standing. The layout of the floor plans is changed in such a way that is was not possible for the residents to stay in their apartment during the refurbishment.

People were not involved on the design of the floor plans, but they had the possibility to chose out of one of the developed floor plans by the cooperation. This was only possible for the people who returned to the housing block and not for new residents.

**Costs**

The reason to add two more floors on top of the building was because of the urban situation, it was possible in its surroundings. It also gives the possibility to make bigger and more apartments. This way the exploitation of the building can be realised.

The total costs for the project was about 14,5 million Euros (some of these costs were paid back by grants). In front 10,5 million Euros was calculated for the total project but because of some unconventional solutions, like the sound reducing glass façade and the stone façade the costs in the end were a bit higher. In total the building counts 96 apartments: 72 renewed and 24 extra apartments because of the extra floors on top of the building.

During the process of the refurbishment a lot of companies worked together on this project to bring it to a good end. In an early stage contractors discussed and talked about some interventions how this project can be realised. The costs in the end were about €2,000,000,- lower than the 14,5 million Euros in the beginning. The costs per apartment was about €130,000,-
De Rembrandtflat, Zwolle (1968)
In Zwolle three flats from the 1968s in the district Holtenbroek are standing next to the highway A28. These three flats will be refurbished. Two out of three flats already finished. One of these two is ‘The Rembrandt’. The flat consists of eleven floors and is a remarkable building in the neighbourhood (fig. 1).

The flat contains 103 apartments for one or two persons. The idea for the building was to give it a new and fresh appearance for the people that are passing by. Next to that improving the energy efficiency was an important aspect for the building.

The social environment of the buildings was not good anymore so a total refurbishment of the building including its surroundings was necessary.

Strategy
The flat needed some major maintenance. This was for the housing company a moment to also do something about the energy consumption of the building. This is necessary, otherwise it risks vacancy and impoverishment. People do not want about the energy consumption of the building. This is necessary, otherwise it risks vacancy and impoverishment. Energy-saving refurbishments can reverse this process and will take care people will stay or want to move into a particular residential building.

The WOB (Wet Openbaarheid van Bestuur) understands the fact not the rent of a house is important, but the housing costs of the dwelling. Especially in the relative cheap dwellings of the housing stock the costs of the energy is a big part of the total charges.

EE-vision is a company which advices how energy reduction can be accomplished. They made a feasibility study on the building how the building can be refurbished in such a way the building get an energy label A. This will lead to significant reduction in energy costs and also to a large reduction (> 50%) of CO2 emissions. For WOB this is a great contribution to the national and local agreement reached in 2020 to achieve a 20% reduction in CO2 emissions.

The goals and targets for the cooperation was to take a look at the energy need of the residents. The intention was to look at conventional and innovative energy supplies for hot water, heating and electricity. The main goals of the renovation are:

- Reduce use of fossil fuels and reducing CO2 emissions
- Lower housing costs
- Enhance quality living environment
- Use knowledge for refurbishment of the Wanningflat, started in the autumn of 2009.

In this building, the Rebrandtflat, more sustainability interventions will be added by installing a new ventilation system. In the dwellings the kitchen, bathroom, toilet, glazing and the entire piping including radiators are renewed.¹

Façade construction
The interventions that are done for the façades helped to increase the energy efficiency of the building. The façade gets a new insulation layer in front of the old structure and the old windows are replaced for HR++ glazing, the old window frames will stay and new insulation will be placed in the frames.

The Rc-value of the roof is 4,1 m²*K/W. The Rc-value of the floors and façades are 3,5 m²*K/W.

The U-value of the glass is 1,2(W/m².K).

Energy use and comfort (old vs. new)
The refurbished building has decreased the energy use of the building in such a way the CO2 emission of the building is reduced with at least 23%. The total CO2 reduction will be about 24 tonnes each year.

The energy label of the building was E/F but is increased to label A. The housing costs are also lower because of the improvement of the energy efficiency of the building.

At least 103 houses will save 30% on their energy bill. This is about €50,- per month.¹ There are done some intervention to get the people aware of their behaviour. The individual measure device for hot water consumption and space heating, but also the measurement device in the hall of the building which shows the temperature of the water of the solar collectors.

¹ http://www.naarenergieutraal.nl/nieuws/42/Zwolse-flat-is-energetische-verspringer.html (visited on 12/12/2010)
Climate design
The chosen energy concept is a combination of thermal solar collectors, a heat recovery system, heat pumps and a central High Performance boiler for space heating and to supply hot water. The thermal solar collectors will be placed on the top of the building and will be in total 240m² (fig. 2) with a storage tank of 8000 litre. In the basement 2 x 5000 litre tanks are placed. The heated water by the sun will be collected in the storage tanks. A high efficiency boiler will heat up the water and in a separate tank a heat exchanger will heat up the water further so it can be used to heat up the apartments.

The complete roof will be renewed and will be insulated with a new insulation layer. The end walls of the building will have a new insulation layer and a new finishing. The apartments will have collective heating in the building with an individual device to measure the use of space heating and hot water. The first idea was to give each apartment an individual heating device, but because of the high costs related to this intervention is chosen for a central heating system.

The ventilation of the building is done by natural intake. The dwellings will be ventilated continuously by taking out the air mechanically. The temperature of the exhausted air is about 21°C. A heat recovery system the heat from the air and leads the released heat to the central heating system. It only has to warm it to the desired temperature. The hot water is not only used for hot water consumption, but also for heating up the apartments.²

Product & materials
The products that are used to make the building energy efficient are thermal solar collectors (240m²), heat pumps and a heat exchanger, combined with a central High Efficiency combination boiler. The boilers are replaced from 4 x 400 KW to 2 x HR 462 KW. A new insulation layer is added and replaced. Also HR++ glazing is replaced for the old glazing.

People
An important part of the refurbishment was to involve the local people in the project. Informing the residents about the ideas and solutions to refurbish the building was an important topic. The energy saving interventions in the flat is working in a different way than traditional facilities, so this must be explained properly to the people. If the people are not informed properly they do not know how they can have benefit out of the energy saving interventions.

The people in the building had the choice to move out temporary, but about 90% of the residents decided to stay at home during the refurbishment. For the people who are disturbed by the drilling and demolishing a day-care is placed by the entrance of the building. The refurbishment will be about two weeks per apartment.

Costs
The total costs of the project is about 10 million Euros. About 1,9 million will go to energetic interventions as mentioned before. A grant of 0,5 million Euro will cover this costs. The total costs per apartment will be about €100,000,-.³

Principal: Woningstichting Openbaar Belang
Design: Studio Groen + Schild, Deventer
General Contractor: Salverda, ’t Harde
Façade/Climate installer: Unica, Zwolle

² http://www.unica.nl/referentie7364/rembrandtflat.htm (visited 10/12/2010)
The Brandaris and the Noordwachter, Zaandam (1969)
The intersection of the highway A7 and A8 in Zaandam is marked by large apartment buildings since 1969. The buildings are standing next to the highway which produces a lot of sound. The proposed construction for a flyover by the highway asked for the construction of a sound barrier along the road, but instead placing a wall, the (sound) insulation of the building is improved. 'Rijkswaterstaat' was willing to pay for the insulation of the façades.
The amount of dwellings inside the Noordwachter is 168 and the Brandaris has got 368 apartments. The building company J.P. van Eesteren NV introduced in 1964 the ERA-building method. Industrialization was the starting point of this construction method.
The building is made of a structural work and a finishing work of concrete. The foundation and supporting structure are made of in-situ concrete (casted). The manufacturing process is done mechanical with tunnel moulds which have the size of one house. This was the first time a span of 7,2 meters was achieved. By the application of this building method floor plans have got a flexible layout. Supporting walls inside the house were not necessary anymore. In total, approximately 10,000 ERA flats are built in the Netherlands this way. Particularly in the west of the Netherlands.1, 2

The 'Brandaris' is build like the ERA-house method. It has got 14 floors with 384 apartments in total. The building has got collective heating plus gas heated boilers. Individual boilers provide hot water for each apartment. The performance of the heater is not good anymore and influences the indoor air quality and comfort. Mechanical ventilation and heating is difficult to control and lead to an unnecessarily high energy consumption. The 'Noordwachter' is refurbished and has got a metamorphosis. The building is completely packed into a new façade which closes the balconies of the highway and provide sound insulation. The residents are free to open the glass front of the new façade. In addition, the end wall is insulated with an extra cladding. The interior of the housing is also renewed. Both buildings are refurbished during the year 1998.

Strategy
In the beginning there was thought about a new sound barrier between the new flyover and the buildings that are standing next to the highway. 'Rijkswaterstaat' was prepared to invest in new insulations for the buildings instead of a new sound barrier in between the flyover and the buildings. Next to the common approach to overdue maintenance and improvement of interior a feasibility study is done on the use of solar energy in refurbishment. There is chosen for a plan to improve the indoor environment, energy savings of the building and the use of renewable energy as an important component. The Housing Cooperation 'Patri- monium' has given the building a new injection to stand for at least 20 years longer. Both buildings used a different strategy. The 'Brandaris' has got thermal solar collectors on the roof with an area of 760m² and the first 3 floors have got a new façade, a glass façade in front of the balconies to provide sound insulation for the high way next to it. The solar collectors are placed in such a way it looks like they are floating on top of the roof.
The 'Noordwachter' has a total new façade in front of the balconies and is also made of glass. The original balconies are still there, but are now behind the glass. The glass façade will reduce the noise on the apartments and increase the indoor climate and comfort. The entrances of the buildings are improved by a slender steel construction with a lot of glass end clear lettering. Also the dark staircases are renewed and gain more light now.

Façade construction
The façades on the highway side of the building are made out of a glass. The façade hangs in front of the old structure. Especially the Noordwachter has got a total façade of glass. The Brandaris has the same elements, but only the first three floors have got the glass façade in front of the old structure. The façade is designed by Hans van Heeswijk architect BNA from Amsterdam. Together with Schüco and Hermeta (façade builder) a façade system is designed for this building (fig 4 & 9).
The façade is build out of prefabricated elements with the dimensions of 7,8 x 2,6m. Each element has got 6 glass panels of 1,3m x 2,6m. The panes in the middle can be opened or closed by the residents.

1 Donze g., Vollebregt R., Boonstra C.; 'Bouwfysica - Renovatie Brandaris' , in: Vol. 9 NO.1 (11); Printhouse Drukkers & Uitgevers, Voorschoten, 1998
2 Tienstra N.S.A.; Wegwijzer wederopbouw - toekomst voor wederopbouw wijken; Molenberg Repro b.v., Overijssel, 2009
In the profiles of the elements ventilation gaps are integrated to provide overheating during the summer when the panels are all closed. The façade is sloped 70° to increase the sound reduction on the inner balconies, but it also decreases reflection from the sun and the water drainage is better regulated this way. The façade is mounted from the outside because the dimensions of the elements were too big to do it from the inside. Also the existing balcony railings are still there. The prefabricated elements are placed with the help of a lifting bracket which placed the elements in one handling on the façade hanger and also in the right slope. To fix the elements in a slope, balcony reinforcement is mounted on the edge of the balconies. The balcony reinforcement is provided with a steel bracket on every floor. On the bottom the elements hang in the bracket and on the top the elements are supported by the bracket as seen in figure 4 & 5.

Structure
Both buildings are built in the same period with the same building techniques. The structure is made of in-situ concrete and for the refurbishment of the building nothing is done with the structure. On one side there is a gallery for the routing through the building to enter the dwellings. On the other side of the building there are balconies for every apartment. Both buildings have got 14 floors.

Energy use and comfort (old vs. new)
For the energy use and comfort of the building different strategies are made and simulated in a computer. One part of the refurbishment is the placement of 760m2 solar collectors on top of the roof. The collectors will provide hot water and space heating for the apartments. In the end the environmental benefits will be a gas reduction of 200m3/year per apartment, with a total of about 72800m3/year for the whole building. The CO2 emission will be reduced by 129 tonnes/year. The comfort of the building will be increased by the use of a glass façade in front of the balconies. The balconies can be used 100 days more than the old situation, the thermal bridges of the structure will be gone. The energy use will be less because of the use of solar energy. Because of the new façade the transmission losses will be lesser. The façade gives the possibility to pre-heat the air for ventilation into the dwellings. The façade reduces the sound that comes from the highway. Because of the glass façade in front of the structure the average temperature in the veranda will be 4° C higher than in the standard situation. This way air can be taken out of the veranda and can be used for fresh air ventilation. The demand for heating will decrease for about one third compared with standard refurbishment. This will result in a reduction of about 1400 kWh of the heat demand for a middle dwelling. Also the heating season will be decreased. The energy reduction of the Brandaris is estimated on 67 kWh/m2 each year. This is about 46% of the energy use before the refurbishment.

Climate design
To reduce the energy consumption there is placed a glass façade in front of the old structure. The idea is to create a veranda which becomes a sheltered outdoor area. There is chosen for proper basis ventilation for the veranda. This is done with single glass an aluminium profiles without thermal interruptions. Opening the façade sufficient will feel as outside and will ventilate the veranda and the apartments enough. If the façade is closed the veranda will have its own basic ventilation and will have no negative influence on the ventilation of the apartments. For the permanent opening in the glass façade is assumed 500 cm2 (air velocity 1 m/s). The ventilation strategy of this project is based on pre-heating the air in the veranda and use this for the ventilation of the apartments. Not only the ventilation of the veranda is important, but also the apartments must be

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3 Fuchs H.; ‘Geluidweren met glas’, in: de Bouwwereld nr. 2, 1999 (36 -38)
4 Novem b.v.; De Brandaris, Zaandam - Zonnewarmte: grote zonneboilers, Warmtekrachtkoppeling;
ventilated enough. After the refurbishment the apartment will have better me-
chanical extraction of the air with individual influence. The supply of air is to open
facilities (mostly a folding frame) and gaps and seams. The existing sluice (spuivoor-
ziening) drainage facilities stay intact.
The gap seal on the gallery side is improved, but on the side of the balconies no
additional seals are added. During the winter draft-free air can be taken from the
verandas if they are closed off. This way 2/3 of the total amount of fresh air can be
taken out of the verandas during the heating season. This value is used to deter-
mine the energy savings of the building.
The design of the veranda allows energy savings but only when it is used the right
way. Therefore it is important to inform the residents about the relationship be-
tween the use of the veranda and the energy use and comfort.
In the summer the climate is manageable. If the façade is opened for 30-40% de
maximum temperatures are acceptable. This is confirmed by experience and simu-
lation computations for ‘the Brandaris’. If the refurbishment would be done with-
out the glass façade the average temperature raises in the living room. During the
heating season this is comfort improvement, but in the summer the maximum
temperature will be 1°C higher till 29°C compared with the old situation before the
refurbishment.
By adding the closed façade without sun shading the indoor temperature will rise
and 2% of the time, the temperature in the living room will exceed the 32°C with a
maximum of 34°C. The temperature in the veranda will be 2% of the time exceeds
34°C with peaks till 44°C.
That will be the situation without blinds and openings in the façade. Opening of the
façade appears to be the most effective. The climate of the veranda will be almost
the same as the outdoor climate. Only blinds in the veranda façade performs sig-
ificantly less compared to opening the glass façade (Fig. 7). Combination of both
makes the solar energy inside the veranda manageable and makes applying the
façade easily. The comfort of the apartments will be improved because the use of the solar collec-
tors on top of the roof. They will provide hot water in the apartments. The old open
geyser can be removed, this way the emission of NOx, CO2 and the humidity in the air will be less in the apartments.

Products & Materials
For this project are used prefabricated aluminium profiles with laminated glass. The
other products are solar collectors (760m2) on top of the roof of the Brandaris.

People
During the refurbishment the people were able to stay in their apartment. The re-


Costs
The total costs of the renovation was about € 6000,- per balcony (42 Brandaris and
168 Noordwachter) makes a total of € 1,260,000,- for the glass façade.
The total cost per apartment €24,700,-
The costs of 760m2 solar collectors was (760*€ 1210,-) € 919,600,-

Principal: Woningstichting Patrimonium, Zaandam
Design: Hans van Heeswijk architecten BNA, Amsterdam
General Contractor: Hermeta Gevelbouw BV, Asperen
Façade Builder: Hermeta Gevelbouw BV, Asperen
Profile elements: Schüco,

7 Sterneberg M.L.; ‘De zon bij renovatie - Zonne-energy in de na-oorlogse gestapeld bouw’, in: Noem (12); Kampert Drukwerk bv, Oss, 1999

Fig. 7 - Effect of the different façades types and temperature

Fig. 8 - Solar collectors on top of the roof of the Brandaris

Fig. 9 - Lifting and placing the façade element
De Valk, Apeldoorn (1965)

‘De Valk’ is the last remaining building from a series of six buildings. Housing cooperation ‘Ons Huis’ owns the building and wanted to keep this building. It is a typical building out of the late sixties. To make the building both functionally and architecturally attractive again a major renovation was necessary. The building is located in the city Apeldoorn in the district Zevenhuizen. The flat is part of an urban revitalization in the district. 500 former flat houses will be demolished and new houses will be built in the area. The 100 apartments in the flat ‘De Valk’ will be have a major refurbishment. These houses will be occupied by former residents out of different buildings. Most of the people are elderly people. After the refurbishment a 45 years old flat looks as new again (fig. 1). The old flats do not meet the current building requirements anymore. The housing cooperation therefore decided to demolish all the buildings. The residents liked to life in the flats so the municipality and the neighbourhood decided to refurbish one out of six flats. This way the appearance of the neighbourhood also stays authentic.

The architects ‘Architectenburo Groosman Partners’ was assigned to give the building a modern appearance with a new façade which meets the building regulations. In 2008 ‘de Valk’ was refurbished completed.

Strategy

The idea was to keep one out of six gallery flats. This is done because of the authentic appearance of the area. One out of two building compartments has got a new orientation. The gallery on the original balcony side is replaced to the other side of the building. This way the building looks as two building, but it is still one building.

The refurbishment of the building is done by stripping the total building including the prefabricated concrete elements. In the end only the concrete structure was left. The new concrete elements are attached to the concrete structure. The old thermal bridges are gone in the new situation. The vertical transport with elevators and stairs is brought the center of the building. This way the vertical element does not play a dominant role in the façade appearance anymore.

For every section of the building a separate entrance is made. The social control and thus the feeling of security will increase this way. The floor plans of the apartments are optimized by turning around the living room and bedrooms.

A major architectural intervention with major implications for the scale and contrast between the building parts, was the addition of precast concrete grid of the residential façade. It shows a graphical area division over several floors without any direction. The gallery side has a strong horizontal façade. The massiveness horizontal lines and lack of identity that characterized the building are gone by this adjustment.

Technical investment has such a high level refurbishment barely benefits over demolition and built a new building. Environmentally refurbishment surely preferable to the residents but also socially and emotionally it is preferred.

Façade construction

The total building was stripped only the concrete structure was not demolished. The new façade for this building is placed in front of the concrete structure. This way the new building does not have thermal bridges anymore.

The flat gets a modern appearance by adding new galleries and concrete frames. These elements have a depth of about 80 centimeters in front of the residential façade. The old elements are removed and replaced for a new concrete elements.

In the first design, done by Groosman Partners, the intention was to make a special steel structure to support the concrete elements. This solution was to expensive so another option

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has to solve this financial problem.

The solution was brought by the company NormTEQ. This company developed the ‘Heli-system’. This system was just the half of the budget of the steel structure. Besides that the maintenance of this system is less compared to the steel structure. The new elements are not heavier than the old balconies or galleries, so the structure was able to catch up these forces.

The system is based on anchors with steel rods which are pre-stressed. These rods are casted in the prefabricated concrete elements. In the existing structure gaps and holes are made in the walls, ceilings and floors. The pre-stressed rods of the elements are put into the drilled holes and will be anchored in the gaps of the concrete structure as seen in figure 4.

Because the municipality was not familiar with this ‘Heli-system’ it was necessary to make a test console of the system. The console was attached to one of the weakest wall of the structure. The console was tested on strength by putting a load on the end of the console. First of all the own weight of the element and with that a load of 250 kg/m2 with a safety factor of 1.5 was put on the element. The deformation was not even one millimeter. By doubling the load the deformation was about 9mm. When the load was gone the element went back to its original form, without any permanent deformations.

In between the concrete framework prefabricated façade elements from Solarlux are placed. The Solarlux façade is a thermal skin with a U-value of 1.7 W/m²K. The elements are made out of an aluminium frame with glass windows and panels. The lower part, the parapet, is made of glass without any opening. The top part is made of a folding element with glass windows in it as seen in figure 6&7. Because the top part can be fully opened, balconies are not necessary. The reason to choose for this system and not for a veranda is because this way a bigger floor area for the living room can be created.

The façade can be cleaned from the inside, this way a façade cleaning installation was not necessary. The elements are not totally façade filling, but are attached to a wooden frame which can be adjusted. In between the elements strokes of (Trespa) plates will cover the self-regulating ventilation grills. On the side of the gallery is chosen for wooden frames with plastic window frames with a wooden structure.

Structure

The original structure of the building has got 10 floors and was about 100 meters long. The middle part with the elevators and stairs is removed and is build over again. The left and right blocks are mirrored in the middle of the building. This way the left part is orientated to the east and the right part is orientated to the west.

Energy use and comfort (old vs. new)

To increase the comfort of the apartment new installations will be placed in the apartments. A screed floor will be made and also a lower ceiling of metal stud will added in the apartment to increase the sound insulation of the apartments.

The self-regulation ventilation system will help in the reduction of the energy consumption of the building. On both sides of the building two different types of glass are used. On the sun-side of the apartments a solar resistant glass pane is used with a LTA/ZTA of 73/39 and a U-value of 1.1W/m²K. On the other side there is used normal insulation (HR++) glass with the same U-value. Together with the aluminum façade element a U-value of 1.7 W/m²K can be reached.

The total reduction of CO2 emission from the building is about 32.9% this means a CO2 reduction of about 500 tonnes/year.

To increase the inside comfort of the apartments a new insulation layer is placed against the building, but also the floor and roof insulation is increased. The R-value of the façade is 2.5 m²*K/W, the floors 3.0 m²*K/W and the roof has got an R-value of 3.5 m²*K/W. The leaks in the façade are improved because the new façade has got better requirements in terms of leakage percentage.

The collective heating system is replaced for an individual heating system with a high-efficiency boiler. Every apartment has got its own teller to measure the energy use.

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2 Wind H.; ‘Nieuw prefab beton aan bestaand casco’ in: Bouwereld #09, 2008 (6)
3 Hoppe T, Bressers H, Lulofs K; ‘Energie besparing in woonwijken blijkt weerbaar’, in: Milieu dossier (18); VVM, Den Bosch, 2010
4 http://www.aluminium-award.eu/2009/competitions/benelux/entries/flategebouw-de-valk/
Climate design
To get enough fresh air in the apartments there is chosen for natural ventilation in combination with mechanical ventilation. Natural ventilation is for the inlet of the fresh air and the air will taken out by the mechanical ventilation system. To reduce the water consumption in the building there is placed a hot-fill connection for the washing machine and the dishwasher. For the residents there is a guideline how they can reduce the energy consumption of their behaviour. The gaps/leaks in the walls and doors are better, so this way the heat losses will be reduced. The collective system is replaced for an individual heating system so people have their own influence in their apartment.

Products & materials
The products that have been used for this project are prefabricated elements made out of aluminium or concrete. The aluminium profiles are used for the façade elements. The concrete elements are used to extend the structure of the building and get rid of the cold bridges.

People
The refurbishment building with new floor plans is bigger than the original floor plans. The new dwellings are for the elderly people. During the refurbishment people had to move out of the building and some of the old residents returned to the building, but some chose to live somewhere else in new built houses.

Costs
The costs of the refurbishment are relative high; approximately more than €100,000,- per apartment. The extra investments cannot be passed to the residents because of the grant for the rent is becoming too high then. So the costs of the investment are totally for the housing cooperation.

The total costs for the renovation of the building is about €15 million Euros.

Principal: Ons Huis, Apeldoorn
Design: Groosman Partners architecten, Rotterdam
General Contractor: Draisma, Apeldoorn
Façade Builder: Solarlux Nederland bv, Nijverdal
Concrete elements: NormTEQ, Hengelo

Fig. 7 - View of the new façade from the inside (right) and the outside (middle & left)
Conclusion refurbishment projects

All the analyzed buildings come from the period 1958 till 1968. All these buildings are refurbished because the comfort of the building was that bad it was necessary to do something with these buildings. During the time the comfort demands of people is changed. The analyzed buildings did not meet these comfort demands anymore so it was important to improve the comfort of the buildings.

For all buildings counts the energy efficiency of the building must be improved. This must be done to encounter the desirable reduction of greenhouse gas emissions for the Kyoto protocol for 2020 by the government, but also because of the comfort demands of the housing sector. Because the structure of the building is not that bad there is chosen to refurbish the buildings instead of demolishing and built new residential building.

Every analyzed housing block is refurbished with a different kind of strategy. Each strategy has got its advantages and disadvantages and it depends on the situation which strategy will fit the best for the building. In most situations demolishing the old building was not an option, because of the interests of different parties or the place of the building. In the case of ‘de Leeuw van Vlaanderen’ the position of the building was important for the neighbourhood. The building acts like a sound barrier and no new building may be build that close to the highway. There was decided to keep the building as it was and to refurbish it. For the other buildings counts that residents or municipality just want to keep the building for the appearance of the neighbourhood.

The amount of people living in the housing block is also an interesting topic, because moving out 100 people is less difficult than moving out 1000 people. So the amount of people can influence the strategy that has to be chosen.

For the residents it is very important to inform them about what is going to happen and how this will be realised. If they miss the right information they will have complaints about how the project proceeds. If people know what the consequences will be, they will accept the interventions of the refurbishment better.

It depends on the concept of the refurbishment, but another subject that is important for the residents is what the end result will be. What benefit they will have out of it. The project is done to create an energy efficient residential building. If the residents do not get the right information about how they should use the new techniques or climate installations, they will not have benefit out of the adjustments.

For some projects, like the ‘Torenflat’ in Zeist, the idea was to implement (Photovoltaic) PV-cells on the façade elements. The architect designed the elements with the energy label of the building in mind. With the solar cells on the façade elements the label of the building could reach label A. Only there was not enough money. So the PV-cells were cut out of the budget.

This means the people are willing to implement innovative materials, but because of the money these interventions are cut out of the budget.

The used strategies differ from totally stripping the building till replacing the old glazing for high efficiency glazing with new insulation in the façade elements. Every strategy has got its own costs with it and what the benefit of the energy reduction in the end will be.

For all analyzed buildings the old façade elements are replaced for a new façades. Only the ‘Rembrandtflat’ in Zwolle kept its old façade element, but with new insulation and new HR+++ glazing. The other projects have got new façades elements in front of the old structure. All the façade elements were prefabricated. This way the building time on site can be reduced and less building space is needed. All the prefabricated elements are made of aluminium or plastic profiles.

The façades do not have any special innovative products with it. The elements are just ‘standard’ elements with ventilation facilities in it.

The air tightness plays an important role in the energy efficiency of a building. The better the gaps are sealed off, the better the energy efficiency will be. But this also means the ventilation of the building will decrease and there must be thought about a ventilation concept which fits in the energy efficiency of the building.

Thus for the indoor climate of the building the ventilation of the dwelling plays an important role. A ventilation concept can influence the energy consumption of the building. Most of the refurbishment projects use natural intake of air with a mechanical outlet of the air; this outtake can be combined with a heat recovery system.

Another interesting solution that is used in 3 out 5 projects is the hot-fill connection for hot water. In two projects solar collectors are used. This is beneficial on the energy use of the building, because a lot of energy is used to heat up water (page 15). This water can be used for cleaning, showering, washing machine, dishwasher, but also to heat up the apartment.

The CO2 reduction in the projects differs from 23% to about 50%. This means different strategies will have different outputs on the energy reduction of the building.
An interesting part of these analyses is the extra façade in front of the structure. The energy reduction by placing an extra layer in front of the structure is an option which looks very good in terms of energy reduction. This can be explained by the fact the extra layer creates a thermal buffer between the old and new façade. This way the cold temperatures can be kept outside and can heat up the space in between the façade of the dwelling and the outer façade (Noordwachter & Leeuwarden). This way the heating season of the building can be reduced. On the other hand, the change of overheating during summertime increases.

Next to the discussed refurbishment projects other refurbishment projects are analyzed. The results are shown in the appendix. The flat ‘de Remijden’ in Amsterdam is also a refurbished building. It is refurbished in August 2010 and in March 2011 the first complains of the residents were there. They are complaining about draft and cold in the dwellings. This means the given solution is not proper. Maybe theoretical, but in practice the refurbishment is not working well.\(^1\)

To summarise the conclusion of the previous refurbishment projects:

- Each project has its own approach
- The energy reduction is different for each approach
- Increase comfort of dwellings in terms of energy efficiency / sound reduction / climate
- Inform resident is an essential part of refurbishment
- In all project the façade elements and glazing is been improved.
- Project used a lot of prefabricated elements
- Social improvement neighbourhood

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Total dwellings</th>
<th>Residents could stay in their apartments</th>
<th>Old residents had the choice to get back in the new building</th>
<th>Residents could stay in their apartments, but also had the possibility to move out temporarily</th>
<th>Residents could stay in their apartments</th>
<th>Old residents had the choice to get back in the new building</th>
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<tbody>
<tr>
<td>Façade</td>
<td></td>
<td>Placing façade in front of old structure, then removed the old façade</td>
<td>Stripping total building and new façade for structure</td>
<td>New insulation, new glazing</td>
<td>New façade in front of old structure, old façade remained</td>
<td>Stripping total building and new façade for structure</td>
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<tr>
<td>Floor plans</td>
<td></td>
<td>Simular</td>
<td>New floor plans and extra floor on top of the building</td>
<td>Simular</td>
<td>Simular</td>
<td>New floor plans, extra floor area per apartment</td>
</tr>
<tr>
<td>Climate installations</td>
<td></td>
<td>No extra installations added, only renewed</td>
<td>Added some mech. ventilation for the gallery</td>
<td>Solar collectors, heat pump, central heating and recovery system, mech. Outtake air</td>
<td>Solar collectors, mechanical extraction air</td>
<td>Mechanical extraction air, hot-fill conection to reduce water</td>
</tr>
<tr>
<td>Reduction total/year</td>
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<td>40% (heating costs)</td>
<td>54 tonnes</td>
<td>129 tonnes</td>
<td>Unknown</td>
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<tr>
<td>Reduction CO2 (%)</td>
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<td>46</td>
<td>32,9</td>
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<td>E/F –&gt; A</td>
<td>Unknown</td>
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<td>Costs/house (€)</td>
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<td>100.000</td>
<td>24.700</td>
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<td>4.150.000</td>
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<td>Costs / m² (€)</td>
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<td>Total floor area (m²)</td>
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<td>10.033</td>
<td>13.100</td>
<td>16.000</td>
<td>10.000</td>
<td></td>
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</table>

Table 1 - Overview of the analysis of the previous refurbishment projects

\(^1\) See appendix for other investigated projects
Problem description

The housing stock in the Netherlands has developed during the years. In the Second World War a lot of dwelling were demolished and damaged. After the Second World War a lot of new dwellings are built, but these buildings do have a lot of problems now. Not only technical problems arise in the building, but also social problems. Nowadays approximately 1% of new dwellings will be added to the total building stock each year. This is not enough compared to the question for new dwellings. The ageing building stock can help to catch up the demand for extra dwellings. This means the necessity to refurbish the ageing building is there.

The amount of existing dwellings will by far exceed the amount of new dwelling with new building regulations. This means the energy efficiency of the new built residential building will meet the new regulations, but the biggest amount buildings (mainly post war ’51 to ’74) do not meet these requirements.

The focus of the energy efficiency of the building stock therefore must not be on the newly built buildings, but on the existing buildings. The Kyoto-protocol has the target to reduce the greenhouse gas emission by at least 30% in the year 2020 (target year 1990).

In the Netherlands buildings can be rated to an energy label. This label works from a scale A++ (very energy efficient) till G (not energy efficient). The dwellings built between 1951 and 1974 are not labelled very well. Most of the building out of that period are labelled D or lower. This means most of the buildings out of this period use more energy than is necessary.

The households approximately consume about 26% of the energy in the building sector. In the households about 57% of the energy is used for space heating and 25% is used for water heating. The other energy is used for cooking (7%) and other electricity devices (11%).

The comfort demands for the residential building are written down in the book for Dutch building regulations. The newly built buildings have to be built according these building regulations. The post-war buildings do not meet these regulations and that is why these building need to be refurbished. People do not accept the lack of comfort in dwellings anymore. This is one of the reasons the dwelling are not that popular anymore.

The technical problems of the building build in the post-war period are problems with noise, draft, moisture, mold and poor insulation. The building method contains cold bridges which causes low surface temperatures where condensation can occur. In a continuous high relative humidity there can exist mold, this has got as a negative effect on the health of the people who lives in the dwellings. This phenomenon occurs in balconies, galleries, lintels, beams and roof edges.

To do something about these problems in the residential building stock it is necessary that these buildings will be refurbished. There is a lot of discussion about refurbishment because, most of the times refurbishment is too expensive compared to demolishing the building and building a new building instead. The reason sometimes is chosen to refurbish a residential building depends on the situation. Sometimes the building is positioned in such a way only refurbishment is possible (Leeuw van Vlaanderen, Amsterdam) and sometimes the residents themselves do not want to demolish the building because of the characteristics of the building in the neighbourhood (de Valk, Apeldoorn).

The building that will be refurbished does not meet the building regulations and comfort demands of the people nowadays. If a building will be refurbished it is necessary to refurbish it in such a way it will meet this demands otherwise people do not want to live in the dwellings. People do have higher demands in terms of comfort and energy consumption of the building so it is important to refurbish the building in a way they are willing to live in the ‘new’ building again.

Out of the analysis from the previous refurbishment projects can be concluded every project is different and stands on its own. It depends on the people who are involved in the project where the focus of the refurbishment will be and how the refurbishment will be executed.

The ambition of different parties is not always the same and sometimes money plays an important role in the decisions that have to be made. In every project it is important to inform the residents about the developments of the refurbishment and how they are involved in the project.

The energy efficiency of a building depends on the insulation value of a building, but is also influenced by the additional installations within the refurbishment. As mentioned before the most energy used in a dwelling is to heat up the space and the use of hot water. In 3 out of 5 projects is seen that a combination of improvement of the insulation layer and the use of solar collectors or hot-fill connection; both will help in the energy reduction.

In refurbishment projects most of the time there is a lot of discussion about money and the question if it is not better to demolish the building and build a new building. Sometimes demolishing is not an option as explained before, but demolishing a building means also that a lot of effort, money and energy is gone. Most of the times a building has got some value so demolishing it will be throwing away money. The issue about refurbishing a building will always be a discussion, but if there can be found an energetic solution to refurbish a building in an efficient way it can be interesting for different parties to think about these solutions. This means solutions will be investigated to make the ageing building stock energy efficient again. Hereby the focus will be on the façade of the building.

The second part of this master thesis will be a search for energetic solutions to refurbish a building in an efficient way. This will be further explained in the next chapter.
Case study building

The next steps for this master thesis will consist of the search for an energetic refurbishment concept for a case study (CS) building. To develop a concept for case study building it is necessary to use requirements which the CS building has to meet. There must be determined how and which program can be used to calculate the energy consumption of the building. For the CS building a building in the Netherlands will be searched and analysed. The state of the building as it right now will be explained. The analysis of the building will consist of the floor areas, amount of dwellings, the building method, energy use, energy label, façade types, orientation of the building, material use, floor plans, sections, detailing, installations etc. After the analyses of the building are done different refurbishment concepts will be developed and tested on the building. In total 4 strategies will be developed and tested on the case study building. The differences between the concepts will have influence on the energy consumption of the building. Within these 4 concepts several option will be calculated like façade improvement or façade replacement. This will be explained further in the chapter about the different refurbishment concepts on page 56.

How to calculate the energy reduction for the different strategies?
To calculate the energy reduction of a refurbishment strategy different simulation programs can be used. To make a good comparison between the old and new situation it will be necessary to put the original building in the simulation program as it is right now. That means all the necessary data of the building will be put in the program. The energy use / loses of the old building can be simulated and compared to refurbished situation.
For the refurbished building the same data can be put in the program, but with new values that are used to refurbish the building. Points of attention will be the heat loses caused by transmission, ventilation and infiltration per strategy. These results can be translated to a refurbishment strategy that can be used for the case study building.
The input of the dwelling depends on the floor plans, but the important aspects are: the total floor area, the floor area of different spaces, the volume of the spaces and the orientation of the façades. The properties of the façades, floor and roof will be determined and put into the program and the type of glazing will be an important aspect. The way of ventilation of the dwellings will be added to the program also.
The requirements for the indoor temperature are described in the program of requirements for the case study building. In the appendix a guideline to calculate the internal heat load will be given. This guideline determine different values for heat loads and calculation time for a typical space in the dwelling.
The simulations can be done in different kind of programs. Some examples are Capsol, Trisco or TRNSYS. These programs only measures the energetic configurations of the building and do not mention the environmental impact or the health of the people. For this thesis the program Capsol will be used and will be explained in a later stage.

How to determine the EPC value of a building?
The EPC value of a building says something about the energy efficiency of a building. To reduce the energy consumption in the Netherlands the Energy Performance Coefficient (EPC) is introduced. The EPC is based on the building characteristics, installations and user behaviour. This way an assessment of the building can be given and this tells how energy efficient the building is. A lower EPC value means a better energy efficiency of the building. Nowadays the EPC is 0,8 but after January 2011 the EPC-value for the housing sector will be 0,6 and in January 2015 the EPC-value has to be 0,4 or less.
In the new standard NEN7120 the new calculation method is explained how the EPC can be determined. It is for now not sure if the standard will be ready on time (June 2011), but there are some new developments in the software for the EPC calculations. With the program EPW - NPR 5129 V2.2 the old EPC value can be calculated.
There are products that will help in the energy efficiency in the building and give it a lower EPC-value, but this does not always means the CO2 will also be reduced compared to other solutions. Some installations will have a positive influence on the EPC-value of the building, but will have a negative influence on the CO2 reduction of the building.¹

Energetic materials and products
To reduce the energy of ageing building a lot of materials and products can be used to accomplish this. In the projects that been analyzed some product and materials already mentioned. In this chapter some products will be discussed and how they can help with the energy efficiency of the building.

¹ http://www.senternovem.nl/epn/epc_in_2006/vermindert_de_co2_uitstoot_door_de_epc_te_verlagen.asp
Requirements for case study building

The requirements for the case study building are developed during the analyses in the first part of this master thesis. The requirements are the results of the building regulations for Dutch buildings and the comfort demands for the indoor temperature. The points that will be described are the minimum requirements for the case study building. The following points will be used as requirements for the case study building:

Façade requirements

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Building regulations</th>
<th>Design value (EPC: 0,6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rc-value façade</td>
<td>2,5 m² • K/W</td>
<td>4,0 m² • K/W</td>
</tr>
<tr>
<td>Rc-value roof</td>
<td>2,5 m² • K/W</td>
<td>5,0 m² • K/W</td>
</tr>
<tr>
<td>Rc-value floor</td>
<td>2,5 m² • K/W</td>
<td>4,0 m² • K/W</td>
</tr>
<tr>
<td>U-value doors/windows</td>
<td>4,2 W/m²•K</td>
<td>1,5 - 1,2 m² • K/W</td>
</tr>
</tbody>
</table>

The building regulation values are the minimum requirements, but for all the values a higher standard is required to make the building more energy efficient. The design values are the requirements to make a building with an EPC of 0,6 (January 2011) but additional installations are required then. In January 2015 an EPC of 0,4 is required for new buildings, but if this feasible for refurbishment will be the question.

Thermal Comfort

For the occupied floor area of housing rooms some requirements for the temperature will be pointed out. These values are the design temperatures for the dwellings with the extreme outdoor temperatures. In wintertime -7°C & in summer time +30°C

- Minimum temperature : 18,0 °C
- Lower comfort limit : 20,0 °C (Winter)  PMV = > -0,5
- Upper comfort limit : 25,5 °C (Summer) PMV = < +0,5
- Maximum temperature : 28,0 °C

To complete the requirements for thermal comfort

In the publication GIW/ISSO 2007 (Installatie-eisen nieuwbouw eengezinswoningen en appartementen) is required:

The total amount of hours that may exceed the PMV of 0,5 (or exceed the 25,5°C) cannot be more than 300 hours. If it will exceed this amount of hours the indoor climate is not good enough. The indoor climate will be the best if the PMV of 0,5 will not exceeded 200 hours. The calculation must meet what is described in BRL 9501. With it, the starting points according to data sheet 5.2 handled. This data sheet is shown in the appendix.

Acoustics

The sound insulation for the façade will be will be a point of attention for this master thesis. The value of the maximum amount of sound in dB(A) that is accepted in a house depends on the location of the building. The regulations for a building which has to deal with road-, rail-, or industrial noise counts a maximum of 35 dB(A) inside the building is accepted or conform the regulations.

The requirements for air and contact noise between dwellings are also a point of attention, but will be worked out in the detailing of the façade and will not be calculated.

Ventilation

Most of the spaces in a dwelling are ventilated natural, but some spaces need mechanical ventilation. In the bathroom, toilet and kitchen mechanical ventilation is required because of the smell and humidity inside the spaces. The regulations says that the minimum ventilation rate of a living room and bedroom in house must be at least 0,9 dm3/s per m² with a minimum of 7 dm3/s. For the other spaces counts: kitchen 21 dm3/s, bathroom 14 dm3/s and toilet 7 dm3/s. This is the amount of air refreshing in the particular space. The air velocity inside a room cannot be bigger as 0,2 m/s otherwise the people will feel draft.

1. van Overveld M.; Praktijkboek Bouwbesluit 2003; VROM, Den Haag, 2005
Analysis case study building (current situation)

The case study building that is chosen to develop different refurbishment concepts is located in Zaandam, a city near Amsterdam. The building stands in a typical post-war district ‘Poelenburg’. In the district a lot of post war buildings are built and nowadays the municipality and the housing cooperation are thinking about renewing the area. This must be done by refurbishing different buildings, but also with demolishing some buildings and build new buildings instead. In the surrounding area more of the same buildings are built as the case study building as seen on figure 1.

The building is built in 1963. The architect of the building is ‘Dienst van volkshuisvesting Rotterdam’ (J.M. van Dokkum). The construction method of the housing block is the ‘Rottinghuis’ building system. This system is developed after the Second World War.

The building method of the ‘Rottinghuis’ concept is used for middle high building. Prefabricated concrete elements are used to make the walls and floor of the building. The prefabricated elements will be mounted on site with the help of a crane. The elements are as high as the floor to floor height and are as wide as a connected space. The floor elements do have a maximum wide of 2,5 meter.¹

Existing situation

The main entrance of the building is located on the corner of the E. Heimansstraat and the Suringarstraat. There are two other entrances at the end of the galleries of the building. The dwellings can be entered by these galleries. The galleries of the dwellings on the E. Heimansstraat are located on the street side. The galleries of the dwellings on the Suringarstraat are orientated on the inside garden of the housing block.

The complex contains 96 dwellings which consist of 4 rooms. The average area of a dwelling is about 68m². There are 3 types of dwellings in the building as seen in the floor plan. All dwellings do have three bedrooms and one of these bedrooms can be entered through the living room. The kitchen is closed off of the living room and the toilet is a separate space next to the bathroom. A typical floor plan is shown in picture 6 (page 48).

In 1992 some maintenance is done to the building. On the outside of the dwellings the wooden window frames are replaced for plastic frames but the plastic frames are without a proper insulation value. The galleries and balconies are refreshed and some interventions are done on the front doors, staircases and the main entrance. On the inside of the dwelling the kitchen, douche and toilet are renewed.

Some apartments do have double glazing, new bathroom, new toilet and central heating system, but not all the apartments do have this.

Because of the corner in the building the apartments do have 2 orientations. One orientation is north – south with the living room on the south side. The other orientation is the east – west with the living room on the east side.

There are some plans to refurbish the building by the housing company, but for now it is not sure how and when this is going to happen. The plans to refurbish the building are for at least 25 years. The dwellings will stay in the social rent sector and people will not have to move out of their apartment. Most residents of the building have a Turkish background.

The energy labels of the housing block are rated on label D till F. The company 'ABC Bouwkundig' did some research to the energy label of the dwellings. Out of this research it becomes clear most of the dwellings are rated label E or F.²

During a site visit with the housekeeper (Ron Veldhuys) it became clear there are several problems with the technical state of the building as well as the social aspect in the neighbourhood. On the technical aspects there are complaints about the building. People complain about mold in the corner connections of their apartments, draft from the façade connections (leaks) and noise from the neighbours.

These problems can be explained. The ventilation in the apartments is not good enough. This way mould will arise in the corner connections. Moist will arise because of the thermal bridge of the building and without proper ventilation mould will occur.

Draft in the apartments is because of the bad connection from the façade element to the building structure. The rubber strips that are connected to the façade elements and the structure do not seal of the gaps properly. The noise from the neighbours can be explained by the lack of sound insulation between walls, floors and ceilings.

During the visit there was shown how people changed their floor plan to create a bigger living room. This was done by removing the wall in between the living room and the hall way. This way the living room becomes bigger, but does not meet the requirements according the building codes. The bedroom next to the living room also was used as an 'extra' room instead of a bedroom.

**Structure**

The structure of the building is made out of concrete elements. The building is five stories high, storage space on ground level and 4 layers of dwellings. The building has got 2 wings of about 101meter and 104 meter long. The grid of the floor plans is 7530mm width and 10740mm long. Within is the grid of 7530mm a separation wall is placed.

For the typical floor plan en section of the building are shown on figures 6 & 7 (page 48).

² See appendix 3.0
The load bearing (separation wall between dwellings) wall has got a total thickness of 200mm with a minimum weight of 1800 kg/m³. The load bearing wall in the dwelling itself has a thickness of 160mm.

The floors are made of a prefabricated concrete plate with a maximum width of 1830mm and maximum length of 5500mm. The total thickness of the floors is 230mm (180 mm structural and 50mm finishing layer). The finishing layer is made of 10mm insulation (Lapinus) and 40mm concrete on top of that.

**Façade**

The building has got different façades. All these façades do have their own properties and structure. There are 5 typical façade principles for the building. An explanation of the different façade principle is written down in table 5 (page 67). Out of the drawings provided by the housing company ‘Rochdale’ can be concluded the existing insulation values of the walls do not meet the requirements of nowadays by far. Also out of the report of the company ‘ABC-bouwkundig’ it becomes clear the insulation of the existing walls is not good enough. According the report by ‘ABC-bouwkundig’ the following insulation values are given to the different wall types:

<table>
<thead>
<tr>
<th>Type</th>
<th>Insulation Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The end wall</td>
<td>Rc = 0.36 m²*K/W</td>
</tr>
<tr>
<td>Front door</td>
<td>Rc = 0.12 m²*K/W</td>
</tr>
<tr>
<td>Gallery side</td>
<td>Rc = 0.24 m²*K/W</td>
</tr>
<tr>
<td>Loggia side</td>
<td>Rc = 0.19 m²*K/W</td>
</tr>
<tr>
<td>Prefab element</td>
<td>Rc = 0.19 m²*K/W</td>
</tr>
<tr>
<td>Double glazing</td>
<td>U = 2.9 W/m²*K</td>
</tr>
<tr>
<td>Single glazing</td>
<td>U = 5.2 W/m²*K</td>
</tr>
</tbody>
</table>

**Climate design and installations**

The climate design of the dwellings is ‘low’ tech. On the ground floor some space is reserved for a central water system together with a central cabinet (electricity/lighting etc.) to supply the building. The ventilation of the dwellings is done by natural ventilation. The façade elements do have ventilation grills which can provide natural ventilation for the spaces behind the façade. The windows of the façade can be opened and provide natural ventilation. The bathroom and toilet are natural ventilated by a shaft which is connected to the outside. The shaft is going from the ground floor through the roof and all the bathrooms and toilets are connected to this shaft. The exhaust system of the toilet and bathroom works not properly. The residents are complaining about mold in the bathroom. During the visit it becomes clear the natural ventilation inside the bathroom, toilet and kitchen was not working proper and that caused the mold inside.

The dwellings have individual central heating systems, some dwellings have High Efficiency boilers and other dwellings have an old heating system. There are individual systems in the dwellings for hot water supply.
Floor plan & section

The following pages will show the technical drawings of the building. This way an impression about the existing situation will be given. The floor plans, sections, façades, 3d sketch and 3d floor plans will be shown. After the drawings the building system that is used for this building briefly will be explained. The typical details and critical connections of the building will be explained also.

Fig. 6 - Floor plan of middle dwellings

Fig. 7 - Cross section building
Façade & sketch impression

Fig. 8 - Façade gallery

Fig. 9 - Façade living room

Fig. 10 - Sketch impression building
Façades and floor plan
Fig. 11 - South façade

Fig. 12 - North façade

Fig. 13 - Floor plan north - south wing
Typical floor plans and 3d model

Fig. 14 - Floor plan and 3d impression middle dwelling

Fig. 15 - Floor plan and 3d impression corner dwelling
Rottinghuis building method

The case study building is built in 1963. During this post-war period a lot of new building methods and techniques were developed by different companies. The used building method for the building is the so-called 'Rottinghuis system'. Typical details of the construction method 'Rottinghuis' are shown on this page. The building method of the 'Rottinghuis' concept is used for middle high building. Prefabricated concrete elements are used to make the walls and floor of the building. The prefabricated elements will be mounted on site with the help of a crane. The elements are as high as the floor to floor height and are as wide as a connected space. The floor elements do have a maximum wide of 2,5 meter. In total about 11,532 dwellings are built with this method in the period 1957 - 1968. The building method is used for gallery flats and porch flats as well.¹

Façade
The building has got different kind of façades. All these façades do have their own properties and structure. There are 5 typical façade principles for the building. A detailed explanation of the different façade principle is written down in table 5 (page 67).

The end wall is a wall with 2 stone layers and a cavity in between, the storage wall on the ground floor is a massive stone wall. On the gallery and living room side façade elements are used to close of the structure. Also a prefabricated (holith) elements are used which are made of 2 stone layers (11,5 cm thickness) and polystyrene insulation in between of 1,5 cm. Underneath and on the next page typical details of the building are shown. The details show the lack of insulation in the building. In these critical points a lot condensation, moisture and mold can occur. Improvement of these details will be necessary.

Façade detailing

Fig. 19- Vertical details of the building: Left galery side, right livingroom side (roof and storey)

Fig. 20 - Horizontal details of the building: Left galery side, right livingroom / loggia
In the previous chapter the current state of the building is explained. The structure, façade, climate, materials and construction method are discussed. The next step is to develop refurbishment strategies for the case study building. In these analysis the most important properties are pointed out and together with the technical (sketch) drawings it gives an overview about the current stat of the existing building.

The next chapter will be about the different refurbishment strategies that can be used for the case study building. Different solutions will be developed and explained.
Refurbishment concepts

Different concepts or strategies can be used to refurbish residential buildings. During the first part of this master thesis different refurbishment project are investigated. In these projects different strategies and methods are used to refurbish the building. The refurbishment strategy depends on the building itself together with the properties of it like the structure, façade construction, floor plans etc. Not all the building can be refurbished with the same strategy.

First of all it will be important what the criteria will be to refurbish the building and how this is related to the different strategies. Not every criteria is that important as another, but they can be a point of attention to take it into account. Criteria that can influence the choice of a strategy will be explained underneath. To make difference between the importance of the criteria, weight factors are used to give an important criteria more influence on the final decision.

In total eight different refurbishment concepts are developed and are shown in figure 1. After the explanation of the criteria and weight factors the different refurbishment concepts will be explained. In the end the different concepts will be rated on the different criteria and weight factors. The rates will be shown in table 1 and schedule 1 on page 61.

Explanation criteria and weight factors

The classification of the different criteria is done by personal arguments. In total 25 points are divided over 9 criteria. The higher the points in total the better the solution will be. The importance of the weight factors depends on own experience and knowledge which is developed during this master thesis.

Impact on residents/floors plans/structure/architecture/surrounding and climate

This means the impact (physical, mental or visible) on the particular topic and how much it will affect the building because of the chosen refurbishment strategy. The impact on the residents means how much the residents will suffer from the intervention that the strategy will bring with it. During the execution of the chosen strategy there will be some displeasure by the residents. It will be important to inform the residents the right way so they know what will happen during the refurbishment. A chosen strategy can influence the floor plans in such a way that the layout of the floor plans must change. This can happen because of extra floor area or another orientation of the dwelling.

Next to the changes of the floor plans also the structure plays a role, because if a strategy has got extra floor space for the dwelling that means something must be done to the structure. The impact on the structure and the architecture depends on the strategy. Some strategies will have no influence on the architecture and the neighbourhood, but other strategies will have a major impact on the architecture and the surroundings. An example without impact on the architecture can be façade improvement and a strategy with a lot of changes in architecture can be façade replacement or extension of the façade/structure. Also adding extra floors on top of the building do have influence on the structure and the appearance of the building.

Impact residents: 3

The impact on the residents is quite an important topic because the residents have to suffer during the refurbishment. The more the residents will be involved and will be informed during the execution the more they will accept the intervention of the refurbishment.
Impact building: 2
The impact on the building is important, but not that critical. Too much impact on the building means a lot of the building will be changed and a new appearance of the building will occur. This can be a positive aspect to the neighbourhood, but it is not the main objective for this master thesis.

Execution
The execution of the refurbishment strategy can be influenced by the decision if people can stay or must leave their dwelling. If there is decided people must stay in their apartment the intervention on the building cannot be that big or there must be thought about an innovative way to handle the strategy.
For example if people have to move out, there can be decided to strip the whole building so only the structure will stand and from that point start building over again. On the other hand if people stay in their apartment the intervention on the façade can be done in such a way that it can be executed in a short time period.
The way of execution and placing the different elements is part of this criteria. The elements can be made on site, but they also can be prefabricated. This way the elements brought to the site and can be placed onto the building. There must be thought about the connections between the old structure and the new elements.
Execution: 2
The execution of the refurbishment strategy is a point of attention and a point where must be thought about, but just like the previous point this will not be the main objective for this thesis.

Indoor climate
The impact on the indoor climate is an import topic. Nowadays the indoor climate is not sufficient in the existing situation. It will be important to think about the fresh air inside the dwellings. The use of fresh air in the dwelling is desirable. This way the \( \text{CO}_2 \) concentration inside can be reduced.
Each strategy will have impact on the ventilation concept of the dwelling. Maybe it is possible to ventilate the building on a natural way, but maybe it will be better to ventilate the building mechanically.
Climate: 4
The indoor climate of the dwelling is an important topic of this thesis. The indoor climate is part of the comfort of the dwelling. If the climate can be improved a lot with a concept this will have more influence on the total points and final decision.

Installations
Inside the dwellings there are not a lot of installations. The only installation which ‘officially’ is present in most of the dwellings is a central heating system which provides hot water and the heating of the dwelling. In some dwellings still a fireplace is used to heat up the dwelling. Not all the existing installations are efficient in terms of energy use. Also the indoor climate can be improved by adding new installations in the dwellings. A new ventilation concept will be necessary to provide fresh air inside of the dwellings. Every strategy will have its own ventilation concept and it will be necessary to think about clear concept for each strategy.
Installations: 1
The installations in the dwelling are part of the total concept for the dwelling, but for every strategy different installations can be used. In the end there a total concept must be proposed, but because the focus is on the façade the installations in the dwelling are less important.

Façade possibilities
The main focus of the refurbishment strategies will be on the façade of the building. The main objective is to get an energy efficient building. This can be accomplished to reduce to energy consumption of the building by doing interventions on the façade of the building. This way the heat losses can be lesser and the building can be energy efficient again. The more possibilities there are which can be done with the façade, the more solutions there will be to design an energy efficient building. A strategy to replace the whole façade gives more opportunities to do something with the façade then only improve the existing façade. So the more possibilities there are what can be done with the façade, the better the strategy will be. Façade possibilities means the extra adjustments that can be done to the façade itself, like ventilation grills for example.
Façade possibilities: 3
The façade possibilities are an important topic of this master thesis because the focus of the refurbishment of the building will be on the façade. The façade itself is important, but also the possibilities what you can do with it will be important.
Technical bottlenecks improvement
The building method out of the post-war period is a method with technical problems in the connections of some elements of the structure. These connections are one of the reasons of the heat losses of the building and the energy consumption. The thermal bridges of the building (method) take care of moisture and mold in the corner connections of the building. That is why the improvement of these connections is a critical point of attention. If these problems can be solved with in a strategy this will be an interesting strategy to use.

Technical bottlenecks: 4
Solving the critical connections of the building is important. If the connections can be improved this means draft, moisture and mold will not be a problem anymore.

Generic solution
A chosen strategy is maybe useful for one building, but it can be the question if this also is a solution for another building. Not every strategy will be useful to apply it on a particular flat, but it can be applied to the case study building. A generic solution for the case study building will mean that the strategy also can be applied to another building with the same properties like a gallery flat or even a porch flat. The more the strategy can be applied to other buildings the more generic the solution will be. Of course every building is different, but the main concept of the strategy can be applied to another building.

Generic solution: 4
The different strategies are developed during this master thesis. Not every strategy will be easily applicable to a typical post-war (gallery or proch) flat. The more generic the solution will be the better the strategy is applicable to this kind of buildings.

Costs
The costs will be taken into account, but this will be a rough interpretation about how much impact a strategy will have, how much material will be used and what the building time this will be. The costs of a chosen strategy depend on some factors. Some examples of different factors are: building method, building time on site or factory, execution method, materials, residents (moving out or stay) etc. It will be a rough estimation of the costs and it will be hard to find some exact numbers about how much a strategy in the end will cost.

Cost estimation: 2
The cost estimation is not the main objective for this master thesis, but the costs of a refurbishment project is always a discussion point. The cost calculation of a refurbishment project is hard to calculate because it depends on many factors like; execution, building method, materials, façade area, building time etc. For the classification of the costs the execution, materials, façade area, and building time are taken into account.

Explanation refurbishment concepts

Improvement existing façade
Improvement of the existing façade means the improvement of the façade without removing the original elements. Partly removing of some parts or elements, to install extra insulation, can be an option. This means the existing façade elements will stay within the structure with the addition of some other (insulation) layers on the outside of the façade. With this strategy the impact on the building and residents will be low. The climate will be improved, but not that much because there are not much façade possibilities. The technical bottlenecks will not be improved. The strategy is a generic solution because it can be applied on several types of buildings. Probably this will be the cheapest solution to improve the façade elements in terms of extra insulation.
Replacement existing façade
Replacement of the existing façade will mean that the old façade elements will be removed and replaced for new façade elements. This way new products can be used with the new façade elements and the insulation value can be made as good as it needs to be. The impact on the residents will be a bit higher compared to improvement of the façade because the existing elements have to be removed and the new elements will be attached to the structure. The climate and the façade possibilities are better than the improvement strategy because the elements are new and can be designed the right way. The possibility to improve the critical details is good, because the details can be designed in a better way. The strategy is a generic solution because it can be applied on several types of buildings. The costs of this solution will be higher than the first one but this depends on several aspects as mentioned before.

Close of gallery / loggia
Closing of the gallery or loggia can be done by adding a layer in front of the normal structure of the building. Closing of some areas of a building can influence the inside climate on a positive way because a buffer zone can be created between the thermal inside and the outside. The impact on the residents is less because the façade is not part of the dwellings and is going ‘around’ the building so the execution is also positive on the building site. The climate concept is an important topic, because of the extra façade in front of the structure. This way natural ventilation is possible, but it asks for a new ventilation concept. The façade possibilities are not that much for the existing façade, but for the new façade layer new concepts can be introduced. The improvement of the technical bottlenecks is good because the thermal layer is replaced to the outside of the structure. The intervention can be done while the building is still occupied. The strategy is a generic solution because it can be applied on several types of buildings.

Extension of building
Extension of the building means that the building will gain some extra floor area because an additional structure will be applied to the existing structure. This way a new façade is placed in front of the old façade and will have a positive impact on the building. This intervention will have a lot of impact on the residents because of the old façade also has to be removed and a good connection has to be made to the extended façade. This makes the execution of it quite difficult, but not impossible. There are several options to realize this extension, for example by creating a secondary structure in front of the building or hang the extension in front of the existing structure. The climate can be improved because of the façade possibilities and the possibility to put extra installations in the extension. The technical bottlenecks will be improved also because of the new better connections. There are a lot of possibilities that can be done with the façade and the strategy is quite generic, because it can be applied to other residential building with this structure.
Additional stories
Some refurbishment projects are done by adding some extra stories on top of the existing structure. This is done to create more differs floor plans in the building to attract other people. Another reason to add extra layers on top of the building is because of the exploitation of the building. The building will have a higher value so this is an interesting option for developers in economic point of view. This strategy is not directly related to façade refurbishment and is not generic for every residential building which is a gallery flat.
The improvement of the insulation on top of the roof is beneficial with this strategy. This strategy needs more investigation to the structure of the building and can be a combination with the other refurbishment strategies.

Improvement from the inside
To reduce the energy demand of a building extra insulation is one of the first things that can be improved. This can be done from the outside, but in some situations it is done from the inside. This solution is not desirable because of the impact on the residents and the floor plans. Also the connection from the outside to the inside will stay the same only the inside will be better insulated. It is not a very common solution to reduce the energy demand of a building because of the difficulties with moisture in between the old and new façade elements. The façade possibilities are less because only extra insulation is added to the existing façade. It is a solution that can be applied on every building. This solution is used for historical and listed buildings most of the time. These buildings may not be changed from the outside of the building.

Create green house between buildings or corners
An green house can act as a buffer zone between the inside and outside of a building. This way the heat load, but also the heat losses of a building can be reduced. It depends on the shape of the building if this strategy can be worked out as a refurbishment possibility. This solution will have a lot influence on the architecture, surrounding area and the building. The climate will be total different compared to a normal dwelling. The relationship between inside and outside will be complete different. The critical details will be no problem anymore when a new façade is placed in front of the existing structure. This solution will not be very generic because not every building will be suitable for this intervention.

Thermal layer in front and on top of the building
This strategy will ‘wrap’ the building into a second skin façade. This way the thermal layer of the building will be replaced from the existing structure to the new second skin façade. This will give the inside a total different climate and also with this strategy a ‘buffer’ zone will be created between the existing façade and the second skin façade. The influence on the people, architecture, climate and the building itself will be very high. A lot of new possibilities occur within this strategy. The critical connections can be solved and even extra floor area can be created. It is not a generic solution for this types of buildings (residential).
Evaluation different refurbishment concepts

Each concept has got its pros and cons for the different criteria. The 8 concepts can be applied to the case study building, but not every concept will be as good as another concept. An important issue is the generic solution for the building. If it can be applied to this building it also can be used for another building. Two other important criteria are the improvement of the indoor comfort indoor climate and the improvement of the technical bottlenecks.

To get a clear view about the different refurbishment concepts and their criteria a table is made. In table 1 the different concepts and criteria are shown. Next to the different criteria the weight factor is shown. This weight factor is added to classify the different criteria because not every criteria is that importance as another. The weight factor shows how important the criteria will be and is classified from 1 till 4; 1 stands for low importance and 4 stands for big importance. The points given by the different strategies differ from 1 till 5; 1 is not that good and 5 is good.

The table shows the total points for each different strategy. The strategy with the most points will be the best that can be used for the case study building. In the end four out of eight strategies will be used to work further with. Within these four strategies different options are still possible to investigate, but this will be explained further on in the thesis.

Out of the criteria for a generic solution for the concepts, concept 7 & 8 cannot be used. The concepts are solving the problems with the technical bottlenecks and gives new façade possibilities with the new façade elements. The climate concept of the dwellings will be an important aspect because the indoor climate of the dwellings will change a lot. The dwellings must be ventilated with fresh air and a new façade in front of the existing façade makes this hard to regulate. The strategies are maybe applicable for this building, but in general it will not be a very generic solution. It brings a lot of new parts which has to be investigated if a building will be refurbished this way. Parts like overheating, ventilation, fire and regulations.

Concept 5 will not be used because the addition of new stories is not a façade refurbishment, but a total new concept to refurbish a building. This concept can be used in combination with other refurbishment concepts, but on its own it will not really help to make the building energy efficient.

For the case study it can be an interesting research if it can be realized, but for now it will not be taken into account. It is also the question if it is a generic solution because not every building or it structure will be strong enough to put extra floors on top of the building. The extra floors on top of a building can make refurbishment an interesting investment, because this way more money can be gained out of the extra floor area that can be sold or rent. It depends on the height of the building and if the existing structure is strong enough to catch up the extra loads on the building.

Improvement from the inside (6) is a concept which is not desirable because of the smaller floor area that will occur out of the extra insulation layer on the inside of the structure. Also the impact on the building physics is not that good, because insulation on the inside is an intensive intervention with difficult solutions for moisture. This intervention will not solve the problem of the critical connections of the building. The solution is a very generic solution because every building can be insulated from the inside.

Table 1 - Criteria and refurbishment strategies

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</table>

Table 1 - Criteria and refurbishment strategies
Concept 1, 2, 3 and 4 are the best overall solutions that can be applied on this type of buildings. Out of these 4 concepts, the concept of the extension will be the most intensive because with the extension old and new elements must be connected. Therefore this solution will also be the a generic solution.

Concept 1, improvement of the existing façade, is the easiest intervention to make the building more energy efficient. The impact on the residents will be acceptable because the façade only will be improved and not removed. The impact on the building and the execution is good, because the energy efficiency will increase and this can be executed on a simple way. The concept will not remove the critical connections of the structure. Also the façade possibilities are limited. It is a generic solution to refurbish the building. This method is used in more projects.

The replacement of the existing façade (2) will give a lot more options to do with the façade, but this will have more impact on the residents. The existing façade elements must be removed and replaced for new façade elements. The execution of this replacement can be quite fast because the elements can be prefabricated. This way the old elements can be removed in total and new elements can be placed in total. The impact on the indoor climate will be positive and the critical connections can be improved. The prefabricated elements can be placed and there are façade possibilities to install extra facilities.

Closings of the gallery or loggia (3) is a concept to create a buffer zone between inside and outside. This means one side of the building will be improved a lot. On the other side of the building extra improvement on the façade also will be necessary. The climate in the buffer zone is an interesting point because overheating in the buffer zone can occur if the ventilation rate is not enough. The impact on the residents will be low because the façade will be putted on the outside of the structure. The execution of the elements can be done with prefabricated elements so the building time on site can be reduced. The new façade layer in front of the structure will take care of the critical connections of the structure because the thermal layer is placed to the outside of the structure. The solution is generic because this method is used in more refurbishment projects.

Façade extension (4) is the most intensive concept because a new structural element will placed against the building. The old façade will be removed and a new connection will be made to the old structure. A big advantage is the extra floor area that will be gained. Also the technical improvement of the thermal bridges which will be gone with this concept. The impact on the residents will be high, but on the other hand the impact on the building will be good because of the extra floor area that will be added. Extra floor area is interesting as well for the residents as the housing company. There are enough façade possibilities together with extra installations that can be used in the extra floor area. The solution is not generic because not every gallery flat will be suitable for extra structural elements. This can be because of the height of the building or the structure that is not strong enough.

Schedule 1 shows the different concepts and the total amount of points for each concept. The concepts 1 till 4 are the best overall refurbishment solutions to use for the case study building. These four concepts will be developed further in this thesis.

Concepts 5 till 8 are also refurbishment solutions which can be used to refurbish the case study building, but will not be taken into account anymore.

Within the different concepts it is possible to use all kinds of different façade solutions and make combinations between the different concepts.

The next step is to calculate the different strategies with the program Capsol and see what the output will be. This way the most efficient solution can be used to refurbish the building. In the end there can be concluded which strategy will fit the building the most. It is also possible more than one strategy will be used to refurbish the building. A combination between different strategies is a possibility.

Within these refurbishment strategies it is important to upgrade the whole building to the current standards of energy efficiency, fire protection and sound insulation. Also the other parts of the building should be improved, like the entrances of the building and the addition of an elevator in the empty shaft (which is there for an elevator).

It should be remembered with all measures that the refurbishment should satisfy the requirements of the next 30 years. Shorter refurbishment intervals are certainly uneconomic. Whether complying with the minimum standards is the right objective must be checked before starting any planning work.1

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1 Renda; kennis platform bestaande bouw; Baxtel, 2011
Impact on the building per concept

All the concepts do have influence on the building. Some concepts will have more impact on the architecture than another concept. Out of the 8 strategies 6 concepts can influence on the appearance of the building. The next pictures are impressions of the concepts that can influence the building on its appearance. The sketches of the ‘new’ building are used to give an idea about the changes of the building in its appearance and are not saying anything about the architecture and materials.

Sketch sections of different strategies:

Fig. 1 - Section existing situation
Fig. 2 - Section existing closed gallery (and loggia)
Fig. 3 - Section extension
Fig. 4 - Section extra floor on top
Fig. 5 - Section green house
Fig. 6 - Section second skin
Energy calculations

Computer model in Capsol

In the case study building there are 3 types of dwellings. The standard dwelling is the middle dwelling as seen in figure 1. This type is representing 84 out of 96 dwellings. The first step is to calculate the energy consumption and comfort in the existing situation per dwelling. The company ‘ABC Bouw-Kundig’ (Heiloo) already did calculation for the energy use of the dwelling. The energy use and comfort of the dwelling can be simulated and calculated with a computer program. This simulation can be compared with the calculation from ‘ABC Bouw-kundig’. If the outcome is similar the model in the computer program can be used to test different kind of refurbishment concepts.

A program that can be used to do these simulations is ‘Capsol’. The existing situation of the dwelling will be used to compare the different strategies with each other in terms of energy consumption for space heating and indoor comfort. Capsol builds up a model by defining different zones in a section of a building. These zones define a space or room in the total model. These zones are divided by walls/surfaces. The program is able to calculate the temperature in a space and the amount of energy that is used in that space. Within these calculations the different circumstances will be taken into account by the program like, sun radiation, outdoor temperatures, surface temperatures, materials, insulation values etc.

The input functions which are used to simulate the standard section in Capsol are: wall types, walls, (function) references, zones, ventilation principles, sun obstacles, view factors, controls and sensor points. A short description of the different inputs will be given underneath.

Wall types

The standard dwelling has got different wall types. These wall types are divided in façades, floors, ceilings and inner walls. These walls do have a particular construction and can be defined in the program. The walls that are used to put into the program are shown in figure 1 and 5. All the walls, façades and floor elements are defined in the program with the properties of the walls as they are in the existing situation. In the program the materials and thickness of the walls are defined.

Walls

The wall types are defined on page 67. These walls needs to be simulated. This means the surface and the boundary of each wall has to be determined. Each wall has got its own properties and area. Façade elements are simulated as walls too. These elements are influenced by the outside weather conditions like the temperature and the sun. For the façade elements it is necessary to define the orientation of the walls. The walls are always located in between two spaces or boundaries. This means in the model, a wall always faces 2 sides, an inner zone to an external zone, two inner zones or an inner zone with an adiabatic boundary.

The in- and outside spaces are simulated as zones, which are explained more into detail later in this chapter. The adiabatic boundary functions as mirror axis and is used at the margins of the model. For example; a separation wall between two dwellings, of which only one dwelling is modeled, is modeled by the input of half a separation wall, with an inside boundary on one side and an adiabatic boundary on the other side. The wall is mirrored at the adiabatic boundary and therefore it will be counted as a whole wall in between two dwellings.
Zones

As mentioned before, zones are divided into an inside area and an outside area. The zones are defined by their comfort control possibilities. The outside zone cannot be controlled, but the inside zones in the dwelling is controllable. The zones that are used in the Capsol model are shown in figure 2.

View factors

Walls that are in visual contact with each other will start radiating heat. Capsol will automatically calculate so called view factors for the surfaces that are situated in an internal zone. If the walls are in the same surface, like window frames and a glass pane of the façade, the surfaces will not be able to radiate heat to each other. The view factor will be set back to ‘zero’.

Function References

The functions references represent the environment from the outside temperature to the internal heat loads from people and electrical devices inside. There are five different functions, temperature (T), ventilation (V), power (P), diffuse sunlight (D) and global solar radiation (G).

For the function references different (target) values are put into the program. This is done because every zone has got its own properties and its own comfort temperature, ventilation amount or internal heat load.

The functions that are added to the Capsol model to make a simulation are: temperature, ventilation, internal heat load, weather conditions, controls building obstacles and sensor points.

Temperature

Each zone has got its own temperature properties. These properties can be put into Capsol. This way a target temperature can be created for a zone. Every zone has got its own demand about how high the comfort temperature has to be. This is explained in the chapter with the building requirements.

T01: Outside temperature measurements of the Bilt in the Netherlands are used to simulate the temperatures over a year.

T02: Target temperature for the living room. During daytime 21 °C and during nighttime 15 °C

T03: Target temperature for the bed rooms. During daytime 18 °C and during nighttime 19 °C

T04: Target temperature for the kitchen. During daytime 19 °C and during nighttime 15 °C

T05: Target temperature hall. During daytime 19 °C and during nighttime 15 °C

T06: Target temperature bathroom. During daytime 20 °C and during nighttime 16 °C

Ventilation amount

Every zone has got its own ventilation demand. For every zone is a ventilation file is made. This way the right ventilation amount can be put in to the program for each zone.

V01……04, differs just like the temperature during day and nighttime, but also during winter and summer time because in the winter the heat must stay inside the dwelling and in summer the heat must get out of the dwelling by more ventilation. The ventilation amount in wintertime is related to the minimum demands for ventilation written down in the building requirements code. In summer time comfortable ventilation amount in taken into account.
Power (internal)
Internal heat loads (P01……07) are calculated for each zone separately. The calculation parameters can be found in the appendix. For the internal heat loads some standards are made up for heat loads by electrical devices, people and lighting. Also a calculation time is added because not every moment of the day a zone will be used or occupied.

External references
The diffuse sunlight (D) and global solar radiation (G) will used for the program and are a standard file just like the outside target temperature of the Bilt.

Ventilation principles
The ventilation principle is also simulated in the program. The basic ventilation scheme is based on natural ventilation. The ventilation rate differ for each room and has got its own requirements. The ventilation rate for the living room (example) is 1.5 vol/hour (input for Capsol). This is the same as in the requirements, but with another unit. 1.5 vol/hour = 0.9 dm³/s per m² (according minimum requirements building codes). The basic scheme is shown in figure 3.

Controls
To simulate the radiators inside the dwelling, controls can be added to the model. The controls can take care of extra heating inside the dwelling. Inside the different zones a ‘sensor point’ is added which can be related to a typical target temperature (T02…..6). When the sensor point is higher or lower than the target temperature the controls automatically switch on or off.

Sensor points
To get insight in the indoor climate of the dwellings, sensor points are placed. The sensor points can be used to calculate the temperature in a specific zone. In these points also the controls can be located in different zones.

Sun obstacles
Sun obstacles describe objects on a building, like a gallery or loggia, which will block the sun in such a way the sun will not reach transparent parts of the façade. For the dwelling in the south – north orientation a sun obstacle is present by the loggia. For the dwelling in east – west orientation the gallery acts as a sun obstacle. An example of a sun obstacle of the building is shown in figure 4.
Existing materials put in Capsol

The following wall properties are used in the program Capsol. The values are calculated according the materials that are found in the drawings handed out by 'Rochdale'. In the construction archive of the municipality some text is found with the used materials.

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<th>Weight (kg/m²)</th>
<th>Lambda (A)</th>
<th>R-value (m².K/W)</th>
<th>U-value (W/m².K)</th>
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Energy calculation existing situation

For the energy calculation of the dwelling a calculation must be made for the existing situation in the program Capsol. This way the calculated energy consumption done by 'ABC-bouwkundig' can be compared with the simulated model in Capsol. Different strategies can be tested on the model if the model is reliable. This way a comparison can be made between the existing simulated situation and the new simulated situation.

An energy calculation about the existing situation is done by 'ABC-bouwkundig'. These calculations are written down in a report which is handed by the housing cooperation 'Rochdale'. In this report the properties of the dwelling can be found. Also the different façade elements are described in this report.

There is made an energy calculation in the existing situation. This calculation will be used to compare the calculation done by 'ABC-bouwkundig' and the simulation of the energy use in the computer program Capsol.

The energy use is calculated energy and divided in several energy consumers (ABC-bouwkundig):
- Heating 651 m³ gas 22.888 MJ Primary energy
- Water 277 m³ gas 9.745 MJ "
- Extra energy 237 kWh 2.184 MJ "
- Lighting 420 kWh 3.877 MJ "

The report of 'ABC-bouwkundig' shows the amount of gas that is used to heat up the dwelling during the year. During the year 651 m³ gas is used for space heating. To make the comparison between the calculation and the simulation the different values must be calculated. Capsol calculates the energy use in kWh (kilo watt hour). To recalculate these values to Mega Joules or the other way around the following values can be used: ¹

- 1 kWh = 3,6 MJ
- 1 m³ gas = ± 10 kWh

In the calculations of 'ABC-bouwkundig' insulation values are given for each façade element:

The end wall Rc = 0,36 m²*K/W
Front door Rc = 0,12 m²*K/W
Gallery side (element) Rc = 0,24 m²*K/W
Loggia side (element) Rc = 0,19 m²*K/W
Prefab element Rc = 0,19 m²*K/W
Double glazing U = 2,9 W/m²*K (ZTA= 70%)
Single glazing U = 5,2 W/m²*K (ZTA= 80%)

If the insulation values of 'ABC-bouwkundig' is used in Capsol the energy use for space heating will be 91,5 kWh/m². This means 91,5 x 70 m² = 6405 kWh for the total dwelling (6405 / 10 = 641 m³ gas).

The difference between the calculation of ABC-bouwkundig and the simulated model in Capsol is: 1 - (641/651) x 100% = 1,53 %. The difference is quite low, it shows the model is accurate to work further with. Only the difference between the insulation values given by 'ABC-bouwkundig' and the information on the drawings and text is different. The insulation values according the text and drawings are higher than the used values by ABC.

¹ ABC-Bouwkundig; Energie prestatie advies voor woningen; Heiloo, 2010
² http://www.unitjuggler.com/energy-conversion.html
The energy use is calculated energy and divided in several energy consumers (ABC insulation values in Capsol):

- **Heating** 641 m³ gas 22.500 MJ Primary energy
- **Water** 277 m³ gas 9.745 MJ +
- **Extra energy** 237 kWh 2.184 MJ +
- **Lighting** 420 kWh 3.877 MJ +

38.306 MJ Primary energy use

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If the model is simulated with the higher insulation values Capsol shows an amount of 75,8 kWh/m² is used to heat up the dwelling. In this calculation the insulation values are used according the original drawings and information (insulation values are shown in table 5 on page 67). This means the existing facade elements are better insulated than is assumed by ‘ABC-bouwkundig’. The area of a dwelling is about 70 m². In the simulated model with better insulation values 75,8 kWh * 70 = 5310 kWh per year is used for space heating. This value must be recalculated to m³ gas. 5310/10 = 531 m³ gas is used to heat up the dwelling according the simulation program.

The difference between the ‘ABC-bouwkundig’ and the second simulation with the higher insulation values is bigger. The difference is about 120 m³ gas. This is about 1 - (531/651) x 100% = 18.4% deviation.

The energy use is calculated energy and divided in several energy consumers (higher insulation values according drawings and text):

- **Heating** 531 m³ gas 18.670 MJ Primary energy
- **Water** 277 m³ gas 9.745 MJ +
- **Extra energy** 237 kWh 2.184 MJ +
- **Lighting** 420 kWh 3.877 MJ +

34.476 MJ Primary energy use

---

![Fig. 7 - Energy use per application in % of the total of the simulated model in Capsol according ABC values](image-url)

![Fig. 8 - Energy use per application in % of the total of the simulated model in Capsol new insulation values](image-url)
Energy calculations different models

The calculations for the different strategies shown in graph 1 (page 72). The existing situation is calculated first. These results are compared with the energy calculation made by ‘ABC-bouwkundig’ in the previous chapter. The model with the higher insulation values is used.
The insulation values used by ‘ABC-bouwkundig’ were a bit low to use. The insulation values used in the 2nd calculation with an energy use of 75,8 kWh/m² is used to work further with. The new calculation will be compared to this calculation.
In the existing situation the amount of ventilation during winter time differs to the ventilation rate during summertime. The ventilation rate during the summer is higher.
The ventilation amount for the new strategies will remain the same as the ventilation amount of the existing situation. This way a comparison can be made between the different strategies.
The indoor climate is sufficient if the total amount of overheating hours is < 200 hours. If the amount of overheating is > 300 hours the indoor climate will be insufficient.

1. Existing situation (figure 8)
The properties of the existing situation are put into Capsol. The properties of the dwelling like floor areas, wall properties and orientation are put into the program.
The ventilation amount during winter and summertime is the minimum amount that is needed according the regulations (1,5 vol/h). The amount of ventilation during summertime is higher because during summertime people will open up more windows. This way the ventilation rate will increase during summertime and will prevent overheating.

2. Façade improvement
Façade improvement means a better façade used with extra insulation on the outside. The Rc-value of the façade will be improved. The Rc-value will be improved till 2,5 m²K/W. The façade can be improved more, but then the total wall thickness will be that thick the gallery will become too small. Also the existing windows will be replaced with High Efficiency (HR++) glazing to reduce the energy consumption.

3. Close gallery
The strategy to close of the gallery means an extra thermal layer in front of the gallery. This way one side of the building will have a buffer zone. Closing of the gallery will reduce the heat loses to the outside during the winter. One side of the building will be improved, but the other side will stay as it is in the existing situation.

4. Close gallery and façade improvement living room side
This strategy is based on the previous strategy but with façade improvement on the living room side. The improvement means façade improvement on the outside and replacement from the existing glazing. The glazing will be replaced with HR++ glazing.

5. Close loggia
The strategy to close of the loggia means the loggia is closed with a façade in front of the existing structure. The loggia of the building is an area with 3 different types of façade with a bad insulation value. To put a façade in front of the loggia these 3 façades will be closed off to the outside and this way the heat losses can be reduced. The façade on the gallery side will stay as it is as in the existing situation. Also the other façade elements will stay as they are in the existing situation.

6. Close loggia and façade improvement all other elements
This strategy is based on the previous strategy but with façade improvement on the living room side and gallery side. The improvement means façade improvement on the outside and replacement from the existing glazing. The glazing will be replaced with HR++ glazing.
7. Close gallery and loggia (figure 9)
This strategy is a combination of strategy 4 and 6. This means the gallery and the loggia will be closed off. The insulation value of the living room will be the same as in the existing situation. This will be the only façade elements which will not be improved. To do this the influence can be investigated between an insulated façade element compared to a non-insulated façade element.

8. Close gallery and loggia with façade improvement
This strategy will be the same as the previous one but now with façade improvement on the living room. The element on the living room will be improved with better insulation and new HR++ glazing. This way a comparison can be made between the previous solution and the new solution.

9. Façade replacement
Façade replacements mean removing the existing façade elements and replace these elements with new façade elements. The new elements can be designed with insulation values that meet the requirements of nowadays. The replaced façade elements will have an insulation value with a minimum RC-value of 4,0 m²K/W. This will be the minimum value for the closed parts of the façade. For the open parts, (HR++) glazing with a U-value of 1,2 W/m²K will be used.

10. Façade extension (figure 10)
Façade extension means the extension of the existing structure by a new designed element. This element will have the same insulation values strategy number 9. With the extension the floor area of the dwelling will increase. It depends on the design of the extension how much this extra floor area will be.

11. Close loggia and façade with replacement
This strategy is the same as strategy number 6, but within this strategy the façade elements will be replaced instead of improved. This way the new façade can be designed with a minimum Rc-value of 4,0 m²K/W. This is the minimum insulation value according the design values of Senternovem. For the open parts, glass with a U-value of 1,2 W/m²K will be used.

12. Close gallery & loggia with façade replacement
This strategy is the same as strategy number 8, but within this strategy the façade elements will be replaced instead of improved. This way the new façade can be designed with a minimum Rc-value of 4,0 m²K/W. This is the minimum insulation value according the design values of Senternovem. For the open parts, (HR++) glazing with a U-value of 1,2 W/m²K will be used.

13. Façade improvement without glass replacement.
The existing façade elements will remain as they are, but with extra insulation in front of the elements. The insulation value of the elements can be increased. The glass which is applied to the building will be remained. This way a comparison can be made with the existing situation and the new situation with façade improvement without glass replacement.

14. Glass replacement without improvement insulation value
This calculation will show the difference between the energy use of the existing situation and the situation with glass replacement with a U-value of 1,2 W/m²K. This is done to see what the influence will be by only replacing the glass for new HR++ glazing.
Results energy calculations

The energy calculations for the different strategies are shown in the graphs 1, 2 & 3. The calculations/simulations of the existing situation and new refurbishment concepts are made in the program Capsol. For each refurbishment strategy the energy consumption is calculated for the whole year. The output in Capsol is given in kWh/m². These calculations together give the energy consumption for space heating for a whole year.

The calculations of the energy consumption of the dwellings are done for both orientations, the ‘north – south’ and the ‘east – west’ orientated dwellings. The north - south orientated dwelling has got the gallery on the north side and the living room on the south side. The east - west orientated dwelling has got the gallery on the west side and the living room on the east side of the building. This is done to see which strategy will fit the best for each orientation. It is possible that one strategy will fit the best for one orientation, but maybe another strategy can be a better solution for the dwelling with the other orientation.

First a calculation is done for each strategy during the whole year to see what the energy consumption for space heating will be. This way all the different strategies can be compared and a decision can be made between the different refurbishment concepts.

During wintertime most of the used energy consumption is used for space heating. A second calculation is made only about the energy consumption during wintertime. It could be possible the energy consumption during wintertime can be totally different than the whole year calculations.

Next to the calculations for the energy consumption of the dwellings a calculation about the overheating is done. The overheating is represented in the amount of hours that the temperature will exceed 25,5 °C. The calculation of hours of overheating is done without any extra interventions on the façade, for example, no sun shading is used.

The graphs 1 & 2 representing the energy use for space heating (blue bars) in kWh/m² for the whole dwelling. Each room or zone in the dwelling has got its own control. The number of the blue bar represents the average energy use for all the zones together.

The orange bar represents the amount of overheating for the whole dwelling. The numbers are the average temperature in the dwelling which is higher than 25,5°C. The number in the orange bar says how many hours the temperature is above 25,5°C in the dwelling.

Energy use middle dwelling North - South orientation

Graph 1 - energy use and hours of overheating of different strategies (North-South orientation)
**Graph 2 - energy use and hours of overheating of different strategies (East-West orientation)**

**Graph 3 - energy reduction in % compared to the existing situation for both orientations**
Energy use during wintertime

During wintertime more energy will be used for space heating. There is made a calculation to see if there is any difference between the energy use during wintertime and the energy use during the whole year. Of course the energy use during wintertime will be less than during the whole year. The average difference between the whole year calculation and the winter calculation is about 4 to 5 kWh/m².

Another aspect to look at is to investigate which strategy will have the most energy reduction during wintertime. If the reduction of the different strategies is calculated a comparison can be made between them.

First a calculation is made between the different strategies and the energy consumption for the winter period. This is done for both orientations and is shown in graph 4 & 5.

Graph 4 shows the different energy use for space heating for each strategy. There is a relation between the strategies and the energy use. In most cases the energy use of the east – west (E-W) orientated dwelling is higher than the north – south (N-S) orientated dwelling. Only in the case of strategy 12 the energy use of the N-S orientated dwelling is 0.3 kWh/m² higher.

The next step is to take a look at the energy reduction in relation with the existing energy use. This is done in percentage to see how much reduction there is in relation with the existing energy use. This is shown in graph 5 (next page).
Graph 5 - energy reduction in % compared to the existing situation for both orientations during wintertime
Discussion results calculations

North – south orientated dwelling

The simulated energy consumption of the north – south orientated dwelling is shown in graph 1. The different refurbishment strategies are calculated and simulated. The graph is split into 14 different calculations. A calculation represents the dwelling in the existing situation (number 1) or a dwelling in the new refurbished situation (number 2 till 14). The explanation of the different strategies is explained earlier in chapter ‘Refurbishment strategies’ on page 70.

Calculation 1 is the calculation of the dwelling in the existing situation. The result of 75.8 kWh/m² can be compared with the energy calculation done by ‘ABC-bouwkundig’. The amount of overheating is too much (338 hours). A reason for overheating is the amount of ventilation during the summer. If the ventilation amount is too little the hours of overheating will be bigger than with more ventilation. Also the insulation values of the façades will have influence on the amount of overheating.

Calculation 2 is the calculation whereby the existing façade is been improved. The improvement of the façade means an extra insulation layer is added to the outside of the façade. The minimum R-value of the closed parts of the façade is 2.5 m²K/W. The glass panels also will be improved till High efficiency glazing with a U-value of 1.2 W/m²K. The energy consumption of this strategy is 30.3 kWh/m². This means a reduction of about 59.9% compared to the existing calculation (75.8 kWh/m²). The hours of overheating is decreased till 266 hours.

The 3rd strategy is closing of the gallery. This means the gallery will become an internal space and will be a buffer zone between the outside and the inside of the dwelling. The energy reduction is not that much compared with other strategies, the total the energy reduction is 19.4 kWh/m². This means a reduction of 25.7% compared to the existing situation. The hours of overheating is about 232 hours which is acceptable, but still high.

The calculation of strategy number 4 is closing of the gallery with façade improvement on the living room side of the dwelling. This calculation is a combination of strategy 2 and 3. The energy use is 33.4 kWh/m² which is a reduction of about 56.0% compared to the existing situation. The hours of overheating is decreased till 213 hours which is acceptable.

Calculation 5 is closing of the loggia. This means the loggia will become an internal space. A thermal façade layer will be placed in front of the loggia. This way the loggia will become a buffer zone between the outside air and the inside of the dwelling. The energy consumption for space heating will be 51.4 kWh/m². This means a reduction of 32.2% on the energy consumption only by closing of the loggia. The total amount of overheating increases by 384 hours. This is caused by the new façade element in front of the structure and the old façade elements are still in use.

The next strategy (6) will be closing of the loggia (the same as the previous strategy), but with façade improvement on the rest of the dwelling. This intervention results in an energy consumption of 23.1 kWh/m². This is an energy reduction of 69.6% compared to the existing situation. The amount of overheating also decreases till 240 hours during summertime. This is still a bit high, but acceptable.

Strategy number 7 is a combination of strategy number 3 and 5, close of loggia and gallery. This means for this calculation the gallery and the loggia will be closed off from the outside. A buffer zone is created this way between inside and outside. The energy consumption is about 37.8 kWh/m². Compared to the existing situation this means a energy reduction of 50.8% for space heating. 358 hours of overheating will occur in this situation, which is higher compared to the existing situation.

The next calculation (8) is the same as the previous but now with façade improvement on the living room side. The total energy use during the year is about 24.4 kWh/m². This is a reduction of 67.9% compared to the existing situation. The amount of overheating is 285 hours, which is a bit high compared with the demand of < 200 hours.

The 9th calculation is done for façade replacement. This means the existing façade is removed and new façade elements are attached to the building. The new elements do have a minimum Rc-value of 4.0 m²K/W. This strategy results in an energy consumption of 27.4 kWh/m². This means a reduction of 63.9% compared with the existing situation. The total amount of overheating will be about 298 hours.

Façade extension is the 10th strategy that has been calculated. Façade extension means an additional structure will be added to the existing structure with a minimum Rc-value of 4.0 m²K/W. The total amount of energy use during the year will be 28.6 kWh/m². This will be a reduction of 62.3% of the energy consumption for space heating. The total amount of overheating will be about 254 hours. This is acceptable, but is still a bit high.
Calculation number 11 is almost the same as number 6 (close loggia and façade improvement) but instead of façade improvement now façade replacement is used. This results in an energy consumption of 23,1 kWh/m² which gives a reduction of 69,6% compared to the existing situation. The amount of overheating is 252 hours.

The 12th strategy is the same as strategy number 8 (close gallery and loggia with façade improvement), but with façade replacement instead of façade improvement. This results in an energy consumption of 25,3 kWh/m² during the whole year. This means an energy reduction of 66,7%. The total amount of overheating will be 291 hours during summertime.

The strategy with façade improvement without glass replacement (13) is calculated to see what the influence will be if only the façade will be improved. The energy use of this strategy is 58,7 kWh/m² each year. This means an energy reduction of 22,7% compared to the existing situation. The amount of overheating will be 265 hours which is a bit too high compared to the demands.

The last calculation (14) is a calculation done by only replacing the old glass panels for high efficiency (HR++) glazing with a U-value of 1,2 W/m²K. This results in an energy consumption of 45,6 kWh/m² each year. This means an energy reduction of 39,9% compared to the existing situation. The amount of overheating is 244 hours.

To summarise these calculations for the north south orientated dwelling:

<table>
<thead>
<tr>
<th>Strategy (N-S)</th>
<th>Energy use in kWh/m²</th>
<th>Reduction in % N-S orientation</th>
<th>Overheating in hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Existing situation</td>
<td>75,8</td>
<td>-</td>
<td>338</td>
</tr>
<tr>
<td>2. Façade improvement</td>
<td>30,4</td>
<td>59,9</td>
<td>266</td>
</tr>
<tr>
<td>3. Close gallery</td>
<td>56,4</td>
<td>25,7</td>
<td>232</td>
</tr>
<tr>
<td>4. Close gallery &amp; Fl LR side</td>
<td>35,4</td>
<td>56,0</td>
<td>213</td>
</tr>
<tr>
<td>5. Close loggia</td>
<td>51,4</td>
<td>32,3</td>
<td>384</td>
</tr>
<tr>
<td>6. Close loggia &amp; Fl all</td>
<td>25,1</td>
<td>69,6</td>
<td>240</td>
</tr>
<tr>
<td>7. Close gallery &amp; loggia</td>
<td>37,6</td>
<td>50,5</td>
<td>358</td>
</tr>
<tr>
<td>8. Close gal. &amp; log (Fl LR side)</td>
<td>24,4</td>
<td>67,9</td>
<td>285</td>
</tr>
<tr>
<td>9. Façade replacement</td>
<td>27,4</td>
<td>63,9</td>
<td>298</td>
</tr>
<tr>
<td>10. Façade extension</td>
<td>28,6</td>
<td>62,3</td>
<td>254</td>
</tr>
<tr>
<td>11. Close loggia &amp; Facade repl.</td>
<td>23,1</td>
<td>69,6</td>
<td>254</td>
</tr>
<tr>
<td>12. Close gallery &amp; loggia repl.</td>
<td>25,3</td>
<td>66,7</td>
<td>291</td>
</tr>
<tr>
<td>13. Facade imp. (wo glass repl.)</td>
<td>58,7</td>
<td>22,7</td>
<td>265</td>
</tr>
<tr>
<td>14. Glass replacement</td>
<td>45,6</td>
<td>39,9</td>
<td>244</td>
</tr>
</tbody>
</table>

*Fig. 1 - Summary of the energy use, reduction an amount of hours of overheating for the north - south orientated dwelling*
West - east orientated dwelling

The simulated energy consumption of the west - east orientated dwelling is shown in graph 2. The different refurbishment strategies are calculated and simulated. The graph is split up into 14 different calculations. A calculation represents a dwelling in the existing situation (number 1) or a dwelling in the new refurbished situation (number 2 till 14). For the west – east orientated dwelling all calculations are done the same as the calculation for the north-south orientated dwelling.

A summary of the results will be given:

<table>
<thead>
<tr>
<th>Strategy (E-W)</th>
<th>Energy use in kWh/m²</th>
<th>Reduction in % E-W orientation</th>
<th>Overheating in hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Existing situation</td>
<td>83,3</td>
<td>-</td>
<td>213</td>
</tr>
<tr>
<td>2. Façade improvement</td>
<td>36,8</td>
<td>55,8</td>
<td>197</td>
</tr>
<tr>
<td>3. Close gallery</td>
<td>71,6</td>
<td>14,0</td>
<td>274</td>
</tr>
<tr>
<td>4. Close gallery &amp; Fl LR side</td>
<td>38,6</td>
<td>53,7</td>
<td>252</td>
</tr>
<tr>
<td>5. Close loggia</td>
<td>60,1</td>
<td>27,9</td>
<td>259</td>
</tr>
<tr>
<td>6. Close loggia &amp; Fl all</td>
<td>28,6</td>
<td>65,7</td>
<td>190</td>
</tr>
<tr>
<td>7. Close gallery &amp; loggia</td>
<td>42,6</td>
<td>48,9</td>
<td>402</td>
</tr>
<tr>
<td>8. Close gal. &amp; log (Fl LR side)</td>
<td>27</td>
<td>67,6</td>
<td>311</td>
</tr>
<tr>
<td>9. Façade replacement</td>
<td>33,7</td>
<td>59,5</td>
<td>227</td>
</tr>
<tr>
<td>10. Façade extension</td>
<td>34,7</td>
<td>58,3</td>
<td>191</td>
</tr>
<tr>
<td>11. Close loggia &amp; Facade repl.</td>
<td>25,5</td>
<td>69,4</td>
<td>189</td>
</tr>
<tr>
<td>12. Close gallery &amp; loggia repl.</td>
<td>25,3</td>
<td>69,6</td>
<td>291</td>
</tr>
<tr>
<td>13. Facade imp. (wo glass repl.)</td>
<td>67,6</td>
<td>18,8</td>
<td>233</td>
</tr>
<tr>
<td>14. Glass replacement</td>
<td>53,6</td>
<td>35,7</td>
<td>197</td>
</tr>
</tbody>
</table>

Fig. 2 - Summary of the energy use, reduction an amount of hours of overheating for the north - south orientated dwelling
Conclusion calculations middle dwelling

The calculations are done for both orientations. Out of these calculations for the different strategies some strategies already can be dismissed. This can be done because of the energy consumption for space heating is too high. The energy reduction which is 50% or higher is good, but a lower ranking will not be good enough. The reason for a reduction of at least 50% is because of the Kyoto protocol. In this protocol the European Union decided to reduce the greenhouse gas emission with at least 20% in 2020, but in new agreements they want to reduce the greenhouse gas emissions with at least 30% in the year 2020.1

For this calculation counts 60% of the energy consumption is used for space heating. To accomplish the 30% reduction target for these dwellings at least 50% reduction is already good enough to accomplish this (60% * 50% = 30%). Every other part that will change in the building will be beneficial for the energy reduction of the building.

Another point of attention for the calculation is the amount of hours the dwelling will be overheated. Overheating means the indoor temperature of the dwelling is > 25,5 °C. If there is overheating > 300 hours, the comfort of the indoor climate is insufficient. A desirable amount of overheating is < 200 hours, if this is accomplished a good indoor climate is achieved.

The reason to choose for a strategy depends on the energy reduction during the whole year and during wintertime. Also the amount of overheating can influence the decision to choose for a strategy. So a strategy can be dismissed if the energy reduction is too small or the amount of overheating is too much.

With this in mind there are 8 strategies left to refurbish the building. First the calculations of the north - south orientated dwelling will be discussed. The energy reduction differs from 53,7% - 69,6%. This means the higher the percentage the better the energy reduction is for the dwellings. In this case strategy 4 has got a positive impact on the energy use. Strategy 2, 9 and 10 are even better. The best strategies are number 6, 8, 11 and 12 out of these calculations. The differences are not that big but each strategy is also influenced by other criteria. These criteria (table 5, page 82) also must be taken into account.

The results of the calculation during wintertime are shown in table 2. The same strategies are used as the strategies used in the whole year calculation. The energy reduction during wintertime differs from 57,0% - 69,8%. This means during wintertime almost the same energy reduction can be accomplished compared to the whole year calculation.

The strategy with a good energy reduction is: strategy 2 and 4. A better strategy will be 9 and 10. Strategy 6, 8, 11 and 12 will be the best solution. During wintertime strategy 6, 8, 11 and 12 will reduce the energy demand for space heating the most.

The amount of overheating for the different strategies also must be taken into account. Graph 1 (page 72) shows the amount of overheating > 25,5°C together with the energy use in kWh/m². None of the strategies meets the requirements of < 200 hours. The amount of overheating lies between 240 – 298 hours for the chosen strategies. This amount of overheating is still too much, but this can be reduced with more ventilation, sun shading or additional balcony. Out of the calculations strategy 2 (266), 8 (285), 9 (298) and 12 (291) are the ‘worst’ solutions. Strategy 6 (240), 10 (254) and 11 (252) are the best solutions.

### Table 1 - Energy use and reduction of the best overall solutions during the year

<table>
<thead>
<tr>
<th>N-S energy use 75,8 kWh/m²</th>
<th>Energy use</th>
<th>% Energy reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Façade improvement</td>
<td>30,4 kWh/m²</td>
<td>59,9</td>
</tr>
<tr>
<td>4. Close gallery &amp; Fl LR side</td>
<td>33,4 kWh/m²</td>
<td>55,9</td>
</tr>
<tr>
<td>5. Close loggia &amp; Fl all</td>
<td>33,1 kWh/m²</td>
<td>69,5</td>
</tr>
<tr>
<td>8. Close pat. &amp; log (Fl LR side)</td>
<td>28,4 kWh/m²</td>
<td>67,6</td>
</tr>
<tr>
<td>9. Façade replacement</td>
<td>27,4 kWh/m²</td>
<td>63,9</td>
</tr>
<tr>
<td>10. Façade extension</td>
<td>28,6 kWh/m²</td>
<td>62,3</td>
</tr>
<tr>
<td>11. Close loggia &amp; Facade repl.</td>
<td>23,1 kWh/m²</td>
<td>69,5</td>
</tr>
<tr>
<td>12. Close gallery &amp; loggia repl.</td>
<td>25,3 kWh/m²</td>
<td>66,6</td>
</tr>
</tbody>
</table>

= Good

= Better

= Best

### Table 2 - Energy use and reduction of the best overall solutions during wintertime

<table>
<thead>
<tr>
<th>N-S total energy use winter time 69,8 kWh/m²</th>
<th>Energy use</th>
<th>% Energy reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Façade improvement</td>
<td>29,5 kWh/m²</td>
<td>57,7</td>
</tr>
<tr>
<td>4. Close gallery &amp; Fl LR side</td>
<td>32,3 kWh/m²</td>
<td>57,0</td>
</tr>
<tr>
<td>5. Close loggia &amp; Fl all</td>
<td>22,7 kWh/m²</td>
<td>69,8</td>
</tr>
<tr>
<td>8. Close pat. &amp; log (Fl LR side)</td>
<td>23,9 kWh/m²</td>
<td>68,2</td>
</tr>
<tr>
<td>9. Façade replacement</td>
<td>26,8 kWh/m²</td>
<td>64,3</td>
</tr>
<tr>
<td>10. Façade extension</td>
<td>27,8 kWh/m²</td>
<td>63,0</td>
</tr>
<tr>
<td>11. Close loggia &amp; Facade repl.</td>
<td>23,1 kWh/m²</td>
<td>69,2</td>
</tr>
<tr>
<td>12. Close gallery &amp; loggia repl.</td>
<td>24,7 kWh/m²</td>
<td>67,1</td>
</tr>
</tbody>
</table>

= Good

= Better

= Best

1 http://www.europahoortbijnederland.nl/toon/1/14/23/Milieu%20en%20Energie#Kyoto_IL_van_20__naar_30__ (visited 21/03/2011)
The second calculations are done for the east-west orientated dwelling. Both calculations are done; the whole year calculation and wintertime calculation will be taken into account. The results of the calculations with 50% or more energy reduction for the whole year are shown in table 3. In total 8 strategies are left to refurbish the building. The energy reduction differs from 53,7% – 69,6%. For the calculation during the year strategy 4 is good. Strategy 2, 6, 9 and 10 are better, but strategy 8, 11 and 12 are the best according to these calculations. The difference between the ‘worst’ strategy (53,7%) and the ‘best’ strategy (69,6%) is 15,9%.

The results for the calculation of the energy use during wintertime are shown in table 4. The same strategies are used as the strategies for the whole year calculation. The energy reduction during wintertime differs from 53,2 – 66,5%. This is a maximum difference of 11,2% energy reduction. In this case strategy 2 and 4 will be a good solution, strategy 9 and 10 are a better option, but 6, 8, 11 and 12 do have the best energy reduction during wintertime.

The amount of overheating hours for these strategies differs from 190 – 311 hours. The worst solution with 311 hours is strategy 8 (close gallery and loggia). The amount of overheating for this strategy can be reduced with more ventilation or with extra sun shading on the gallery side.

The amount of overheating for the strategies 4 (252), 9 (227) and 12 (291) is better, but still the hours of overheating are too much. The strategies with the least hours of overheating are: 2 (197), 6 (190), 10 (191) and 11 (189). This means these strategies meet the requirements of <200 hours overheating for a comfortable indoor climate.

### Table 3 - Energy use and reduction of the best overall solutions during the year

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Energy use kWh/m²</th>
<th>% Energy reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Façade improvement</td>
<td>38,6</td>
<td>55,8</td>
</tr>
<tr>
<td>4. Close gallery &amp; FLR side</td>
<td>38,6</td>
<td>53,7</td>
</tr>
<tr>
<td>6. Close loggia &amp; FL all</td>
<td>28,6</td>
<td>65,7</td>
</tr>
<tr>
<td>8. Close gal. &amp; log (FLR side)</td>
<td>27</td>
<td>67,6</td>
</tr>
<tr>
<td>9. Façade replacement</td>
<td>33,7</td>
<td>59,5</td>
</tr>
<tr>
<td>10. Façade extension</td>
<td>34,7</td>
<td>58,3</td>
</tr>
<tr>
<td>11. Close loggia &amp; Facade repl.</td>
<td>25,5</td>
<td>69,4</td>
</tr>
<tr>
<td>12. Close gallery &amp; loggia repl.</td>
<td>25,3</td>
<td>69,6</td>
</tr>
</tbody>
</table>

### Table 4 - Energy use and reduction of the best overall solutions during wintertime

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Energy use kWh/m²</th>
<th>% Energy reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Façade improvement</td>
<td>34,9</td>
<td>53,2</td>
</tr>
<tr>
<td>4. Close gallery &amp; FLR side</td>
<td>34,5</td>
<td>53,8</td>
</tr>
<tr>
<td>6. Close loggia &amp; FL all</td>
<td>27,8</td>
<td>62,7</td>
</tr>
<tr>
<td>8. Close gal. &amp; log (FLR side)</td>
<td>26,5</td>
<td>64,5</td>
</tr>
<tr>
<td>9. Façade replacement</td>
<td>32,2</td>
<td>56,8</td>
</tr>
<tr>
<td>10. Façade extension</td>
<td>33</td>
<td>55,8</td>
</tr>
<tr>
<td>11. Close loggia &amp; Facade repl.</td>
<td>25,5</td>
<td>65,8</td>
</tr>
<tr>
<td>12. Close gallery &amp; loggia repl.</td>
<td>24,4</td>
<td>67,3</td>
</tr>
</tbody>
</table>
Calculations roof dwelling

The top dwelling of the building is connected to the outside. This means the floors and the walls are connected to another, adjacent dwelling, but the roof is connected to the outside. There are made energy calculations for the top dwellings of the building. These dwellings do have a flat roof with insufficient insulation on top of it. The existing insulation Rc-value of the roof is 1,0 m²K/W. This not according the design values of 5,0 m²K/W, the requirements for the case study building. An insufficient insulation layer is bad for the energy efficiency of the building. That is why a proper insulation layer can take care of a lot of energy reduction.

For some strategies there are made calculations in the situation with the existing roof insulation (1,0 m²K/W) and calculations with roof insulation (5,0 m²K/W). The results of these calculations are shown in graph 6.

Out of the calculations can be concluded that the energy consumption for a roof dwelling can be reduced a lot. Next to the refurbishment strategy the roof insulation has got a positive influence on the energy use. It depends on the strategy, but the energy reduction is between 21,9% - 38,4% for the whole year calculation. The energy reduction is the reduction compared to the situation without roof insulation. Every strategy has got its own reduction, but out of the calculations it becomes clear a lot of energy can be saved by an extra insulation layer on top of the roof.

Extra insulation on top of the roof gives a positive influence on the energy use of the dwellings. The new insulation layer can be put on top of the old insulation layer, but maybe it is better to replace the old insulation layer for a new one. This is something which has to be investigated.

Graph 6 - energy use of different strategies (roof dwelling)
Overall conclusion calculations

For the overall conclusion it will be necessary to take a look at the other criteria mentioned before. The different criteria like: impact on the residents, impact building, execution, climate, installations, facade possibilities, technical bottlenecks improvement, generic solution, impact on energy use, costs (estimation) will be taken into account. Next to that the energy reduction of each strategy will be taken into account. This way a decision can be made for the refurbishment solution.

The remaining strategies that are left are:

2. Façade improvement
4. Close gallery and façade improvement
6. Close loggia and façade improvement
8. Close gallery + loggia with façade improvement
9. Façade replacement
10. Façade extension
11. Close loggia and façade replacement
12. Close gallery + loggia and façade replacement

Out of the calculations for the north – south orientated dwelling strategy 6 (lose loggia and façade improvement), 8 (Close gallery + loggia with façade improvement) and 11 (close loggia and façade replacement) are the best overall solutions in terms of energy reduction and hours of overheating. To see if these strategies are feasible the other criteria also must be taken into account. Also the other strategies will be tested on the other criteria to see which strategy is the most beneficial.

For the east-west orientated dwelling the best solutions are strategy 6 and 11. Strategy number 11 is the best solution in terms of energy reduction during wintertime and has got the least hours of overheating.

Out of the different solutions and calculations there can be concluded that there are several options to refurbish the case study building. It depends on the criteria which solution will be the best. Out of the investigated solutions it becomes clear all the solutions have got different influences on the energy use of the building/dwelling.

Façade improvement is a solution which can be used for this type of building, but this way only the façade will be improved and the thermal bridges will stay intact. There are not a lot of façade possibilities because the existing façade elements will used again. The existing frames are not that good insulated so it is better to replace these elements. The impact on the energy use is positive, but there are strategies which have better results on the energy use. The insulation value of the façade elements can only be improved limited because of the thickness of the walls if an extra layer is in front of the elements.

If the façade elements will be replaced the big advantage is that the insulation value can be increased a lot. This is harder to do by façade improvement because of the extra thickness of the elements. If the elements will be replaced the insulation value can be determined by the demands that made up earlier in this thesis. The façade possibilities are better because in the new façade facilities can be added.

The strategy to close of the loggia or gallery is a strategy which can be used for these types of building. The calculations show this solution is beneficial for the energy use, but not always that high compared to other solutions.

Closing of the loggia has a positive impact on the energy use of the dwelling. This can be explained by the fact the 3 façades of the loggia are not well insulated. Also the connection from the loggia to the structure is not that good. The connection has got thermal bridges from the outside of the structure to the inside.

Closing of the loggia can influence the building in its appearance and the interaction with the outside, but these points can be solved by architecture and building materials. People with a closed loggia can open or close the panels for to ventilate the loggia and the underlying space. The interaction can still be there with the street. Another point to close of the loggia can be that this way the loggia can be used a longer period during the year. It can be seen as a 'winter garden'.

Closing of the gallery is a total different aspect because the gallery is everybody's property. Everybody can use the gallery. Also the interaction with street level is lesser if you close of the gallery. On a 10 or more story high flat the interaction with street level is will be lesser than on a 4 story high building. On a lower building there can be interaction with the outside and the street.
In a gallery which is placed on the east, south or west side the temperature can raise a lot. If the temperature is too high ventilation will be necessary otherwise residents will complain about the high temperatures inside the gallery. Another point of attention is the ventilation of the underlying spaces like the living room, the kitchen, hall and bedrooms. If the gallery is closed these spaces cannot be ventilated with fresh air directly. The bathroom and toilet can be ventilated with air out of the other spaces. During the year the façade should act like a thermal buffer. It must have got the possibility to open or close some elements. Because the area is everybody’s property this will be hard to regulate. On the other hand this solution directly solves a lot of technical problems because of the extra façade that is placed in front of the structure.

There is also the possibility to close of the gallery and the loggia both. This way a lot of technical problems will be solved. On the side of the gallery the thermal bridges will be gone because of the new façade in front of the old structure. The bad insulated walls of the loggia will be closed off to the outside. This way the loggia is not a thermal leak anymore but just a ‘winter garden’ where people can stay more days during the year. The loggia can be used by each resident individually, but the gallery is used by everybody. Closing of the gallery brings more problems that must be solved. First of all the use of the gallery during the year must be regulated. During winter and summertime there are other climate conditions. It cannot be too cold inside the gallery but also not too hot. The second problem is the indoor climate of the dwellings. The spaces in the dwellings must be ventilated on a natural way with fresh air. The bathroom and toilet can be ventilated with air which comes from the other spaces. There are two options to accomplish this: Direct connection to the outside, with a duct or to ventilate the gallery that much the air can be used to ventilate the dwelling, but then the thermal buffer will be lost.

The last solution to refurbish the dwellings is to extend the structure. This extension can be done on two side of the dwelling. One option is the gallery side and the other one is the living room side. By adding an extra layer in front of the structure the thermal bridges can be removed. Extension on the living room side will create a bigger living room thus extra floor area and a bigger loggia. Extension on the gallery side will give bigger bedrooms and a bigger kitchen. The old gallery will be part of the dwelling and the new structure will become the new gallery. This intervention is intensive and new connections from the old to the new structure must be created. This situation will mean new floor plans will arise and a lot of interventions and adjustments to the dwelling must be done. This will have large impact on the residents.

The end conclusion to refurbish the building is a combination of different refurbishment concepts. It contains improvement, replacement and extension. The prefabricated concrete elements, which are attached to the structure, will be improved with an extra insulation layer. The plastic window frames will be replaced for new window frames with higher insulation values. In the end extra floor area will be gained by the addition of an external balcony. This balcony will have its own structure so it is building independent.
Overall improvement of the building

Next to the façade refurbishment there are other points for the building that must be improved. Not only the façade and with this the energy reduction must be improved, but also other parts needs to be renewed. During the site visit with Ron Veldhuys (Rochdale) and the meeting with Anneke Haringa (Delta Forte) it becomes clear some parts of the building needs to be renewed because this can improve the overall appearance of the building.

There are plans to refurbish the building. For this building there is made a report with some aspects that are planned to refurbish in the building. Points of attention are the social aspect and the accessibility of the building. The building can be entered by everybody who wants to get into the building. The entrances are not secured. This gives an unsafe feeling to the residents of the building. Some points out of the report:

- Improve social security
- Improve architectural appearance of the building
- Modernizing entrances and staircases (more clarity, light and visibility)
- New mailboxes together with videophone installation
- More light in storage space
- Close of the building to gain more security (electronic)
- Placing elevator the improve access to dwellings
- Change appearance of the building by applying new elements on façade (galleries and balconies)
- Improve plinth with new garage doors and colours
- Security system with cameras
- Placing a central antenna system (satellite and analogue TV)
- Improve the roof and chimneys

These are the main points that must be improved on building scale. Points of attention for each dwelling are also discussed in the report.

The main topic is about the insulation of the dwellings. If the insulation of the dwelling improves it will also be necessary to improve other aspects in the dwelling. If the dwelling is not ventilated enough moist and mold can occur. It is necessary to ventilate the dwelling properly. The dwelling can be ventilated by a central ventilation system or by a decentralised system.

In the report some points are discussed but not worked out because these points do not have much in f°luence on the Energy Index = energy label off the dwelling.

The point of extra insulation on the roof is discussed. If 100 mm of insulation is attached to the roof the top dwellings will go from energy label F till energy label B. Insulation of the plinth is a possibility. This can be done, but then also the garage doors must be renewed and isolated. Another option is to add an insulation layer to the ceiling of the storage boxes.

The corner dwellings are connected to another dwelling on one side and to the outside air on the other side. The wall between the inside and outside is a masonry cavity wall. This wall can be insulated extra to prevent the walls will become too cold, but to be sure of the state of the art of these walls, further investigation will be necessary.1

Sketch impression existing situation

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1 Initiatiefnotitie definitief 3.0 AANGEPAST (1) (report provided by DeltaForte, A. Haringa)
Overall conclusions refurbishment case study building

The final decision to refurbish a building depends on many actors. Not only the energy reduction is important but also residents, way of working, execution, exploitation of the building, future plans building or area, costs and the state of the building.

For the refurbishment of this building is chosen to refurbish the building while it will be occupied by the residents. This means the residents can stay in the building during refurbishment. Of course there will be some noise from drilling and workers, but in the end the building needs to be refurbished.

Because of the different orientation of the dwellings different strategies can be beneficial for the energy reduction of the dwellings. The best overall solution is closing of the loggia in combination with façade replacement or improvement. The prefabricated concrete elements will be improved with an extra insulation layer. The energy reduction will be about 67,5% (for space heating) for both orientations with these interventions.

This solution will take care of the thermal bridges on the loggia side. By placing a thermal layer on the outside of the structure these connections will be no thermal bridges any more. Also a new space in the dwelling is added which can be used more days a year. On the living room side an external balcony will be added. This way the thermal bridges can be solved on that part of the façade.

In both orientations it is clear closing of the loggia has got a positive influence on the energy use of the dwelling. In combination with façade improvement or replacement. A reduction of about 67,5% for space heating can be reached this way. Also the loggia can be used more days a year. The loggia is about 4,6 m² so if this area can be used more days a year this will be beneficial for the residents.

There is chosen to replace the existing façade elements for new elements because of the façade possibilities and this way the technical bottlenecks can be improved better. The elements can be prefabricated in such a way the thermal bridges can be improved right away.

The solutions with façade replacement and façade extension are both good options to think about. Façade extension means more floor area can be gained. Façade replacement will have a positive effect on the indoor climate and comfort.

The dwellings are built up with 2 different façade elements. One element is a prefabricated frame which can be replaced easily and the other element is a prefabricated concrete element. This concrete element is attached to the structure so it will not be easy to replace this element. That is why the refurbishment will be a combination of replacing and improving the façade. The façade frames will be replaced for new façade elements and the prefabricated concrete elements will be improved. This can be done by adding an insulation layer in front of the prefab element with a finishing layer.

For the north – south orientated dwelling also a calculation is done for an extension of the façade. An extra balcony is placed on the south side of the dwelling. This additional balcony will gain extra floor area for the residents. Cause of the additional balcony extra space heating will be necessary. Out of the calculations this will be about 6 kWh/m². This means the energy efficiency will be a bit lower. This is caused because of the bigger glass area and the balcony which blocks the direct sunlight into the living room. On the other hand new floor area can be gained and the residents will have an outside area again. During summertime the balcony will take care of protection against overheating. The balcony will protect the living room by overheating because it will block direct sunlight. The energy consumption for space heating will be about 29,0 kWh/m² for the whole dwelling.
**Improvement refurbishment strategy**

The next steps for this master thesis are to work out the chosen strategy and work this strategy out in detail. The chosen strategy must be optimised in terms of energy use, comfort, materials, execution, architecture and impact on residents. The energy reduction can be done by better insulation of the façade and the building in total, but also with new installations and materials energy can be reduced more.

The strategy that will be worked out in detail is strategy number 11, closing of the loggia and façade replacement. This is the best overall strategy to gain the most energy reduction; execution is positive and does not impact the residents too much. The technical aspects can be improved as well as the climate and comfort of the building. The strategy is a generic solution for gallery flats, but also for porch flats.

The prefabricated elements will be improved with an extra insulation layer. Replacing this elements will be a though job because they are anchored to the structure. For this building the façade will be extended with an external balcony. This balcony has got its own structure. It will be independent of the existing structure of the building.

Most of the energy consumption of the dwelling is lost to space heating and hot water. In total 84% of the energy is used for space heating (59%) and hot water (25%). The other energy consumers are: extra energy (6%) and lighting (10%). Most profit can be made by reducing the energy consumption for space heating and hot water.

Reducing the energy consumption for space heating can be done by better insulated façades and to improve the façade connections to the structure. For the hot water a solar collector can be used. This solar collector can provide hot water. This way energy can be reduced for hot water. The energy reduction can be about 45 - 50%, but this depends on the use of hot water.¹

The first step is to take a look at the materials which can be used for the new façades. A lot of materials can be used, but not every material will be suitable to use. The second step is to take a look at the ventilation concept and how this can be regulated. Together with these steps it will be necessary to take the execution of the strategy in account.

**Indoor climate**

The existing ventilation concept of the dwellings is insufficient. The residents have complaints about the ventilation and it is not working properly. To create a sufficient ventilation concept a new system must be used in the building. There are several options that can be used to ventilate the dwellings: Central ventilation, decentralised ventilation, mechanical or natural inlet/exhaust. Some concepts do have the possibility to use heat recovery. This way the energy reduction can be even higher.

**Insulation**

Out of the requirements the insulation values for the building are determined. The design values for the different parts of the building are:

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Design value (EPC: 0.6)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rc-value façade</td>
<td>4.0 m² · K/W</td>
</tr>
<tr>
<td>Rc-value roof</td>
<td>5.0 m² · K/W</td>
</tr>
<tr>
<td>Rc-value floor</td>
<td>4.0 m² · K/W</td>
</tr>
<tr>
<td>U-value doors/windows</td>
<td>1.5 - 1.2 m² · K/W</td>
</tr>
</tbody>
</table>

These values are used to design the building. The values are determined for a EPC value of 0.6 and are a guideline for new designed buildings to make them energy efficient.

**Solar energy**

Solar energy is energy which is provided by the sun. This energy is free for everybody. There are several products which can be used to gain profit out of the solar energy. In building sector the most used products are: photovoltaic cells (PV-cells) and solar collectors.

Photovoltaic’s (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of cells containing a photovoltaic material. Materials presently used for photovoltaic’s include mono-crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium solenoid/sulphide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic panels has advanced considerably in recent years.

PV cells are often associated with buildings: either integrated into them, mounted on them or mounted nearby on the ground. Solar panels are most often retrofitted into existing buildings, usually mounted on top of the existing roof structure or on the existing walls. Alternatively, an array can be located separately from the building but connected by cable to supply power for the building. In 2010, more than four-fifths of the 9,000 MW of solar PV operating in Germany was installed on rooftops.

² [http://regelingen.agentschap.nl/content/concepten-epc-06-energieprestatie-nieuwbouw-epn (visited 10/12/2010)]
Building-integrated photovoltaic’s (BIPV) are increasingly incorporated into new domestic and industrial buildings as a principal or ancillary source of electrical power. Typically, a panel is incorporated into the roof or walls of a building. Roof tiles with integrated PV cells are also common. The power output of photovoltaic systems for installation in buildings is usually described in kilowatt-peak units (kWp). PV-cells can be placed on several parts of a building like: a roof, balconies, façades, roof edges or sun shading.

Solar collectors
A solar collector is a device that turns sunlight into heat. This heat can be used to heat up water. The hot water can be used for hot water consumption or space heating. It is also possible to store heat into the ground in summertime. During wintertime these heat can be used, in combination with a heat exchanger, for space heating. This is an energy efficient method to heat up a space and gives a big reduction on the CO2 emission. The heat of the sun is cached into the solar collector by radiation and conduction. The solar collector is combined with an extra boiler most of the time. The solar collector pre heats the water and the boiler will bring the water on the desired temperature. Solar collectors consist of the following parts:
- Collector
- Circuit
- Storage tank
- Controller

The most important part of the solar collector is the collector itself. This part will catch up the sunlight and turns this into heat. This heat is given to fluid water. The collector consists of a glass layer, an absorber and insulation. The absorber is a plate or more plates which will be heated up by the sunlight. Through these plates tubes are running. Water is running through these tubes and gives the heat to a storage tank. Water is running through a circuit. Some heat will be lost because the absorber will lose something the environment. This can be reduced by the insulation layer on the back of the absorber. In the front the collector a glass plate is there to reduce the energy losses to the outside air by convection. The capacity of the collector to heat up the water is not sufficient enough to produce hot water right away. That is why the system uses a storage tank. The tank can store hundreds litres of water. The tank is a buffer between the storage capacity and the use of hot water. Also when the sun is not shining the tank can be a buffer. The heat is given by a closed system via a heat exchanger. This way the quality of the water is guaranteed.

Trisco models
The most critical connections of the building are the connections from the loggia with the structure and the connection from the gallery to the structure. Improvement of these connections will be necessary to improve the indoor climate and the energy efficiency of the dwelling. These connections, the so called thermal bridges, causes heat losses through the structure. Most of the time in these connection moisture and mold will arise. To prevent this a solution must be found to improve these connections. If a proper solution is found to do this the solution can be used within this refurbishment concept.

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3 http://en.wikipedia.org/wiki/Photovoltaic_effect
4 http://www.zonne-energie.ws/zonnecollectoren/
**Trisco models**

The most critical connections of the building are the connections from the loggia with the structure and the connection from the gallery to the structure. To show this a Trisco model is made. In this model the connection of the gallery and the console to the structure are built up. Trisco is a program to simulate the temperatures and heat flux in a structure on a schematic way. In figure 1 & 2 the existing situation is shown. Left is the model itself and on the right the temperature differences are shown. There are made 2 models. One model is to see what the influence will be if the gallery will be packed into an insulation layer. The other model is to see what the influence will be if the gallery or the loggia will have a new façade layer in front of the structure.

Figure 3 on the left shows the existing situation of the connection of the gallery to the inside of the structure. There is 15 mm of EPS insulation in between the prefab gallery and the structure. This is not enough to have a proper detail. This connection is comparable to the connection of the loggia. The only difference is the loggia has got 3 walls which are connected like the gallery side.

First the model with extra insulation on top and bottom of the gallery will be discussed.

Figure 4 on the left shows the gallery when it is packed into an insulation layer. There is difference with the existing situation, but still there are heat losses by the gallery. The insulation improves the thermal bridge of the gallery to the structure.

Figure 5 on the left shows the gallery when it is packed into an insulation layer for the half of the gallery. There is not a lot of difference with the previous simulation.

An extra insulation layer on top and the bottom of the gallery is a possibility to improve the thermal bridges. The advantage of extra insulation on the gallery will be that the accessibility of the dwellings will increase, because the extra layer will make the gallery higher. The connection of the console to the structure is a point of attention. This is also a thermal bridge. The thermal bridge of the console can be improved by also adding a new insulation layer, but this will be a very intensive solution. This way the thermal bridge will be gone, but the total percentage of thermal bridge already decreases by insulation the gallery. Insulation on the console can be a possibility but for now it will not be taken into account.
The second model that will be discussed is the model with a new façade layer in front of the existing structure. There are simulated two models. One model is with only single glazing in front of the structure and the second one is with an insulation layer in front of the concrete slab. The models are shown in figure 6 & 7. The model is made for both solutions; closing of the gallery and closing of the loggia. The layer in front of the loggia will have more effect because this part of the building has got 3 bad insulated walls. The connection of these walls is not that good so this way 3 critical connections can be solved.

There is not a lot of difference between both models for closing of the loggia. The only difference is the temperatures in the slab itself. The model with the insulation layer in front of the slab acts better than the one without, but this is not that much.

Conclusion Trisco model
Out of the Trisco models the heat losses from the critical connections will decrease for both solutions. The heat losses of the structure with the proposed adjustments compared to the existing situation will be improved. An extra insulation layer on top and on the bottom of the gallery will take care of less heat losses. The temperature difference on the side of the structure will be better and this way less condensation will occur in the corners. The connection will be even better if the façade element can be replaced and can be in one line with the new insulation layer. This way the detail can be improved even better. The extra façade layer in front of the loggia is a good solution to reduce the heat losses at the loggia. Also the bad insulated façades are not in direct contact with the outside air anymore. This way the heat losses can be reduced and a thermal buffer can be created between inside and outside.
Explanation typical details

The most common problems with thermal bridges is explained in the previous chapter. In this chapter 2 typical details will be explained. The two details that will be explained are the gallery detail and the loggia detail. In the previous chapter the behaviour of the detail during by a temperature of -10°C is investigated and explained. These are the two most critical connections in the building. First the gallery detail will be explained.

The first idea was to close of the gallery, but after some pros and cons there is decided to improve the detail on another way. Removing the existing gallery and place a new one instead is investigated, but this is not really a generic solution. Figure 10 shows the typical detail of the gallery in the new situation. In figure 3, 4 and 5 (page 84) the influence is shown of the new insulation layer in front of the window frame on the top and the bottom side of the gallery.

In the figures can be seen it will be not efficient to wrap around the whole gallery. The extra layer of about 250 mm of insulation in front of the window frame will have almost the same impact on the thermal bridge as wrapping around the whole gallery with insulation.

The other improvement is done by replacing the old plastic window frames for new plastic window frames. Plastic frames are chosen because of the higher insulation value compared to aluminium profiles. The $U$-value of the plastic window frames is about 1.1 - 1.7 W/m²K.1

The accessibility of the dwelling can be improved by adding a new structure on top of the gallery. By adding this structure the dwellings will be better accessible for everybody, not only for ageing people but also for disabled people.2

The drainage of the water is regulated by the existing rain pipes which crosses the gallery. When these pipes are blocked for a reason the water can escape on the edge of the gallery. It is not possible to enter the rooms behind the façade because this higher than the lowest point of the gallery.

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1 http://www.schuecoworkspace.nl/kunststof_ramen_deuren.asp?pageID=&w=&pId=10&aV=Omschrijving
2 http://www.q-netics.nl/galerijverhoging.html
The next detail that will be explained will be the loggia detail, figure 13. Out of the calculation it becomes clear that closing of the loggia will be beneficial for the energy reduction of the building. There is the possibility to improve the existing façades, but this way the floor area of the loggia will be less compared to the existing situation. Also the thermal bridges which are there because of the bad connection will not be improved. In figure 6 and 7 (page 85) is shown the improvement of the detail compared to the existing situation. This can never be accomplished by only improving the existing façade elements.

The first idea was to create a new ‘indoor’ space which can be used as an outdoor space or balcony also. This can be done if the additional balcony, which is used for this master thesis, cannot be used. The detail shows the connection of the new Solarlux façade elements to the existing loggia. The elements do have the possibility to open the loggia in total. This way the feeling of an outside area can be simulated and the underlying space still can be ventilated on a natural way. Another option is to remove the old sliding door and add the new floor area to the dwelling as an inside space. This way the floor area of the dwelling will increase and will give more comfort.

Closing of the loggia will take care of erasing 3 bad insulated façades in one time. The insulation value of the loggia will increase by adding a new layer in front of the structure. Also the heat losses from the living room to the outside air will be reduced because the loggia space becomes an ‘indoor’ space and it will be no longer an outdoor space. The residents will have a new area in their dwelling which can be used more days a year.

In the existing situation a concrete slab is recognisable in the façade. To get this ‘slab’ back in the new refurbished façade a slab of polyester concrete will be used. Polyester concrete is concrete made out of polyester resin, quartz sand and quartz grains. It is tougher than normal concrete and has got better mechanical and chemical properties.  \[1\]

Fig. 12 - Example of polyester concrete

In figure 13 it can be seen how the new situation looks. The old sliding door is closed and the new Polyconcrete slab is shown. The new Polyconcrete slab is made of polyester resin, quartz sand and quartz grains. This makes the slab tougher and gives it better mechanical and chemical properties.

In the existing situation a concrete slab is recognisable in the façade. To get this ‘slab’ back in the new refurbished façade a slab of polyester concrete will be used. Polyester concrete is concrete made out of polyester resin, quartz sand and quartz grains. It is tougher than normal concrete and has got better mechanical and chemical properties.  \[2\]

Fig. 12 - Example of polyester concrete

Fig. 13 - Gallery detail in the new situation, more details can be found in the appendix

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2. [http://www.imcoma.com/images/Stora-Drain%20Technische%20handleiding%202010-03%20NL.pdf](http://www.imcoma.com/images/Stora-Drain%20Technische%20handleiding%202010-03%20NL.pdf)
Old vs. new situation

In this chapter the old situation will be compared to the new situation. The old situation and new situation will be shown in pictures, renders and technical drawings. In these drawings the used materials can be explained together with the execution of the refurbishment.

A comparison between the old and new energy consumption will be discussed and how this can help to reduce the energy on bigger scale. The façade will take care of a lot of energy reduction, but there are more techniques to reduce the energy use of the building. Extra installations in the building can take care of extra energy reduction and make the building even more energy efficient.

Not every drawing will be in the report. All the drawings (old and new situation) can be found in the appendix. The new situation will be a refurbishment with closing of the loggia, façade replacement and façade improvement. The window frames will be replaced with new ones. The prefabricated concrete elements will be improved with an extra insulation layer and an external balcony will be added to the dwelling. The loggia will be closed of with a thermal layer so this space can be used more days a year. The façade elements will have the possibility to ventilated the loggia and the underlying bedroom with fresh air. In front of the living room the possibility is investigated to add an external structure to create balconies is front of the structure. This way the floor area will be bigger and the residents will have an outdoor space again. This can be done for this case study building, but it is possible this will not be applicable to other buildings.

The new energy calculations are shown underneath. First the existing situation is shown. Second is the new situation without solar collectors. The third situation is the one with solar collectors.

Simulation Capsol existing situation
- Heating 531 m³ gas 18.670 MJ Primary energy
- Water 277 m³ gas 9.745 MJ
- Extra energy 237 kWh 2.184 MJ
- Lighting 420 kWh 3.877 MJ 34.476 MJ Primary energy use

Simulation refurbished situation
- Heating 203 m³ gas 7.140 MJ Primary energy
- Water 277 m³ gas 9.745 MJ
- Extra energy 237 kWh 2.184 MJ
- Lighting 420 kWh 3.877 MJ 22.940 MJ Primary energy use

Simulation refurbished situation and solar collectors
- Heating 203 m³ gas 7.140 MJ Primary energy
- Water 168 m³ gas 5.900 MJ
- Extra energy 237 kWh 2.184 MJ
- Lighting 420 kWh 3.877 MJ 19.100 MJ Primary energy use

Use of solar collectors
The use of solar collectors is beneficial for the energy reduction. The energy used for hot water is 25% of the total energy consumption of the building. With the use of solar collectors the energy consumption for hot water can be reduced till 45 -50%\(^1\). For this calculation an energy reduction of 40% has been taken into account because the solar collectors will be connected to a collective solar collector and not an individual one. If the use of a solar collector still is feasible in terms of earning back the investment will be the question, but it will help to reduce the energy consumption of the building.

Use of solar collectors

1. http://www.vanderweerd.net/nl/disciplines/klimaattechniek/zonneboiler.html (visited 03/06/2011)
Calculation energy label and EPC
The existing building is calculated by the company 'ABC-bouwkundig'. The energy labels of the dwellings are shown in the appendix. For the middle dwelling a calculation is done and the report show the energy label of the particular dwelling has got energy label D. Parts of this report are shown in the appendix.

The report show the energy label, energy index and energy consumption. In the program ECW V3.00 an energy calculation can be made and this way the energy label, index and consumption can be calculated.

To get an idea about the new energy label for the refurbished dwelling the same properties are put into the program ECW V3.00. This way the new situation also can be calculated with the new energy label and consumption.

The different energy calculations are shown in graph 1. Number 1 is the calculation done by ABC-bouwkundig. These values are given in the report. The other calculations 2 till 6 are the calculations done in the program ECW V3.00. The 2nd calculation is the existing situation of a middle dwelling in the building. The dwelling is labelled D which is not too bad, but it is the best dwelling in the building. 29 dwellings are labelled D. The other 67 dwellings are labelled E (46 dwellings) or F (21 dwellings).

The calculations 3 – 6 are the improved calculations of the building with the new façade elements and the closed loggia, calculation number 3 with energy label A. The 4th calculation is done with natural ventilation (intake) and mechanical ventilation (exhaust). This improves the energy index till 0,89 with an energy label A.

Calculation number 5 is with the use of a collective solar collector system (2,0 m² / dwelling). The energy index is lower till 0,76. Also the use of gas decreases from 394 till 302 m³ gas.

Calculation number 6 shows even an A+ label can be reached. This label can be reached if PV-cells are used in the design. In this calculation 3 m² of PV-cells are used per dwelling. These cells are placed on the façade with an angle of 90°. This is not ideal, but it shows an A+ label can be reached with the use of PV-cells onto the façade.

EPC calculation
Next to the energy label there is another option to calculate the energy efficiency of a building. With the program EPW - NPR 5129 V2.2 the EPC value can be determined.

The EPC is based on the building characteristics, installations and user behaviour. A lower EPC value means a better energy efficiency of the building. Nowadays the EPC is 0,6 (after January 2011) the EPC-value for the housing sector will be 0,4 after January 2015. The EPC is a value for new residential buildings.

First the existing situation is put into the program. The EPC value of the existing dwelling is about 1,35. This is far above the norm of 0,6.

For the refurbished situation all the new values are putted into the program. In this new situation the EPC values is 0,78. This is with the use of solar collectors and pv cells. In this case the pv-cells are not used. So if these pv-cells are removed in the program the EPC-value will be 0,83. This is not enough according the new EPC value of 0,6 for new dwellings.

Out of the EPC calculations there can be concluded the refurbished situation will have a positive impact on the EPC value and the dwellings will become energy efficient again. Not on the level of the new built dwellings, but the energy efficiency will increase a lot. If the value of 0,6 needs to be reached new and extra installations will be necessary, but it will be difficult to reach the EPC of 0,6.¹

¹ EPC calculation in the appendix
Climate and ventilation
For the climate and ventilation of the building there will be used the same system for the ventilation. The only point that will be improved is the new ventilation system. In the new façade elements there will be ventilation grills and windows that can be opened for natural ventilation. The grills can be opened in a way they can provide enough ventilation for the spaces. If it is desirable the windows can be opened to have more ventilation. Because the existing way of ventilation is not good enough an additional ventilation system must be added to the building. Especially for the bathroom, toilet and kitchen extra ventilation is necessary. For the spaces which are connected directly to the outside natural ventilation can be used and this will be enough to ventilate the spaces. For the spaces which are not directly connected to the outside mechanical ventilation will be necessary.

A mechanical system can be placed on the roof and can exhaust the air out of the toilet, bathroom and kitchen. This way the ventilation of these spaces is secured. If this air is taken out of the bathroom, kitchen or toilet the ventilation amount of the other spaces also will increase. This will be better for the health of the people.

A system that can be used to ventilate the ‘wet’ spaces in the dwelling is a system which can exhaust air with a collective system or an individual system. It depends on the installation space that is needed and if there is enough space is in the shaft. The two systems are shown in the pictures 1 & 2.

Floor plans and structure
The floor plans of the dwellings are not changed because the focus of this master thesis was on façade improvement. Nevertheless it could be interesting to take a look at the floor plans. It is possible to improve the floor plans in such a way the kitchen can be bigger by removing the (smallest) bedroom. Another interesting possibility is the addition of a new balcony. This balcony can give the building a total new appearance, but also a bigger floor area.

The structure of the building is not changing much. It depends on the structure if it possible to hang the balconies on the load bearing walls, but of this is not possible the balconies should have their own structure.

On the gallery there will be placed insulation. This provides better insulation to the inside of the structure. By doing this the entrance of the dwellings also can be improved. The doorstep is about 15 cm in the existing situation. In the new situation this can be improved till about 2 cm.

Façade
The new façade elements can be prefabricated and attached to the building. In the technical drawings is shown how this can be done. Of course the tolerances with the existing structure must be taken into account, but according the original detailing it is possible to use prefabricated elements. The loggia elements also can be prefabricated and placed in on time on the loggia. The possibility to adjust the element is shown in the detailing. In the end the insulation layer in front of the concrete beam can be placed and this way the thermal bridges are gone in the new situation.

The next pages will show the old and new situation with the technical drawings
Technical drawings existing situation
The drawings of the old situation are shown on the next 4 pages.
- Typical floor plan and cross section of a middle dwelling(s)
- Impression of the building in the old situation
- Gallery façade
- Living room façade
- Typical detailing and sections of the old situation
Existing façade view

West Facade

East Facade
Existing sections and details
Technical drawings new situation
The drawings of the new situation are shown on the next 4 pages.

- Typical floor plan and cross section of a middle dwelling(s)
- Impression of the building in the new situation
- Gallery façade
- Living room façade
- Typical detailing and sections of the new situation
New façade view

West Facade

East Facade
New sections and details

![Diagram of New Sections and Details]

- Gallery
- Living room
- Loggia

New situation

Scale 1:10

Designer: Edwin Tensen (1547275)

Layout number:

Date:

Project Subject:

Suringarflat Zaandam

Refurbishment project Suringarflat, Zaandam

Master Thesis

23

Console

Gravel

180 10 70 70

330

67 24 150

242

HR++ glazing

U = 1.20 W/m²K

Plastic window frame

U = 1.40 W/m²K

PU insulation 40 mm

Bitumen layer

New situation

24

Console

Gallery

59 25

24

20 113

242

59 25

24

21 113

242

HR++ glazing

U = 1.20 W/m²K

Plastic window frame

U = 1.40 W/m²K

PU insulation 40 mm

Stands for higher gallery access

New situation

28

Loggia

500 9

24

27

PU insulation 40 mm

Polyconcrete slab 20 mm

HR++ glazing

U = 1.20 W/m²K

Solarlux sliding system

Type: SL 60e

Aluminium roof profile

Aluminium window frame

HR++ glazing

U = 1.20 W/m²K

New situation

29

Loggia

160 10 20

500 9 24 27

PU insulation 40 mm

Polyconcrete slab 20 mm

HR++ glazing

U = 1.20 W/m²K

Solarlux sliding system

Type: SL 60e

Aluminium window frame
Refurbishment solutions for post-war housing blocks
Impression existing vs. new situation

Existing situation

New situation
Building sequence

A global impression will be given about the building sequence of the refurbishment.

Figure 1 till 4 represents the dwelling on the gallery side. Figure 1 is the dwelling in the existing situation. In figure 2 the old façade elements will be removed together with the old railing. The prefabricated element will have an extra insulation layer in front and the new façade elements will be attached to the existing structure (3). In the end the new fench / railing will be placed.

The building sequence of one dwelling is explained for the gallery side. This sequence can be repeated for all the dwellings.

For the living room façade the same building sequence can be used as described for the gallery side. Figure a show the existing situation. The old façade elements can be removed (b). The prefabricated concrete element can have an additional insulation layer in front (c). The new sliding door can be placed into the existing structure (d). The next step is to attach the loggia elements the structure and create a thermal buffer between in and outside (e). In the end the external balcony can placed against the structure (f).

The residents of the dwelling can enjoy their new living space and extra floor area (g).
Final result

Existing situation

New situation
Final result

The refurbished building will be an improved version of the old building in terms of energy consumption, comfort, indoor climate, appearance and floor area. Most important for this master thesis will be the energy reduction in total together with the indoor climate and comfort. In the end it will depend on the owner how much they want to invest in the building and reach a certain level of comfort and energy efficiency. In this case the energy efficiency of the building is accomplished by improving the insulation value of the façades and the use of solar collectors. These two interventions will take care of the energy reduction of the building. The demand for space heating and hot water will decrease.

The addition of a mechanical ventilation system will provide better ventilation in the toilet, bathroom and kitchen. This way the comfort and the indoor climate of the dwelling will be improved, but in terms of energy efficiency it will be less efficient. Mechanical ventilation will use more energy than natural ventilation.

By replacing and improving the façade elements the thermal bridges are gone and moisture and mold will not occur anymore. The only way this can happen if there is not enough ventilation anymore.

The addition of the new balcony will improve the comfort of the dwelling. Not only in terms of extra floor area, but also during summertime when the balcony is blocking direct sunlight into the dwelling. Closing of the loggia will be beneficial because the bad insulated walls will be no problem anymore and 4.6 m² extra ‘inside’ floor area can be added to the dwelling.

For the energy reduction of the building there are made 3 different calculations: Capsol, EPC and energy label. Out if these 3 different calculations 3 different energy reductions can be shown:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capsol</td>
<td>34,476</td>
<td>19,100</td>
<td>44,6 %</td>
</tr>
<tr>
<td>EPC</td>
<td>38,787</td>
<td>23,907</td>
<td>38,4 %</td>
</tr>
<tr>
<td>Energy label</td>
<td>43,445</td>
<td>18,931</td>
<td>56,4 %</td>
</tr>
</tbody>
</table>

All three methods give another result. 3 different methods results in 3 different energy reductions. The average total energy reduction is \((44,6 + 38,4 + 56,4 / 3) = 46,4 \%\)

The Capsol calculation almost has got the same energy reduction compared to the average energy reduction out of the three different calculations. The energy reduction of the building will be about 44,6% of the total energy use. This reduction is only accomplished by an improved façade and solar collectors. The energy reduction can be even higher with the use of heat recovery systems or the use of pv-cells. The energy reduction on space heating will be about 65% out of the Capsol calculations.

The comfort of the dwelling will be improved in the new situation because of the improvement of the insulation layer of the building. The extra balcony is beneficial in terms over overheating. The amount of hours of overheating will decrease from 338 hours in the existing situation till 178 hours. The amount of hours is < 200 hours so the indoor climate of the dwelling will be sufficient enough and will classified as comfortable.
The energy consumption in the existing situation is 75.8 kWh/m². The energy consumption for space heating will be about 29.0 kWh/m² for the whole dwelling in the new situation. Because the external balcony is added to the structure the energy consumption of the dwelling is a bit higher (6 kWh/m²), but it will give the residents more comfort in terms of living space.

In the end the refurbishment of this building will contribute to the agreements of the Kyoto-protocol. The reduction of the energy demand with 30% by the year 2020 can be accomplished this way. The total energy reduction for one dwelling is calculated. In the end an energy reduction of 44.6% can be reached. This energy reduction is accomplished by new façade elements and a collective solar collector.

To calculate the reduction in greenhouse gas emission the amount of primary energy [MJ] can be converted to CO₂ in kg. In the existing situation and the new situation the CO₂ in kg can be calculated.

### Simulation Capsol existing situation

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume</th>
<th>Energy (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>531 m³</td>
<td>18.670</td>
</tr>
<tr>
<td>Water</td>
<td>277 m³</td>
<td>9.745</td>
</tr>
<tr>
<td>Extra energy</td>
<td>237 kWh</td>
<td>2.184</td>
</tr>
<tr>
<td>Lighting</td>
<td>420 kWh</td>
<td>3.877</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>34.476</td>
</tr>
</tbody>
</table>

### Simulation refurbished situation

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume</th>
<th>Energy (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>203 m³</td>
<td>7.140</td>
</tr>
<tr>
<td>Water</td>
<td>277 m³</td>
<td>9.745</td>
</tr>
<tr>
<td>Extra energy</td>
<td>237 kWh</td>
<td>2.184</td>
</tr>
<tr>
<td>Lighting</td>
<td>420 kWh</td>
<td>3.877</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>22.940</td>
</tr>
</tbody>
</table>

### Simulation refurbished situation and solar collectors

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume</th>
<th>Energy (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>168 m³</td>
<td>5.900</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>5.900</td>
</tr>
<tr>
<td>Extra energy</td>
<td>237 kWh</td>
<td>2.184</td>
</tr>
<tr>
<td>Lighting</td>
<td>420 kWh</td>
<td>3.877</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>19.100</td>
</tr>
</tbody>
</table>

### The CO₂ emission per situation:

<table>
<thead>
<tr>
<th>Calculation</th>
<th>CO₂ Emission (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation 1</td>
<td>1804 kg CO₂ / dwelling</td>
</tr>
<tr>
<td>Calculation 2</td>
<td>1201 kg CO₂ / dwelling</td>
</tr>
<tr>
<td>Calculation 3</td>
<td>1000 kg CO₂ / dwelling</td>
</tr>
</tbody>
</table>

For one dwelling the energy reduction is about 800 kg CO₂ / dwelling. In total 96 dwellings will be refurbished. 96 x 800 kg = 76.800 kg CO₂ reduction for the whole building.

An average car exhaust about 0.154 kg CO₂ / km. This means a car can drive about 76.800 / 0.154 = 498.700 km in total. This is a distance which is 12.5 times around the world by car.¹

Not only the energetic part of this master thesis will be beneficial for the neighbourhood or the Netherlands. Also the social aspect of the neighbourhood should be taken into account. The building will be improved in its performance and in its appearance. This way the building can attract other people who want to live in the area. The refurbishment can be an example to give the area a new impulse to renew the area in such a way the whole area can be renewed. Not only the buildings but also the public spaces. With this interventions the area will be more liveable again and attractive to other people with another background.

¹ [http://www.energy-aware.org](http://www.energy-aware.org)
Refurbishment of a building is a complex issue with a lot of aspects that must be taken into account. Not only the building itself, but also the residents who live in the building or even the neighbourhood. An important aspect of refurbishment is the economic part of the projects. There is a lot of discussion if refurbishment gives enough profit compared to demolishing and built new buildings instead. In this master thesis the economic issue of refurbishment is not a main subject. This thesis is focused on energetic refurbishment.

The main question of this thesis is focused on the energetic part: How can a housing block out of the post-war period be refurbished in such a way the building can be transformed in a resource-efficient and environmentally healthy building if the focus is on the façade, the indoor climate and energy consumption? To give an answer on this question different sub questions are formulated in the beginning of this thesis. By answering these sub questions the main question can be answered also.

This question cannot only be answered with a ‘yes’ or a ‘no’. Answering this question is quite difficult because there are a lot of possibilities to refurbish a building in such a way that it can meet the requirements of nowadays. The main objective of this thesis is to find a way to refurbish a building. Within this refurbishment the energy consumption must be reduced. This way the greenhouse gas emissions of the building can be reduced. So the objective is to reduce the energy consumption because that is the most important part. To accomplish this, ‘trias energetica’ can be used. Trias Energetica is a simple and logical concept that helps to achieve energy savings, reduce our dependence on fossil fuels, and save the environment. There are three elements that are important in the trias energetica:

1. Reduce the demand for energy by avoiding waste and implementing energy-saving measures;
2. Use sustainable sources of energy like wind, solar power and water;
3. Use fossil fuel energy as efficiently as possible and only if sustainable sources of energy are unavailable.

In the first part of this thesis, the theoretical background, it becomes clear the focus should be on the existing building stock and not that much on the new buildings. The energy consumption of the new buildings is already good and energy efficient. The energy consumption of the ageing building is a lot more and also the amount of ageing building is much more than the new built buildings.

The buildings built in the post-war period (1950-1972) are built with a typical building method out of that period. With this building method a lot of technical problems arose during the time. Not only the thermal bridges are a problem but also the energy efficiency of these buildings. The lack of insulation takes care of a high energy consumption of these buildings. Out of the analysis of the previous refurbished buildings it becomes clear every building is refurbished on its own way. It depends on the approach of the developers how the building will be refurbished and were the focus will be on. In some projects the energy efficiency of the building is more important than another. In every project the minimum requirements of the building code are taken into account, but for some projects better requirements are used. This way the energy efficiency, indoor comfort and indoor climate will be improved.

There are several options to refurbish a building in such a way the building can be made energy efficient again. Not every solution will be suitable for a typical building. The objective to refurbish a building for this thesis was to find a way to make the building energy efficient again. This solution must be generic in such a way the solution also can be used for other residential buildings. Of course it depends on the layout of the floor plans if the proposed solutions can be used. A lot of the buildings out of the post-war period, especially the gallery and porch flats do have almost the same layout. The buildings are built with a comparable building method.

The different refurbishment solutions are simulated and calculated in the computer program Capsol. Out of these calculations several solutions are applicable to the case study building. The best overall solution to refurbish the case study building is the solution whereby the façade will be replaced or improved together with closing of the loggia. This way the energy consumption will be reduced the most. The problems with the critical connections and thermal bridges can be solved and improved. The advantage of closing of the loggia is the thermal bridges will be gone and the loggia can be used more days a year. Also the additional balcony will erase the thermal bridges on the living room side.

Because the building already is built up with façade elements these elements can be replaced for new ones. The new façade elements do have better insulation values and high efficiency glazing. This way the energy consumption on space heating can be reduced. Together with the use of solar collectors a total energy reduction of about 44,6% on the total energy consumption can be reached.
With all these interventions the dwelling has got an EPC-value of 0.83. According to the demands for new dwellings this is not enough. It should be 0.6 for new dwellings, but for the energy efficiency of an old building it is good. The energy label of the dwellings, mostly E or F can be lifted to label A. If the use of pv-cells can be integrated an energy label A+ can be reached.

To improve the ventilation of the dwellings a mechanical system must be added. This way the ventilation of the kitchen, bathroom and toilet will be sufficient. The other spaces of the apartments can be ventilated through the façade directly with fresh air.

**Conclusion on building scale:**
- It is a concept for post-war gallery flats
- Also applicable to porch flats
- With façade refurbishment 37% energy reduction
- In combination with solar collectors 44.6% energy reduction
- More energy reduction can be reached with more interventions
- Overall improvement of the building in appearance and safety
- Improvement floor area / accessibility of the building and dwelling
- Improvement ventilation of the building by mechanical ventilation

**Conclusion on larger scale:**
- Improvement of post-war housing blocks provides better housing quality = better comfort
- Energy reduction on bigger scale, Poelenburg, Zaandam, the Netherlands and Europe
- Municipality can make a ‘green’ statement with refurbishment of post-war housing blocks
- Architect and façade engineers can have benefit out of the research. Possible solutions and how this is related to the energy consumption of the building are investigated and can be used
- By refurbishing the post-war housing blocks the value of the dwelling will be higher and will attract people with an other background also
- Not only the building will be attractive again, the whole area can be redeveloped with energy efficient buildings and liveable public spaces
- Every project has got its own approach and outcome. This thesis shows different approaches and different outcome

This master thesis is based on the energy reduction of the dwellings. It is a façade energetic refurbishment. This means the façade has been investigated on the influence on the energy consumption of the dwelling. To investigate the different solutions a considered decision is made about which strategy will fit the best for this building. In the end this solution will not only be applicable for only this building but it will also be suitable for flats (gallery or porch) with the same layout and building method (prefab or in situ).

It is possible to reduce even more energy with other materials, products or installations but it depends on the approach of the refurbishment. In this case the approach was to refurbish the building focused on the façade and reduce the energy consumption this way. Another approach can be an architectural or economic approach. Of course each of these different aspects are related to each other, but the approach will be different so the focus and end result also will be different.

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1 (Source: http://www.energiebesparingsverkenner.nl/p001.asp)
Recommendation

In this chapter some recommendations will be given for the further steps for this master thesis. During this thesis some points are worked out, but some points need more investigation. The refurbishment of the case study building is based on the energy calculations, replacing or improving the existing façade together with the closing of the loggia, will be the best solution.

This refurbishment is based on the energetic part of the building. It will be the question if this solution also is feasible in terms of economics or exploitation of the building. The fact that a lot of elements can be the same for the building can be an argument that it can be a feasible refurbishment strategy, but this needs more investigation.

The indoor climate and comfort is based on the comfort demands given by the Dutch building code, but for example the installations are not determined exactly. The total installation concept can be worked out further and better. For now just an idea is given to improve the indoor climate by adding extra installations next to the façade refurbishment, but just like the façade refurbishment, it will be the question if this is feasible to accomplish and if it is the best overall solution.

The façade elements are designed in such a way they can be prefabricated without any extra installation with it like photovoltaic (PV) solar cells for example. The reason that this is done is because these pv-cells are a big investment. It could be worth an investigation if the pv-cells could be implemented on the building so this way the energy consumption can be reduced. For now it is not been taken into account because the biggest energy consumers are space heating and hot water. There are possibilities to integrate the pv-cells with the façade. This way the building can be seen as a ‘green’ building because it uses (visible) renewable energy by solar power. It is also possible to place pv-cells on the closed south façade of the building.

For the rest of the building extra investigation will be necessary to make the corner dwellings also energy efficient. For those dwellings it can be investigated if extra insulation can be placed in the cavity of the end wall. Also if it will be possible to add an external balcony to the dwelling and to increase the floor area and to close of the loggia.

Of course it depends on the housing company how much money they want to spend on the refurbishment of the building, but in my opinion this building can be refurbished in such a way that it can meet the requirements of nowadays again. This can be accomplished with the proposed energetic refurbishment and this way the building can be interesting for everyone. Not only for Turkish people (nowadays a lot of Turkish people live in the neighbourhood) but also for beginners or older people. This way a various kind of people can attract not only the building but also the neighbourhood.

Another interesting topic that can be investigated for the building is the floor plan of the dwelling. In this master thesis the floor plans remain as they are. It can be possible to arrange the floor plan in such a way that the kitchen can be bigger by losing one bedroom. A point of attention is dealing with the closet with the electric meter and the hallway. If this can be solved the new floor plans will have 2 bedrooms, a bigger kitchen and more living space. An example is shown underneath.
The reason to do research about refurbishment of the post-war residential building is because of the personal interests in the topic. In my opinion the building out of this period is an interesting part of the housing market because a lot of dwellings are built the same way in a short time period. There is a lot of discussion about the buildings out of the post-war period nowadays. Also what should happen with these buildings, demolishing and built new ones or refurbish the buildings? The building technique out of the post-war period was not that good so a lot of people complain about draft, moisture, mold and bad insulation. Everybody is aware of the use of energy in the world and that the energy consumption has to be reduced. In these particular buildings the energy efficiency does not meet the requirements of nowadays. The post-war buildings are consuming a lot of energy and all this energy is wasted.

In my opinion these two subjects can be combined in one thesis whereby the focus will be on an energetic refurbishment of a post-war residential building. There are still a lot of buildings that are consuming a lot of energy and the prices for energy are increases faster than the prices for buildings (sell or rent). So the more energy efficient a building is the cheaper it will be in using the building.

On social context it will be good to invest in the energy efficiency of the post-war buildings. In the Kyoto agreements the reduction of greenhouse gas emission must be at least 20% in 2020 compared to 1990. The Netherlands even wants a reduction of 30% of GHG emission. The building sector is a great consumer so this can help to reduce the GHG emissions in the Netherlands. Not only for one building but for all the buildings out of the post-war period that are consuming a lot energy. Another aspect to invest in refurbishment of this type of dwelling is to increase the comfort of the dwellings. This way people will live longer in the dwellings and the lifetime of the building can be increased. If the building is refurbished people will feel safer and secure with ‘their’ building. This way not only the building will help in the mood of the people, but even the whole neighbourhood can have profit of the investments in a building.

I think it is important to do research about energetic refurbishment because this way the energy consumption of the ageing building can be reduced in such a way it can be example for other buildings. Every refurbishment project will be different but every project will show aspects that can be improved the next time. The reflection on the followed methodology is, I think, done in a right way. Of course there always be some points that you will have done in another way if you look back, but I think the followed methodology was more or less the right way. The methodology schedule made in the beginning was a good guideline to accomplish the thesis in a right way. Together with the planning it helped me to get a quick overview about what I still had to do and when it should be finished. There were some periods that I was running behind the schedule, but in my opinion this is something you will see much more during lifetime.

In the beginning the ambition level is very high and you want to do research about every topic. This way you want to make a good end product, but this is not really realizable in a short time period. It is necessary to make clear what you want to investigate and how you are going to accomplish this. The start of the thesis was very broad and a lot of information was there. It is hard to delete the information that not will be used because it can be interesting to know but maybe irrelevant for the thesis. The first part of the thesis was mainly about theoretical subjects like housing market, energy use, post-war residential building, comfort demands and previous refurbishment projects. Out of this first part comfort demands and solutions are developed for the case study building. The previous refurbishment projects are analyzed on different aspects. Out of these analyses different problems and ideas are developed. The analyses show the way of refurbishing, materials, installations etc. Also the profit in terms of energy compared to the old situation is investigated were possible.

After finishing the first part I started searching for a case study building. I thought this was just a matter of pick a building, but it was harder than I thought in the beginning. If I knew this in the beginning I started earlier to search and choose one and use this for a case study building. I had a lot of contact with different housing cooperation’s, but it was not easy to find a proper case study building. In the end a case study building was found, but in my opinion this could be faster. After analysing the existing situation the development of different refurbishment solutions can be made. The next step was to calculate these different solutions in their energy performance. For each solution is simulated the energy use (for space heating). After these calculations the solutions are rated on other criteria. The last step was to see which solution will fit the best. The energy simulations took a lot of time. It was hard to put in all the data. In the end all the calculations were done but not really on the right way. I recalculated each solution again. It was better to this part right in one time. In the first calculations I calculated the summer and wintertime separately but after a consultation it becomes clear to do one calculation for the whole year. In the end the calculation not differs a lot for the wintertime. For the summertime this was different. In the first calculations the summertime the energy use was almost as high as the wintertime because of different temperature and ventilation demands. In the second calculation this was worked out better so the end result was more realistic. 
The final decision to choose a solution is supported mainly by the energetic point of view and not from an economic approach. An economic approach is totally different and is a research on its own. In my case the approach was from the energetic point of view. Next to the energetic aspect other criteria like residents, execution, installations, improvement indoor climate and comfort etc. must be taken into account. The used criteria and points that are given to a particular strategy are based on personal intuition and knowledge.

I am quite satisfied with the end result, but there are still enough points that can be improved or worked out better. The overall result of the refurbishment could be worked out better. For now I only calculated the energy consumption of two dwellings. This shows the energy reduction for most of the dwellings, but for the other (corner) dwellings it still can be calculated. On the other hand the middle dwelling and top dwelling are the most common dwellings in the building so it shows the energy reduction quite good. Because the focus was on the façade the climate installations are only described and not worked out in detail. So it is just a concept and not really feasible right now. This is a point of improvement for the whole building. But as mentioned before; I am quite satisfied with the end result.
Final word

During the study on the faculty of Architecture in Delft I learned a lot. After my bachelor period, which I finished in Amsterdam, I was not quite satisfied with the knowledge I gathered during this period. During this bachelor I already followed the pre-master course to start on the TU in Delft. After I was graduated in Amsterdam I decided to start the master course in Delft. After some doubts I decided to start the master course in Delft to develop my knowledge and way of thinking. In the end I am really glad I made this decision because the feeling of satisfaction is a lot higher now. Besides the way of thinking also the level of courses during the master course are on a level you have to work hard. If you are thinking you will do it in a minute you will think quite wrong. This is quite a challenge, but it is an interesting master track and I did it with pleasure.

I am really glad I made it to end of this master track. I started this master track in September 2009. Everything was different compared to the bachelor period in Amsterdam. Not only projects are different but also the level of knowledge by fellow students, professors and teachers. Also the way of thinking was totally different. During the master thesis I was in contact with several peoples and they really helped me to get the right direction. In the beginning of the thesis there are a lot of things that can be investigated. After a while you realize it is not possible to do everything in 5 months.

If I look back to the end result of this master thesis I can conclude I can be satisfied, but...... (There is always a but...). The final result is not as high as it was intended to have in the beginning. On the other hand you cannot do everything. That is why there are boundary conditions for the project, what to do and what to do not. Sometimes I was thinking: "Where does it ends?" and "Where is the end?". But in the end there is always an end. If you can explain some decisions with arguments a decision can be accepted. There are always different opinions and arguments which can be pro or con for your decision, but it depends also on the focus of the project / thesis.

In the end I want to thank everybody who was involved in the project and who helped me during this master thesis. Right now it is a big question what the future will bring, but I am looking forward to it.

Edwin Tensen
June, 2011
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Appendix

1.0 - Indoor climate comfort tables
2.0 - Summary previous refurbished buildings
3.0 - Energy labels dwellings
4.0 - EPC calculations output
5.0 - Energy calculations ABC-bouwkundig
6.0 - Technical drawing

Planning
1.0 Indoor climate comfort tables

Uitgangspunten T.O.B.

specificatieblad 5.2-1

<table>
<thead>
<tr>
<th>Wettelijke eisen</th>
<th>Geen.</th>
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<td>GIW eisen</td>
<td>Ten behoeve van de gegevensinvoer dienen de navolgende criteria te worden aangehouden voor de zomerperiode:</td>
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<td>Referentiejaar: 1964</td>
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<td>Zomertijd: In de berekening meenemen</td>
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<td>Zonnewering buiten?*: Neer bij een zonnewerbing van 300 W/m²</td>
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<td>Te openen ramen**: Geen.</td>
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<tr>
<td></td>
<td>Relatieve luchtdruk: Maximaal 0.2 m/s in de leefzone volgens NEN 1087</td>
</tr>
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</table>

*) Zonnewering alleen in de berekening betrekken indien deze door de ondernemer is aangebracht.

**) Opgrond van NEN 1087 heeft een spuwoesproeier tot doel vervuld lucht in korte tijd af te voeren en niet de vordering op een aangemane temperatuur te houden.

Spuwoesproeien moeten uitsluitend in de berekening meegerekend worden, mits intraatelijk gebruik mogelijk is.

Vertrek | Metabolisme | W/m² | Clo |
---------|-------------|------|-----|
Woonkamer| 1.7         | 64   | 0.5 |
Keuken   | 1.6         | 93   | 0.4 |
Slaapkamer | 0.8      | 46   | 0.3 |
Badkamer | 1.2         | 70   | 0.1 |
Werkkamer| 1.2         | 70   | 0.6 |

Uitgangspunten T.O.B. (vervolg)

specificatieblad 5.2-2

Interne warmtelast personen en verlichting

Verwijzing naar tabel 1 worden de navolgende criteria gegeven:

Verlichting:Aan te houden voor de verlichting 12 W/m².

Interne warmtelast personen:

Aan te houden voor een hoofdslaapkamer c.q ouderslaapkamer 100 W per vertrek.

Aan te houden voor overige slaapkamers 6 W/m² met een minimum van 30 W en een maximum van 100 W.

Aan te houden voor de woonkamer 8,3 W/m² tot 30m² daarbinnen aan te houden 2 W per m².

Aan te houden voor de keuken 10,4 W/m² met een minimum van 93 W.

Aan te houden voor de overige vertrekken 10,4 W/m².

Toelichting: de berekenende interne warmtelast voor personen mag worden gecorrigeerd met het vermelde percentage in tabel 1.

Voorbeeld correctiefactor:

Een woonkamer is 31 m² wat voor de interne warmtelast voor personen geeft van (30 m² x 8,3 W/m²) + (1 m² x 2 W/m²) = 251 W.

De invoer voor het tijdsblok tussen 8:00-9:00 uur is 30% van 251 W = 75 W.

Bij een open keuken dient een fictieve wand te worden getrokken t.b.v. de berekening.
Uitgangspunten T.O.B. (vervolg)         specificatieblad 5.2-4

GW eisen (vervolg)

Voor de absorptiecoëfficiënt voor zonnestraling voor materialen die het buitenoppervlak van de constructie vormen wordt verwijzen naar ISO-Publicatie 21.

Correctiefactor

Personen          0,5
Apparatuur        0,5
Verlichting       0,6

De PMV- en PPD-waarden geven een waarde voor de thermische gewaarwording voor het lichaam als geheel, maar thermische onbepaaldheid kan ook worden veroorzaakt door een ongewenste opwarming of afkoeling van een specifiek deel van het lichaam; plaatselijke onbepaaldheid.

Bij een lichte, voornamelijk zittende, activiteit is hiervoor een aantal aanvullende voorwaarden te geven:

- Het luchttemperaturenverschil tussen 0,1 en 1,1 m boven de vloer moet kleiner zijn dan 3 °C.
- De gemiddelde luchtvisbaarheid mag geen aanleiding geven tot totdaaklachten hiervoor geldt een maximale waarde van 0,2 m/s in de zomerperiode en 0,35 m/s in de winterperiode.

ANBO

Het is aan te bevelen om bij toepassen van buitenzenuwing deze uit te voeren met een wind-
regensensor (automat).

Normen

Bouwbesluit
NEN 1087
NEN 2280
NEN 67730

Ventilatie van gebouwen bepalingsmethoden voor nieuwbouw.
Oppervlakten en inhoud van gebouwen.
Gemiddelde thermische binnenomstandigheden bepaling van de PMV- en de PPD-vaardigheid; specifiek van de voorwaarden voor thermische behaaglijkheid.

Richtlijnen

ISO-Standard 19
ISO-Standard 21
ISO-Standard 32
ISO-Standard 74

Thermisch binnenklimaat: aanbevelingen.
Berekening van het energieverbruik voor klimatisering en verlichting van kantoorgebouwen.
Uitgangspunten temperatuursimulatie berekeningen.
Thermische behaaglijkheidsnormen voor de binnenklimaat in gebouwen.

Researchrapport 5
BRL 9301

Ontwerp binnenomstandigheden en thermische behaaglijkheid in gebouwen. Methoden voor het berekenen van het energieverbruik van gebouwen en de financiële gevolgen van energiebesparende maatregelen op basis van de EER.

Uitgangspunten T.O.B. (vervolg)         specificatieblad 5.2-3

GW eisen (vervolg)

Interne warmelast apparatuur

Tabel 1 geeft een overzicht van de minimale aan te houden interne warmelast.

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Edwin Tensen       1547275              Master Thesis Building Technology       117
2.0 Summary previous refurbished buildings

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<tr>
<td>Total dwellings</td>
<td>99 (76)</td>
<td>180</td>
<td>108</td>
<td>104</td>
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<tr>
<td>Strategy</td>
<td>Old residents had the choice to get back in the new building</td>
<td>Residents could stay in their apartments and if necessary they could move out</td>
<td>Refurbishment to increase social cohesion and comfort of the dwellings</td>
<td>Residents could stay in their apartments, instead of a porchflat it is transformed into a gallery flat</td>
</tr>
<tr>
<td>Facade</td>
<td>Stripping total building and new facade for structure, with extension of the old structure</td>
<td>Windows with HR++ glazing</td>
<td>New facade elements (windows, aluminium) and new structure on facade</td>
<td>Closed facade with extra insulation (10cm EPS) and covered with tiles, window frames replaced for plastic windows with HR++ glazing</td>
</tr>
<tr>
<td>Floor plans</td>
<td>Changed from standard floor plans to bigger dwellings with different types of dwellings</td>
<td>Remained as they were</td>
<td>Remained as they were, but new kitchen and bathrooms + new entrance</td>
<td>Changed in such a way the bedroom is replaced and the entrance is by gallery instead of porch</td>
</tr>
<tr>
<td>Climate installations</td>
<td>Connection with wasted heat of heating company to gain heating for apartments and hot water (hot-fill connection) and Pv-cells on south facade</td>
<td>Gas heatpump on the roof in combination with decentralized (ClimaRad) ventilation system in the apartments</td>
<td>central heating system</td>
<td>Solar collectors for hot water, collective boilers for heating, (LTV) low temperature heating by large radiators</td>
</tr>
<tr>
<td>Reduction total/year</td>
<td>unknown</td>
<td>unknown</td>
<td>unknown</td>
<td>12 tonnes</td>
</tr>
<tr>
<td>Reduction CO2 (%)</td>
<td>unknown</td>
<td>unknown</td>
<td>unknown</td>
<td>EPC = 0.98</td>
</tr>
<tr>
<td>Costs total (£)</td>
<td>10,570,000</td>
<td>unknown</td>
<td>5,300,000</td>
<td>9,850,000</td>
</tr>
<tr>
<td>Costs/house (£)</td>
<td>113,645</td>
<td>unknown</td>
<td>49,000</td>
<td>94,700</td>
</tr>
<tr>
<td>Old --&gt; new label</td>
<td>? --&gt; A+</td>
<td>F --&gt; B</td>
<td>unkown</td>
<td>F --&gt; A / B</td>
</tr>
<tr>
<td>Costs / m² (£)</td>
<td>1,480</td>
<td>unkown</td>
<td>500</td>
<td>1,050</td>
</tr>
<tr>
<td>Total floor area (m²)</td>
<td>9,900</td>
<td>10,800</td>
<td>12,500</td>
<td>9,360</td>
</tr>
<tr>
<td>Extra info</td>
<td>The refurbishment was calculated in the beginning, but after the start the structure was that bad, the other flats will not be refurbished this way</td>
<td>Extra insulation is added to the groundfloor, where the storage space is, to prevent heat losses through the ground floor (Ytong Multipor)</td>
<td>refurbished with sustainable materials, (FSC wood, ceramic tiles, recycled plastic) and to reduce more energy water saving taps are used</td>
<td></td>
</tr>
</tbody>
</table>
3.0 Energy labels dwellings

Gevelraster huisnummers, type, energielabel, isoglas en CV installaties

<table>
<thead>
<tr>
<th>E. Heimansstraat buiten(noord)</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>4e</code></td>
</tr>
<tr>
<td>160</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suringarstraat buiten(oost)</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>4e</code></td>
</tr>
<tr>
<td>106</td>
</tr>
</tbody>
</table>

- **Energielabel**
  - A: Geen isoglas
  - B: Wel iso glas

- **Isoglas**
  - [ ] Wel iso glas

- **CV installaties**
  - [ ] Intergas HR gesloten combi EO
  - [ ] AGPO GWK gesloten combi WV
  - [ ] Stellina MH open tot WV
  - [ ] Niet op de lijst

- **Beteren cijfers**
  - X: Huisnummer
  - Y: Jaartal installatie CV
  - Z: Type woning

Figuur 1 Schematische weergave bestaande situatie.

4.0 EPC calculations output

<table>
<thead>
<tr>
<th>Energie POST</th>
<th>[MWh]</th>
<th>Omvat Vierkant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimiseren</td>
<td>1,123</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>1,223</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>1,050</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,990</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,920</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,910</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
</tbody>
</table>

Aggregaten (m³) 70.95

Energie POST | [MWh] | Omvat Vierkant |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>{Optimiseren}</td>
<td>1,123</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>1,223</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>1,050</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,990</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,920</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,910</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
<tr>
<td>Optimisatie.</td>
<td>0,900</td>
<td></td>
</tr>
</tbody>
</table>

Optimiseren 17351
3 Energiegebruik huidige situatie

3.1 Het Energielabel
In het kader van de Europese regelgeving (EPBD) bent u verplicht om, bij verkoop of verhuis van de woning, een energielabel te overhandigen. Dit label is in tien jaar geldig. Deze woning heeft het volgende energielabel:

<table>
<thead>
<tr>
<th>Energielabel</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energieopbrengst (MWh)</td>
<td>43,445 MWh (550 A/M²)</td>
</tr>
<tr>
<td>Fietserovertrek</td>
<td>- Geleidelijn (e+verbetering) - HH beglazing plaatsen - Zonnedaken</td>
</tr>
</tbody>
</table>

3.2 Het berekenende energiegebruik

Met behulp van een computerapplicatie is het energiegebruik voor de woning berekend. Hierbij is rekening gehouden met de bewoongedrag (zowel bewoners, bijvoorhebbende, verlichting en ventilatie) van de woning. Omdat het energiegebruik door weersverschillen het ene jaar anders is dan het andere jaar, is uitgegaan van het referentiejaarTRY De Bilt. Hierdoor wordt het energiegebruik uitgerekt voor een gemiddeld klimaatjaar.

<table>
<thead>
<tr>
<th>Referentiejaar</th>
<th>175,260 kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middel t/m 30%</td>
<td>175,260 kWh</td>
</tr>
</tbody>
</table>

De normale energie bevat een halve dag en is normaal geheven. De deelposten zijn amper als volgt geregeld (inclusief de bijdrage van het van de zonnecellen PV).

\[
\text{Deelposten (kWh)} = 175,260 \times \frac{1}{10} = 17,526 \text{ kWh}
\]
6.0 Technical drawings