Renovation

Leasing a Prefab Renovation in the Netherlands

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Introduction

In front of you the graduation research by Niels Gondrie is presented.
The thesis is entitled "Renovation, Leasing a Prefab Renovation in the Netherlands".
This report is the result of eight months of research at the Faculty of Architecture
at the Technical University of Delft.
Within the faculty the research has been performed in the mastertrack Building Technology.

Upgrading the existing housing stock to a more sustainable and less energy demanding sector is a current issue. With a view to the European 20-20-20 target and the increasing energy prices, the sustainability and energy performance of people's dwellings become indispensable.
Untill today still a significant portion of the housing portfolio has a weak energy performance. The cause for this postponment of sustainable renovations is often associated with high investment costs.

This research attempts to link a new way of investment with an innovative renovation concept. This requires solving a complex combination of varied subjects such as engineering capabilities, energy performances and financial structures, but also residents' interest and their willingness to pay, risks and opportunities, functions and actors are elaborated in this report.

This reserach is developed under the guidance of three very enthusiastic and benevolant mentors. Due to both the technical as well the financial aspects of the research, the mentors are formed by a combination of the Building Technology Department, and the Department of Real Estate & Housing.
Herewith I would like to thank Dr.-Ing. T. Klein and Dr.-Ing. T. Konstantinou of the Building Technology Department, and Dr. Ir. A. Den Heijer of the Real Estate & Housing Department, for their input, support and interesting discussions.

I also want to thank my roommates David en Eric for the necessary distractions, my girlfriend Laura for her always encouraging talks, and my parents Michel & Lizeth for their contribution and support thoughout my college years.

I hope you enjoy reading the report.

Niels Gondrie

Januarty 20th, 2015

The Dutch Rowhouse

No country in the worlds has as much rowhouses as the Netherlands. If you place each house next to each other, you achieve a length of 16.000 km which can be visualized as a road between Amsterdam and Beijing, uninterrupted with Dutch rowhouses on both sides.

The first rowhouses are dated from the 15th century, with an appearance of a sequence of identical houses around a shared garden. In the 19th century housing associations established and with help of cheap government loans the rowhouse became a more common housing typology in the Netherlands. Due to a housing shortage after World War II, the need for housing became public enemy number one. New technology led to quick and cheap building systems and new districts with almost exclusively rowhouses.

Nowadays the rowhouse is still a popular building typology, with thematized Vinex-districts praised for its large living surface and private gardens. However, the old housing stock can not keep up with the modern and sustainable standards of today. Something needs to be done to change the old unsustainable houses into modern and energy efficient dwellings.

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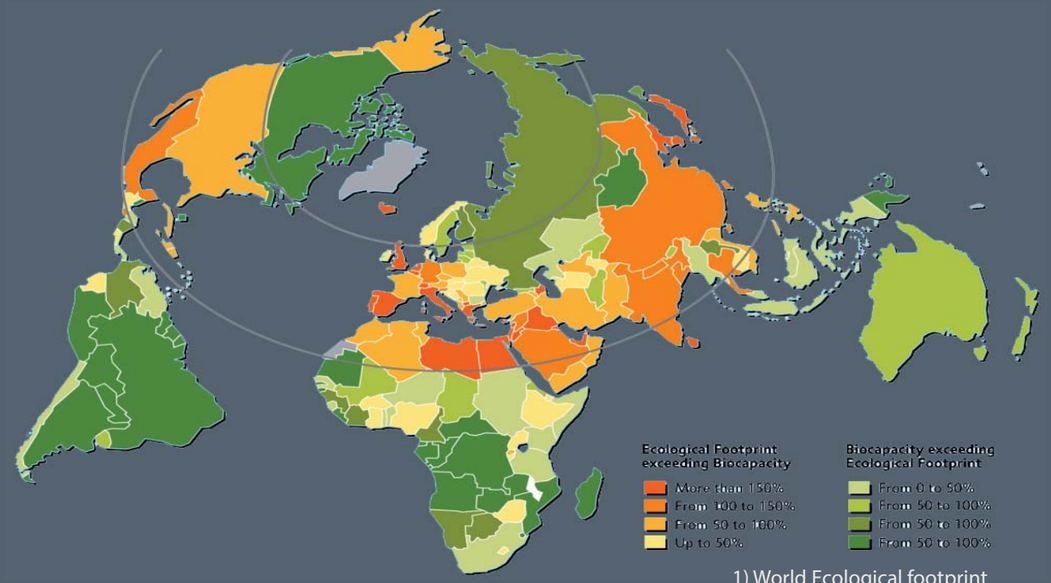
Chapter 1: Background
Problem Statement

The Environment

Depletion of natural resources and climate change is one of the biggest issues served by men. The earth can not handle our demands and waste, we can not continue the way we depauperate our ecosystem (Neederveen, 2009). The entire world population together has an ecological footprint of 2.7 times the earth. Regarding the average European we even need 4.2 planets and the average Dutchmen is doing an extra mile with a shameful 6.3 earths (Grooten, 2012).



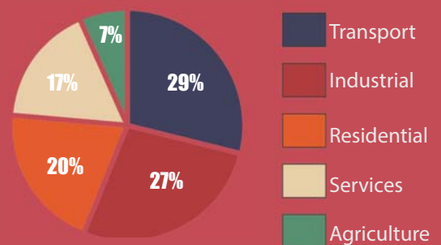
1) World Ecological footprint

The government of the European Union have set the 20-20-20 targets to achieve a more sustainable Europe. Compared to 1990, in 2020 there shall be
1) a 20% reduction in CO2 emission
2) a lower energy demand of 20%, and
3) 20% of the used energy has to be generated by renewable resources.
The targets for the decarborisation in 2050 are even reaching up to 95% (European Commission, 2011).

2) 20-20-20 Target

The Existing Housing Stock

Focussing on the different sectors responsible for the large energy demand in the Netherlands, over 20% of the demand is caused by the housing sector (Eurostat, 2014).

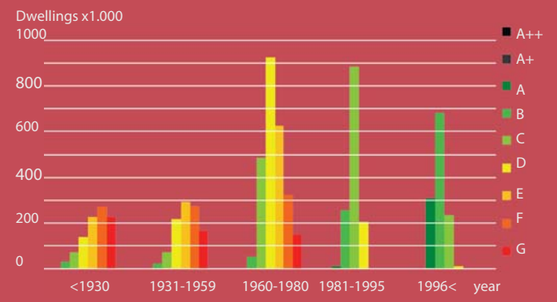


3) Impact existing housing stock

The recognition of the importance for sustainable energy usage has led to a compulsory energy label for dwellings when they are constructed, sold, or rented. The main purpose of this label is to promote sustainable energy improvements. Yet, the energy reduction in the housing sector is not largly improved in the last 20 years (ECN, 2013). Existing buildings are built under lower energy standards than currently expected. Only from the 70's, when the oil and energy crisis began, insulating buildings became more common (Poel, 2007).

46% Of the existing building stock includes buildings which are dated before the 80's (Ministry of Internal Affairs and Kingdom Relations, 2013a). Rowhouses present almost 60% of the existing building stock. The vast majority of the dwellings before 1980 are signed with energylabel D or lower (ECN, 2013). The buildings have a major impact on the energy demand in the Netherlands, but due to the embodied energy used in the construction, demolition should be avoid as extending the lifespan of the building has eventually less impact on the environment (Thomsen, 2005).

4) Development energy demand housing sector



5) Partition energy labels

Chapter 1: Background

Problem Statement: Housing costs

Due to the increasing energy prices, residents have to hand in a significant part of their income to their first living costs (Ministry of National Affairs and Kingdom Relations, 2013b). Therefore the poor energy performing houses become less attractive each year. Housing associations notice the shift in housing and energy costs and have to react to keep their housing stock attractive for the residents.

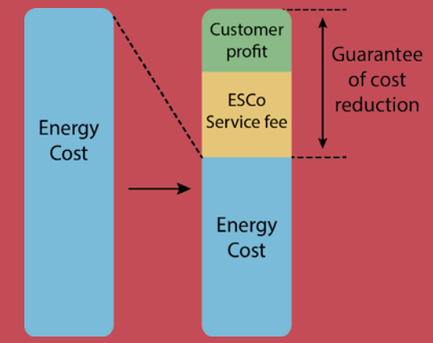
An example is 'The Stroomversnelling', a collaboration between four housing association and six contractors. The housing associations make a large part of their housing stock available for innovation and technology to renovate towards low energy demanding dwellings. The purpose is to collect the positive energy savings of the residents and to use that money to finance the renovation. As a result, the total costs for the tenants remain the same, while they gain more comfort and a healthier indoor climate (Stroomversnelling, 2013). However, a sustainable renovation for private owned rowhouses continues to this day to be a relative expensive investment. For a renovation of an energy neutral rowhouse from the 60s and 70s 40.000euro and upwards is calculated (Stroomversnelling, 2014) while the private dwelling property value is often less than 200.000 (Ministry of National Affairs and Kingdom Relations, 2013a).

Recent surveys shows that around 70% of the people is interested in a energy saving renovation, however, the long-term loan and the large investment are resulting in a great resistance of nearly 40%. Even when people are convinced that the energy savings ultimately will pay for the renovation, the financial issue continues to be a stumbling point (Welzen, 2014)

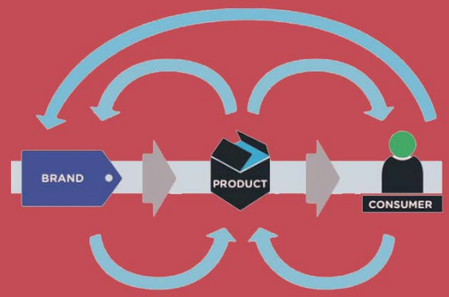
Financial Strategies

Nowadays more companies are developing innovative funding models to bear the financial loads for the client. This can lead to a lease plans where objects are rented at a monthly fee which may include maintenance, or an Energy Service Company which supplies the installations and service to take energy-saving measures in offices, the client only pays for the rent and service which are lower than the energy savings they gain (Berkhout, 2014).

An other developing strategy is the principle of a circular economy, where people not pay for the products and materials, but rather for the service of the object. Here the object remain in property of the company while this product can later be relocated and modified, or the raw materials may become input for a new product. (Blériot, 2014).

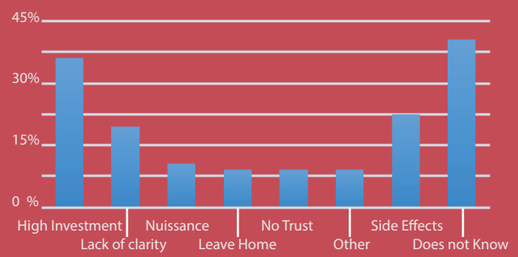


8) ESCO principle



9) Circular Economy principle

6) Gas and elektricity price increase



7) Barriers to participate in energy saving renovation

Chapter 1: Background
Research Question

Content & Structure

The research question is composed of three elements that have emerged from the research in the previous chapter:

1. The need to achieve the 20-20-20 target
2. The impact of the existing housing stock
3. The high investment costs for renovations

Because several renovation concepts for the rental sector are currently under developement (De Stroomversnelling, 2014) (Built4U, 2014), this research focusses on the forgotten private owned dwellings in the Netherlands.

Is leasing a renovation, a solution to improve the energy demanding dwellings in private ownership in the Netherlands?

Lease: to reduce high investments
Energy: reach the 20-20-20 target
Privated Ownership: the forgotten sector

Chapter 1: Background

Research Question: Subquestions

Building typology

- What building typologies have been used?
- What are the existing building characteristics?
- What building system is the most promising to renovate?
- What are the energetic defects of the dwellings?
- What building modifications are required for renovation?

Residents

- Who are the residents, what are their interests and needs?
- Are residents interested in a lease renovation concept?
- What is the willingness to pay for the residents?
- To what extend is the residents behavior affecting the energy usage?

Design

- What are typical renovation concepts?
- Which renovation concept is most desirable?
- What degree of design flexibility is needed?
- Which materials have a sustainable character?
- What are the energetic values of the components?

Finance _ Lease Construction

- What are the traditional renovation costs?
- What different lease concepts exist?
- Where to get financial benefit for home owners?
- Which service and maintenance contracts are available?
- What is the length of lease contracts?
- Are buy options available?

Finance _ Design Related

- What are the construction costs?
- What will happen to the property value of the dwellings?
- What is the expected life time of the renovation components?
- What is the residual value of the renovation components?
- What will happen with the renovation components if homeowners change?

Finance _ Energy Costs

- How much is the current energy bill?
- How much can be saved on the energy bill?
- What is the payback time of the different renovation models?

Other

- Why is doing nothing no option?
- Which actors are involved?
- What future scenarios exist?
- How sensitive is the result?

Chapter 2
Scope

The cheapest energy is the energy you don't use in the first place

Content & Structure

The themes elaborated in this scope are:

1. The building typology, including a research to the history of the Dutch Rowhouse. Leading to the most potential building type.

2. The residents interest, with a research into the housing profiles, including needs and whishes to find matching renovation concepts.

3. Renovation concepts, leading towards an elaborated innovative renovation concept which fits the residents interest and needs

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Chapter 2: Scope

The History of the Dutch Rowhouse

1500 – 1900
The origin of the Dutch rowhouse can be found in the courtyards from the 15th centuries, often commissioned by well-meaning rich people or by churches, built for poor widows and others who could not care for their own housing. The row of houses contain a sequence of identical houses around a shared garden. In the 17th century and later the rowhouse was not the standard. Private housing continued well into the 19th century and became the most common type of housing in the Netherlands. Often one room was rented to an entire family. From the second half of the19th century, when illuminated directors and manufactures started to build residential neighborhoods for their workers, the rowhouse typology begun to rise. One of the first examples is the Agnetapark in Delft, founded in1884 by factory-director van Marken (Hulsman, 2013).

1900 – 1945
Housing association are founded in the second half of the 19th century. The aim of these association is to build proper homes for the low-earning people. This led to cheap government loans and other financing sources such as subsidies. In 1901 the Dutch Housing Law established (in 't Hout, 2011). In big cities, especially just outside the city limits, large districts dominated by rowhouses arose. In the big city themselves the single story apartment was the predominant type of dwelling. From 1915 the so-called garden neighborhoods where also built inside the city: Rotterdam created Vreewijk, and Amsterdam the garden villages in the North. The book 'Garden cities of Tomorrow', by Howard (1902), became the bible for these districts in which the garden city was seen as a beneficial alternative to overcrowded and polluted slums in big cities.

In the 30's, the crisis years, a temporary end came to the march of the rowhouse. The state expenditures for housing were cut, however the build for the middle class went reasonably through because they were less affected by the crisis. In the crisis years of the Second World War the construction came almost to a standstill. 85.000 Homes were destroyed and another 300.000 got heavily damaged. After 1945 there was a great lack of housing and the Dutch government proclaimed housing shortages as public enemy number one (Hulsman, 2013).

1945 – 1975
The first post-war housing were still traditionally built, finished with pre-war details. After a few years when prefabrication and standardization were introduced and stimulated in 1947 by the minister of Reconstruction and Housing (de Jonge, 1988) the building process transformed from a craft activity to an industrial operation which led to a new, efficient and quick construction method in which prefab elements were used at a large scale. Bouwfonds Rotterdam (1948) was founded to coordinate the reconstruction, and published in 1960 5 books with Choice-plans (Lijbers, 1984) The bookwork contained standardized construction plans for rowhouses, which could be used for local authorities, housing associations and building companies, without the intervention of an architect. From the mid-60s, the building sector has increasingly become a contractor sector in which technical quality and the need to produce as fast and efficiently as possible became the main goal (Platform31,2013).




10) Images by Luuk Kramer Photography

Chapter 2: Scope

The History of the Dutch Rowhouse

1975 – 1995
Due to the monotonous and uniform appearance, traditional and rectangular street layouts disappeared in the 70s and 80s, and cauliflower districts, as result of the democratization that took place, arose (de Jonge, 1988). The houses, often deployed in small groups loosely around residential areas still mainly consist of rowhouses. Municipalities and housing corporations realized that the largebscale modern urbanism such as the Bijlmer, could count on little appreciation. The period became the largest breakthrough of the rowhouse, with more experiments in different typologies. Due to the energy crisis of 1973, the use of insulation became more conventional (Poel, 2007).

1995 - Present
In 1995 an overall liberalization of the Dutch economy established. Housing associations and corporations were privatized and state subsidies disappeared. Hence more developers and large construction companies were established, sometimes in conjunction with the municipaliy in Public-Private Partnership. In the VINEX-note of 1995 is determined that new built districts should be more urban and more various (Bontje, 2001). Due to commercial considerations developers take the needs and interest of the residents more seriously than before when housing corporations were focused on the subsidized rental housing, built in a tight housing market.
VINEX-districts have often their own characters from high urbanism to small village, with themes and styles from neo-traditional to neo-modernism and exotic. In January 2006 the VINEX-note is updated to VINAC (Fourth Note Actual). Changes can be found in the reducing number of rules that the government imposes on others, with a more director-carrying role for the province. Local authorities, civil society, private sectors and citizens have now more room for local consideration (Vastgoedmanagement: TU Delft, 2010). The main goal is to generate in a sustainable and efficient manner, more space for the various space-demanding functions in the Netherlands, and to improve the environmental quality of urban and suburban areas. With the start of the worldwide economic crisis in 2008 - when the construction of the VINEX-districts were far from completed - the housing market stagnated. In 2010 the ministry of housing, spatial planning and environment abolished.

Conclusion
Due to the impact of World War II on the building stock, housing shortage was the new public enemy in the Netherlands. It is in this period where industrialization came up to build as quick and efficiently as possible new dwellings in rehearsal. Only from1973 energy saving measures became important (Poel, 2007), however, nearly half of today's housing stock consists of homes before this date (ECN, 2013). The energy label the dwellings of the 60's and 70's s are assigned to are rarely better than label D, which not only means that the energy usage in the dwellings was not a focus point at that time, but also shows that the majority today is not yet been modified and still is a large energy consumer. In order to answer the research question, and to renovate the large energy demanding dwellings in the Netherlands, the building period 1945 - 1975 with a focus towards the system built dwellings from the 60's and early 70's, is the most potential building period to renovate. In the next chapter the specific building systems from 1945 to 1975 will be analyzed.




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The History of the Dutch Rowhouse

Timeline

1500 - 1900



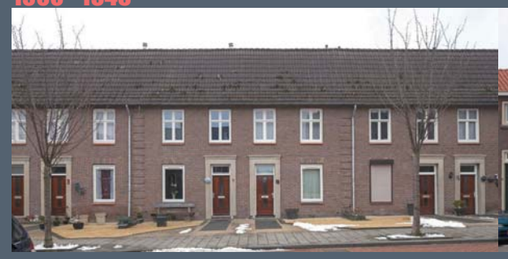


1500 - 1900



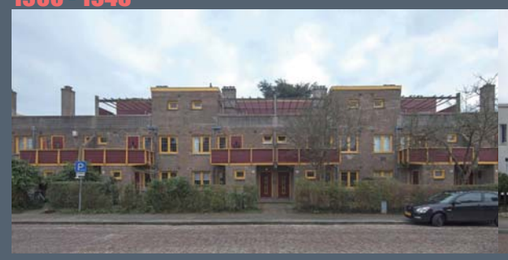


1900 - 1945





1900 - 1945





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The History of the Dutch Rowhouse

Timeline

1945 - 1975



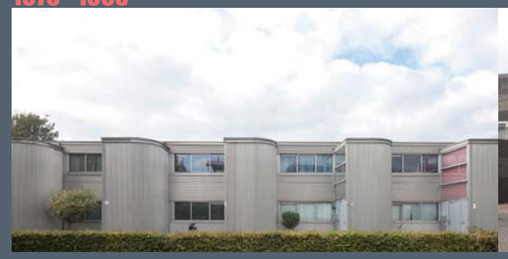


1945 - 1975





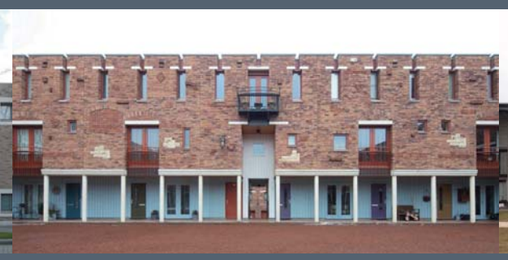
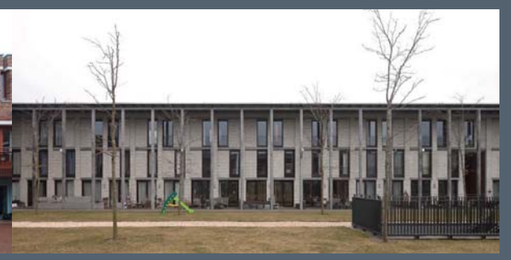
1975 - 1995





1995 - Present



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Chapter 2: Scope

Building Systems

In the period 1945 - 1975 approximately 400 to 450 thousand system-built dwellings are built in the Netherlands (Platform31, 2013). More than 70 systems have been introduced on the Dutch market. The company names are often appointed as an acronym of the original builders (ERA, MUWI, WILMA etc.).

This section discusses the building systems dated from 1945 to 1975. The research contains an analysis of the 21 most common used systems, of which 10 are focussed on the single family dwellings. These 10 systems are presented in this chapter, eventually three building systems will be elaborated more to find the most promosing building system to renovate.

The analysis is based on the articles as described in "A series of system-built houses" commissioned by Knowledge Centre Existing Housing Stock and used in the "Documentation System-built dwellings '50 - '75", a study by independent organization Platform31 (2013). Additional information is provided by Priemus - Non-traditional Housing Construction Methods in The Netherlands (1971)

It should be noted that in the period 1945 - 1975 systems were fully in development, thus systems have been changed and improved during the years.

Building System: Airey (1949-1969)

Article: Airey Dwellings,
memorial with sobriety (2013)

Due to the white appearance and minor roof inclination, the districts are referred to the city of Jeruzalem. The large dimensions - up to 60m2 for the first floor - combined with a high degree of flexibility are of great value for this type of dwelling. The load bearing facades are constructed from lightweight concrete columns, filled with 40mm thick plates of concrete which is typical for the architectural appearance. Floor- and roof construction consists of light steel griders with wooden beams. The house separating walls are built from cinder concrete blocks with specific elements for channels. The majority is prefabricated and mounted at the site. Strong re-loads are unsuitable due to the economic focused construction. The original appearance is in course of time greatly changed. The majority is already renovated around 1990. Dwellings are provided with outer wall insulation or even new masonry, new frames and windows, but still after this renovation the dwellings are stuck with an energy label D or E. At the same time a large part is demolished. In the last decade several dwellings are appointed as monument due to the culture-historic value. The future of the still existing airey-dwellings is most likely restoration or replacement by new buildings.

Company: Airey
Date: 1949 - 1968
Amount: 8.500
Typology: Single family dwelling
Portiek
Gallery

11) Image by Bestaandewoningbouw.nl

Chapter 2: Scope, Building Systems

Company: Geulen N.V.
Date: 1956 - 1975
Amount: 12.000
Typology: Single family dwelling

Building System: PeGe (1956 – 1975)

Article: The PeGe systemdwellings invisible incorporated in the street scene (2013)

A large distributed system focused on private ownership. The system is based on a stacking method combined with prefab elements which results in a flexible floorplan. The house separating walls are constructed from concrete blocks, the facade is built with a cavity and finished by masonry and contains story high wooden prefab-frames. The inner walls are also made out of floor height wooden panels and floors are also often supported by wooden beams. With a ground floor surface of 49m2 the size of the dwellings is reasonable. The weak quality is the energetic value of the facade. Even after earlier adjustments in the 80's and 90's, the energy label rests at level D. The energetic quality, the uniform appearance, and the accessibility of the attic are aspects to take into account in a renovation process. Due to the wooden inner walls, adjustments in the floor plans are relatively easy. It is estimated that in the last 10 years about 15% of the PeGe housing stock is demolished or currently on the list of being demolished. The expectation is as well that a part is thoroughly refurbished, which means that there are about 70% pege dwellings left (8.400) for a possible renovation process.

Building System: Vaneg (1965 – 1975)

Article: Vaneg, a precursor of the precast concrete structure (2013)

The location of these single family dwellings is difficult to determine due to change in name and due to private ownership. The dwellings have large windows at the front and rear therefor they are called typical see-through dwellings [NL: doorzon-woningen]. There is enough living space and often an attic with dormers is included. The dwellings are very technically focused, therfore the architectural value did not get much attention which results in the (nowadays) quit poor appearance. The infill elements usually constist of wooden frames with aluminum plates, complemented by a layer of 4 cm insulation. The large prefab concrete elements for the load bearing structure - and at the same time the house separating walls - are story high and maximal 4.3 meters wide. The floors are also prefabricated, however the first floor can be performed in a wooden floor. Energetically the dwellings are far away from modern standards. Thereby the dwellings seems to have more future value if the image structurally changes.

Company: Vaneg
Date: 1965 - 1975
Amount: 7.000
Typology: Single family dwelling

11) Images by Bestaandewoningbouw.nl

Chapter 2: Scope, Building Systems

Company: Welschen
Date: 1947 - 1955
Amount: 5.600
Typology: Single family dwelling
Portiek

Building System: Welschen (1947 – 1955)

Article: Building system Welschen, the pioneer of industrial building (2013)

With 5.600 dwellings (single family and portiek). Welschen is one of the first systems at larger scale. Concrete is the preferred building material, combined with hollow elements made from coal ash concrete. The homes reflect the 'Rules and Guides' of 1950, therefore the living space is quite limited. Due to the concrete structure with a column in the middle there is some flexibility in the layout of the floor plans. There are several serious physical building problems such as thermal bridges which result in a very low energetic value and few comfort. Many homes are already renovated or demolished (25%). There are sporadic original complexes but they are rarely on the 'renovation agenda', they rather fulfill the function as a reference to the past.

Company: Bakker
Date: 1950 - 1968
Amount: 5.000
Typology: Single family dwelling
Gallery

Building System: Bakker (1950 - 1968)

Article: Bakker systemdwellings, built and almost forgotten (2013)

A brick stacking method in a sober appearance and an efficient dwelling. The size of the complexes and projects are quite small with just an average of 100, but also 30 to 90 dwellijgs in one project are not rare. The dwellings are difficult to localize and are divided over more than 25 districts. The dwellings are probably the smallest systembuilt dwellings in the Netherlands.

Building System: Tramonta (1951 - 1960)

Article: Tramonta, a traditional assembly building system (2013)

A traditional system combined with prefab elements used in almost every building typology. The concrete skeleton with columns and beams in the middle and in the facade, ensures flexible floorplans. Due to this flexibility various architects are involved which led to a diverse appearance of the dwellings, which at the same time makes it hard to localize the dwellings. The most characterizing element is the minor roof inclination of 9 to 10 degrees. Generlly the single family dwellings are quit big and could be restored to their oringal identity, however due to the flexible skeleton a new identity with better energetic qualities is possible.

Building system: BBB (1948 – 1973)

Article: BBB systemdwellings, a history in itself (2013)

A stacking method with masonry concrete block for the load bearing walls. Not the technical originality but the consequent implemented organization is the succes factor. The building execution and details are traditional. Inner walls are created in a conditioned barn close to the building site. Beams are customized over there. Joints and anchors are provided by another wood company and are delivered directly to the site. Nowadays the energetic qualitie is poor, also dwellings need more equipment and comfort.

Company: Tramonta
Date: 1951 - 1960
Amount: 4.800
Typology: Single family dwelling
Portiek
Gallery

Company: Bradero's BouwBedrijf
Date: 1948 - 1973
Amount: 13.000
Typology: Single family dwelling
Gallery

11) Images by Bestaandewoningbouw.nl

Chapter 2: Scope, Building Systems

Company: B-G
Date: 1956 - 1970
Amount: 6.000
Typology: Single family dwelling

Company: Smit II
Date: 1959 - 1970
Amount: 9.000
Typology: Single family dwelling

Building System: B-G (1956 – 1970)

Article: B-G, a system for buyers (2013

Focused on private ownership, this system is not only a method but also contains an organization for the financing, guidance and inspection. The organization is financially supported by the town municipality. Individuals put money in the savings of the organization and can buy a home in a later stage. 85% of costs to mortgage was possible. The construction method was prefabrication, based on wooden frames for load bearing walls and facades, finished with traditional masonry in the exterior. Insulation (4cm) and foils are included, but do not fulfill the energetic standards anymore. All elements were brought to the building site at once, and within a day the home was wind-tight. The bungalows with a inclined roof are typical for this system but also detached and semi-detached dwellings occur. Many homes are demolished at the resale of the house: the site has more value than the dwellings.

Building system: Smit (1959 – 1970)

Article: Smit, almost traditional

This construction system contains an industrial built casco and focusses on the private ownership of the dwellings. Other contractors could use the system to implement their own (facade)elements, but also Smit bought their elements at other fabrics such as Schokbeton. The average project size is just about 32 dwellings, and because other companies could use the system, it is a widely distributed system. There are more than 200 projects spread in the Netherlands. The prefab casco elements are transported to the building site and adjusted on lugs. There are dwellings with concrete floors but also with wooden floors. The wall elements are provided with notches. Stability has been obtained by pouring the concrete floor- and wall elements together, or in case of the wooden beams fixed a bolted connection. Facades are partly equipped with story high concrete elements with masonry, the other part is filled with wooden prefab frames.

Building System: Polynorm (1950 - 1951)

Article: Polynorm, development of a mass product (2013)

With a helping hand of the government it was possible to start a new construction company, which is focused on the gap between supply and demand. The system seemed to be really hopeful but due to the quick recalled financial help of the government only 292 single family dwellings are built. Polynorm was a precursor in technology. The system focused on components instead of the dwelling level, which would have led to a low number of homes to generate a profitable system. It was an industrial production with thick steel H, I, and U-profiles containing holes to save material and to guide pipes and ducts. After the demolition many years later, it turned out the components were easily to dismantle and there was few demolition material. It was a well-developed system for the time, including aspects as double insulation, well-placed vapor barriers and acoustical disconnected concrete slabs.

Company: Polynorm
Date: 1950 - 1951
Amount: 292
Typology: Single family dwelling

11) Images by Bestaandewoningbouw.nl

Chapter 2: Scope

Overview Building Systems

System	Amount	Year	focus	Method	Material	Floor	Facade
Airey	8.500	1949 - 1968	Single family (55%), portiek (35%), flats (10%)	Stacking and prefab	Concrete	Steel griders, wooden beams	Concrete columns and plates
Pege	12.000	1956 - 1975	Single family	Stacking and prefab	Concrete	Concrete or wooden beams	Masonry, prefab frames
Vaneg	7.000	1965 - 1975	Single family	Prefab	Concrete	Concrete or wooden beams	Prefab frame
Welschen	5.600	1947 - 1955	Single family and portiek	Stacking	Concrete	Concrete	Concrete and prefab frame
Bakker	5.000	1950 -1968	Single family, gallerie-etage	Stacking, prefab	Concrete	Concrete	Masonry
Polynorm	292	1950 - 1951	Single family	Prefab	Steel skeleton	Concrete	Concrete plates
BBB	13.000	1948 - 1973	Single family, portiek	Stacking	Concrete	Wooden beams	Masonry
Trammonta	4.845	1951 - 1960	Various	Stacking, prefab, casting	Concrete skeleton	Concrete	Masonry, concrete, prefab frames
B-G	6.000	1956 - 1970	Single family	Prefab	Wooden	Wooden beams	Wooden
Smit	9.000	1959 - 1970	single family	Stacking and prefab	Concrete	Concrete or wooden beams	Masonry, prefab frames
BMB	30.000	1949 - 1973	High-rise (45%), mid-rise (40%), low-rise (15%)	Stacking and prefab	Concrete	Concrete	Mechanical laid masonry
Coignet	31.000	1959 - 1975	Gallery (55%), portiek (24), single family (14)	Prefab	Concrete	Concrete	Concrete
InterVAM	14.000	1959 - 1970	Mid-rise and high-rise (portiek up to 10 floors)	Prefab	Concrete	Concrete	Sandwich infill
Rottinghuis	17.000	1949 - 1970	Gallery (50%), portiek (50%)	Prefab	Concrete	Concrete	Masonry
Wilma	12.000	1960 - 1975	Mid-rise and high-rise	Casting and prefab	Concrete	Concrete	Infill
MUWI	36.000	1951 -1973	Gallery (53%), portiek (46%)	Stacking and prefab	Concrete	Concrete	Concrete and infill
RBM	32.000	1945 - 1975	Mid-rise and high-rise	Stacking, prefab, casting	Concrete	Concrete	Infill
Pronto	18.000	1955 - 1970	Portiek (62%), single family (32), gallery (4%)	Stacking	Concrete	Concrete?	Concrete
ERA	10.000	1964 - 1971	High-rise	Casting	Concrete	Concrete	Infill
Korrelbeton	15.000	1949 - 1970	Portiek (75%), single family (25%)	Stacking, prefab	Concrete	Concrete	Concrete
PLN	8.500	1960 - 1970	High-rise	Prefab	Concrete	Concrete	Infill
EBA	19.000	1958 - 1972~	High-rise	Casting	Concrete	Concrete	Infill
Bouwvliet	2.500	1970 - 1975~	Single family, maisonnetes	Prefab	Concrete	Concrete	Infill

PeGe, Smit and Vaneg

The analysis introduced 3 construction systems which are all used for especially the single family house in row setup and have structural simularities. These 3 buildings systems are Pege, Smit and Vaneg. Together they form a housing stock of 28.000 dwellings spread over the entire country. Besides these three building systems, more single family dwellings use similar systems but due to the branding in the 50's and 60's they have their own system-names and have a smaller individual impact on the existing housing stock. All the less-known brands together form around 50% of the system built housingstock. Thereby, to gain more support for the design, customization options to other sytem-built dwellings should be implemented in the design.

All three have poor energetic quality related to the facade, roof and crawl space, and are often occupied by outdated and unsustainable installation systems. All three systems deal with their uniform appearance. The image of the three types however differ. The Pege dwelling makes use of stability walls in the facade. The infill elements are story-high and placed in between the cavity walls. The system Smit has an industrial casco which gains it stability by pouring the elements together (or bolted in case of wooden beams). The most common Smit-image is the story-high prefab infill elements combined with a vertical stroke of masonry. The Vaneg dwellings are maximum technical focused, therefore the entire facade is an infill of story-high elements made of wood and aluminum plates. The load bearing structure contains concrete prefab elements for walls and floors.

The PeGe system will be appointed as reference and starting point for the continuation of the research. The choice is based on the largest amount of constructud dwellings and the focus on private ownership. Besides, the system seems to be an inbetween version of the extremely technical Vaneg dwelling with its maximized prefab infills, and the more various appearance of the Smit-system, which may lead eventually to an easier to adapt renovation system.

PeGe

Smit

Vaneg

Chapter 2: Scope

PeGe in Detail

The PeGe dwelling is a typical systembuild rowhouse from the 60's and 70's. The original energetic specifications could already not meet the desires in the late 80's. Senter Novem, a energy program founded by the government, released a Energy Manual in 1989 focussing on the PeGe structure. The values presented below are based on the original state of the dwelling, with the specification as described in the Senter Novem Manual from 1989. The presented values in the last column are the values which are currently applied in passive housing (Duin, 2012) Additional information is obtained by "Non-traditional building systems" by Priemus (1971)

Construction part	Surface		Transmission Coefficient		
Cavity wall Front and Rear Facade	2x18,3	m^2	1,5	W/m^2K	[0,15]
House Seperating Walls	2x 53	m^2	1,5	W/m^2K	[0,15]
Ground Floor	48,8	m^2	2,5	W/m^2K	[0,15]
Roof	59,8	m^2	2,6	W/m^2K	[0,15]
Wooden Prefab Facade-Frames	2x 19,3	m^2	1,7	W/m^2K	[0,15]
Glass in Main Departments	13,4	m^2	5,7	W/m^2K	[0,8]
Glass in Secondary Departments	10,7	m^2	5,7	W/m^2K	[0,8]
Exterior Doors	2x2,4	m^2	3,0	W/m^2K	[0,8]

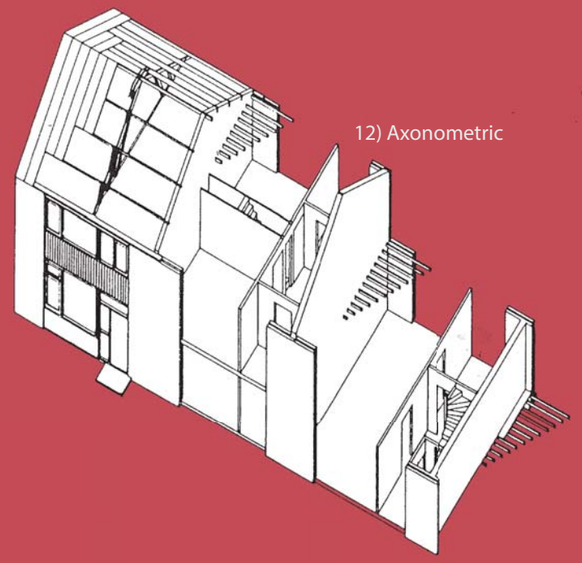
Ventilation system: Natural, via canals through cavity wall

Heating system: Individual, gas heated

Warm water system: Geyser

Load bearing structure:
- House separating walls
  - Concrete wall elements B2-blocks or sand-lime bricks
- Stability walls in facades
  - Concrete wall elements B2-blocks or sand-lime bricks
- Wooden interior walls
  - End studs (60x70mm)
  - Upper stud (95x70mm)
  - Lower stud (40x70mm)
  - In between studs (40x70mm)
  - 9.5mm plasterboard

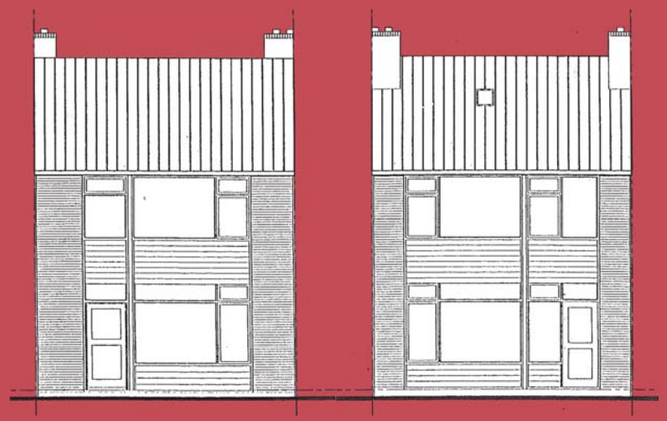
Facade:
- Inner and outer cavity wall
  - Brickwork
  - Cavity 50mm
- Story high prefab timber frames
  - 9,5mm plasterboard
  - Vapor barrier
  - 30mm mineral wool
  - 50mm cavity
  - Redwood laths, asbestos cement sheet, multiplex



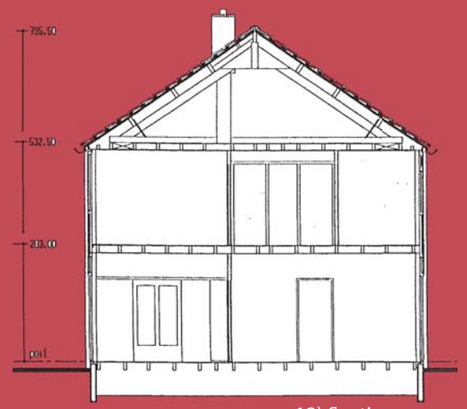
12) Axonometric

Roofconstruction:
- Prefab trusses (70x190mm)
- Purlins each (50x150mm) every 1.25m
- Roof boarding or concrete tiles

Wooden inner walls:
- Prefab elements
  - End studs (35x60mm)
  - Upper stud (35x60mm)
  - Lower stud (40x85mm)
  - In between studs (35x30mm)
  - 9.5mm plasterboard



12) Front and Rear facade



12) Section

Chapter 2: Scope

Residents' Interests

Multiple studies recognize that sustainability measures have the greatest chance of success if the interests of all parties are involved as a starting point (Boer Booms, 2010). The involved parties and residents strive therefore not for a general objective, but their own interests, increasing the involvement and enthusiasm for the plans. Therefore the People, Planet and Profit approach should by pursued in that order. By starting with the interests of the people and to link them to sustainability and energy savings, people will be more excited and are more willing to pay (Tiemeijer, 2009).

To be able to reflect the different interests of residents for the correct target group the segmentation model Mosaic Experian (Experian, 2012) is used, combined with the survey results from "Residents' interests at renovation in occupied state' by Van der Werf (2011). Mosaic is an instrument developed by Experian. They have the intention to supply services in market segmentation and micro market strategies. Within Mosaic consumers are split into groups and types, based on demographic, psychological and lifestyle characteristics. Next to that there is a link created between the household- and neighborhood characteristics. The survey presented in "Residents' Interest" contains a large scale survey among 650 people, concerning the interest factors of the residents at participating in a renovation in occupied state. The results are divided in the different household classifications as described by Mosaic, and thus can be related to the correct target group which present the most common type of resident in the rowhouses of the typical 60' and 70' districts.

The following is a brief description of the household types that mainly live in serially built dwellings from the 60s and 70s. The descriptions are based on segmentation model Mosaic and complemented with research results by Van der Werf (2011). After the descriptions one target group which represents the most common housing typology, will be assigned to explore the interests and needs of the residents. This will eventually lead to a matching renovation concept.

The Free Spirits generally have no permanent job. This group consists largely of students, but also people who are starting in the labor market or are less successful despite their level of education. The Free Spirits have not (yet) a low income, but a high level of education. They have plenty of free time that they would like to fill. A large part of the group is less than 25 years old, but can vary up to 45 years. They are generally single. Free Spirits live mainly in large cities. The choice of a '60 -'70 flat is purely functional and financially, they have a cheap roof over their heads. They feel therefore little concernswith the area and have an individualistic attitude.

The brawlers do not have high education and often a lower than average income. The brawlers are generally younger than 35, but also a significant part of this group is around 50 years old. In general, the brawlers are single households or families. This group consists of both natives and foreigners. The brawlers live mainly in the west of the Netherlands in post-war high-rise districts, because of low housing costs.

The Modal Citizens are families of middle age with children. They have a low to secondary education and below average to average income. The Modal Citizens are living in the west of the country. Since the houses are expensive they live mainly in rowhouses in expansion areas from the 60's and 70's. These districts are very uniform, but due to the diversity of residents, the many children and the sometimes low appreciation or effort residents take care of their homes, it may look messy.

Traditionalists consist mainly of families with children of all ages. They are low to middle educated and belong to the middle class. They generally live outside the Randstad in larger rowhouses or semi-detached homes in neighborhoods from the 60's and 70's. The major part of this group has bought his house. The young Traditionalists have just bought a house here to start a family. The older Traditionalists live for years in their home and want to keep it that way. In the neighborhoods is often little flow.

The Retired Hedonists have mainly low education, are now no longer active in the labor market and are now enjoying a small pension from their well-deserved quiet life. This group is found everywhere in the Netherlands, mainly living in a public housing apartment from the 60's and 70's. They often live for years in their current home and they come not much outside their own neighborhood. They just want to make sure their neighborhood is peaceful and safe.

Chapter 2: Scope

Residents' Interests

The classification 'Modal Citizen' , is selected as target group and to get a closer look into the interest and needs of the residents as they occur in the private owned rowhouses from the 60's and 70's. Below the most important interests and needs are presented, according to the results of the large scale survey in "Renovation in occupied state"'(v.d. Werf, 2011).

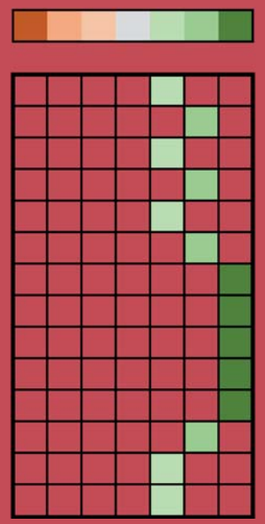
Besides the more general findings as 'more comfort' and 'healthier living environment', the wish to expand the living space and the ability to have a large choice in the renovation options, are found as a striking point in the renovation design and process. In the next chapter different renovation concepts will be examined and the interest and needs of the residents will be matched to the most potential renovation concept.

Groep	Groep omschrijving	Type	Type omschrijving
A	De Vrije Geesten	A01 A02 A03 A04	Degelijke Studenten Jonge Doeners Minder Geslaagden Levensgenieters
B	De Ontwikkelde Stedelingen	B05 B06 B07	Cultuurgenieters Mini Macho's Bewuste Starters
C	De Knokkers	C08 C09 C10	Multiculturele Doorzetters Jonge Flatbewoners Krappe Kassen
D	De Dynamische Families	D11 D12	Succesvolle Starters Moderne Gezinnen
E	**De Modale Burgers**	**E13 E14 E15 E16 E17**	**Gemakkelijke Gezinnen Ruimdenkers Honkvaste Senioren Arbeidsgrijzen Jonge Genieters**
F	De Succesvolle Gezinnen	F18 F19 F20 F21	Familie Dynamiek Familie Doorsnee Weltevreden Stellen Eigenzinnigen
G	De Traditionalisten	G22 G23 G24 G25 G26 G27 G28	Conservatieve Gezinnen Jonge Stellen Brave Borsten Tevreden Gezinnen Ordelijke Dorpsgenoten Noeste Werkers Groen Genieters
H	Het Landelijke Gezinsleven	H29 H30 H31 H32 H33 H34 H35	Welvarende Plattelanders Senioren op het platteland Contente Provincialen Eenvoudige Dorpelingen Agrarische Gezinnen Nuchtere Landelijke Bewoners Gefortuneerde Landbouwers
I	De Welgestelden	I36 I37 I38 I39 I40	Rijke Elite Chique Provincialen Gefortuneerde Kosmopolieten Landelijke Grootgrondbezitters Gedreven Doeners
J	De Pensioengenieters	J41 J42 J43 J44	Tevreden Arbeidsmarktverlaters Eenvoudige Vergrijsden Genietende Arbeidsverleders Huisouderen

13) Mosaic Residents profiles

Survey results 'The Modal Citizens"

1. More Living Comfort
2. Healthier Indoor Climate
3. Reconfiguration Dwelling
4. Extension Living Space
5. Increase Property Value
6. Degree of Control
7. Different Options and Choices
8. Impact on Energy Bill
9. Impact on Monthly Expenses
10. Amount of Investment
11. Length of Payback Time
12. Affect on Property Value
13. Subsidies
14. Funding Opportunities



14) Residents' Interests

Renovation concepts

To follow a first design direction, research has been performed in different renovation concepts. After selecting the most six applicible renovation concepts as described in "Residents Interest in Occupied State" (v.d. Werf, 2011), the results from the survey on previous page will be linked so the most desirable renovation concept can be selected.

The six design concepts are:

- 2D Plug & Play
- 3D Prefab
- Box-in-Box
- Hanging Module
- Slide-in Dwelling
- Components Renovation

On the next two pages the different design concepts are shortly presented. The choosen design concept will be elaborated in a detailed design allowing to calculate costs and energy savings. Eventually a lease construction will be implemented in the next chapter, and the willingness to pay will be tested by literature and interviews afterwards.

Chapter 2: Scope

Renovation concepts

Concept #1
2D Plug & Play

A prefab skin with dwelling-width elements, placed straight on the existing structure. The elements are 1 or 2 stories high. The roofmodule can be split in 1 or 2 elements for front and rear facade, but also one entire prefabricated roof belongs to the possibilites

Renovation in 10 days
Renovation in occupied state
Elements with built-in installations
Thermal bridges through shared walls
Location of window frames partly depended on underlying existing structure

Concept #2
3D Prefab

A prefab 3D module connected to the existing structure, adding extra living space to the dwelling. Various widths and length possible. Special small 3D modules as the 'Smart Portal' (RenovatieTotaal, 2014) are available to integrate installations

Renovation in occupied state
New facade and window layout
Elements with built-in installations
Extra livingspace
Thermal bridges through shared walls
Elements may need their own foundation

Concept #3
Box-in-Box

A prefab system connected by putting the module inside the existing dwelling. Existing facade needs to be removed. May include retention walls, ceilings and installations. A good solution for a - large scale - bathroom swap.

Extra livingspace
Built-in installtions
Change/update interior
Difficult applicable in occupied state
Reduction of existing space by box-in-box construction

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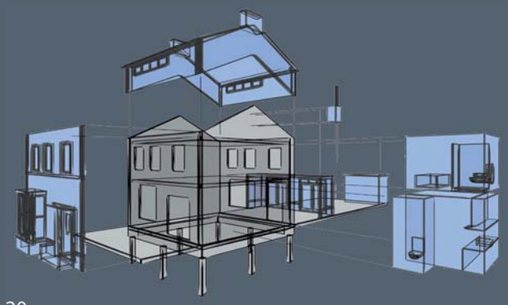
16.

17.

18.

19.



20.

Concept #4
Hanging module

A prefab module, hanging to the existing structure of the dwelling. Extra living space is added. Especially in development for multifamily houses with a large amount of stories and dwellings.

Renovation in occupied state
Elements with buit-in installations
Extra living space
Applicability depends on existing load bearing structure
Not suitable for rowhouses

Concept #5
Slide-in dwelling

Demolition of facades and roof, adding new prefabricated elements. May include boxes with built in installations. Elements or modules can be fixed to floorconstruction. In more extreme scenario floors are removed and an entire prefab etage can be slided in between the house separating walls.

A complete new dwelling
Completly tailor-made
Maximum insulation possibilities
Temporary dwelling required
Large demolition costs and embodied energy

Concept #6
Components

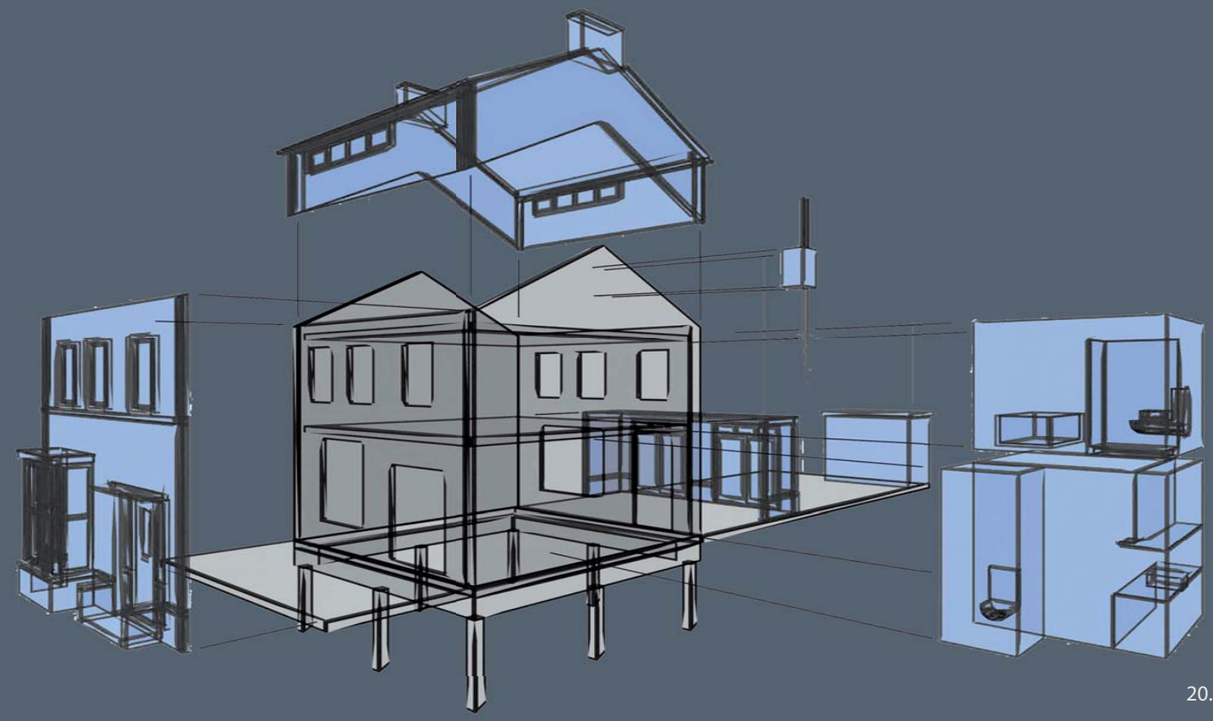
Combination of 2D Plug & Play concept and 3D Prefab module. Renovation contains of seven different components (roof, facade, extensions, installations, equipment kitchen - bathroom - toilet, internal modules, external modules). Appearance, composition, finishing, extra living space and installations can be customized to the personal taste and needs of the residents.

Renovation in 10 days
Renovation in occupied state
Elements with built-in installations
Location of window frames partly depended on underlying existing structure
Renovation of skin (front and rear facade, roof) should be done together for good insulation properties

Chapter 2: Scope

Renovation Concepts

Components Renovation



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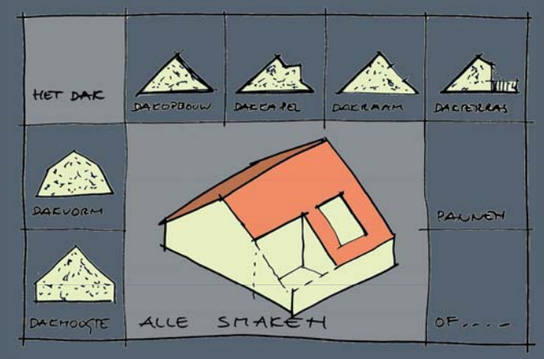


21) Different roof modules

22) Various finishes

7 MODULES:

1. FACADES
2. ROOF
3. EXTENSIONS
4. INSTALLATIONS
5. EQUIPMENT KITCHEN, BATHROOM, TOILET
6. INTERNAL MODULES
7. EXTERNAL MODULES

Advantages:

Renovation in 10 days
Renovation in occupied state
Built-in installations
Installation and elements adapted to households needs
Create additional living space
Create a new appearance of your dwelling
Increase property value
Save on your energy bill

The components renovation has been found as the most promissing renovation concept for the residents of the private owned rowhouses from the 60's and 70's dwellings.

Due to the interest and needs of the residents group 'The Modal Citizen' - as they common occur in the designated housing typology - , the two needs to extend living space and the ability to chose for different options in the renovation concept, are perfect reflected in the components renovation: living space can be added by choosing personal extensions, dormers, raised roofs and 3D extension. The entire finish and appearance can be customized to the residents preferences, as long as it is in line with the local regulations. The renovation may be performed in different steps, by adding different installations as PV panels, sunboiler, heat recovery systems and sunscreens, in a later stage. (Liebregts, 2009)

In the next chapter the design will be elaborated with a focuss on the PeGe building structure as assigned building structure earlier.

Chapter 3
Design

Content & Structure

First the PeGe details will be examined by the literature of Senter Novem Energy Saving Manual (1989) and Non-Traditional construction metods by Priemus (1971)

The load bearing structure, materials and energetic values will be presented along with elavations, a section and axonometry.

When the PeGe structure is known, the design can be elaborated. This will be presented in different renovation steps supported by several sections and details.

In the following chapter the construction costs and energy performance is calculated.

Starting point: PeGe

23) PeGe streetview drawing

Chapter 3: Design

PeGe Construction Details

Load bearing structure:

- House separating walls
  - o Concrete wall elements
    B2-blocks or sand-lime bricks

- Stability walls in facades
  - o Concrete wall elements
    B2-blocks or sand-lime bricks

- Wooden interior walls
  - o End studs (60x70mm)
  - o Upper stud (95x70mm)
  - o Lower stud (40x70mm)
  - o In between studs (40x70mm)
  - o 9.5mm plasterboard

Facade:

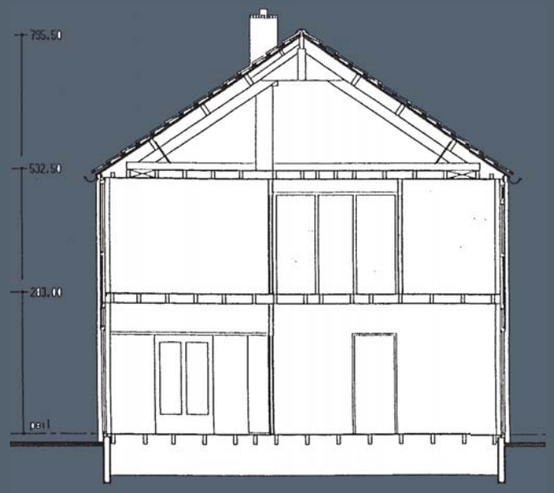
- Inner and outer cavity wall
  - o Brickwork
  - o Cavity 50mm
- Story high prefab timber frames
  - o 9,5mm plasterboard
  - o Vapor barrier
  - o 30mm mineral wool
  - o 50mm cavity
  - o Redwood laths, asbestos cement sheet, multiplex

Roofconstruction:

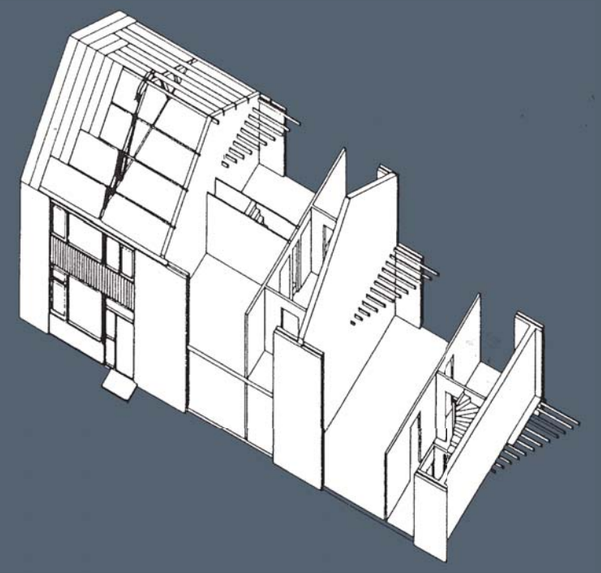
- o Prefab trusses (70x190mm)
- o Purlins each (50x150mm) every 1.25m
- o Roof boarding or concrete tiles

Wooden inner walls:

- Prefab elements
  - o End studs (35x60mm)
  - o Upper stud (35x60mm)
  - o Lower stud (40x85mm)
  - o In between studs (35x30mm)
  - o 9.5mm plasterboard

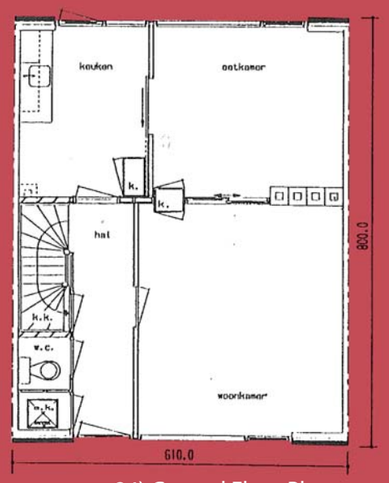


24) Section

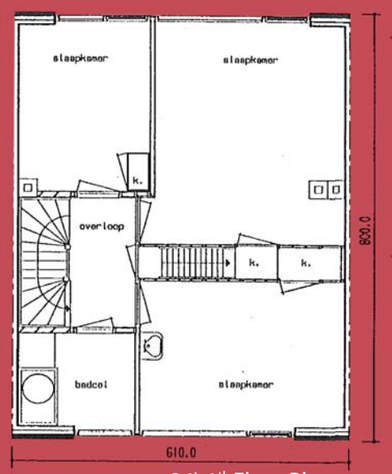


24) Axonometric

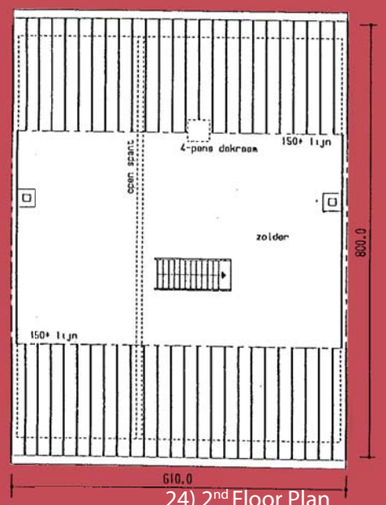
Construction part	Surface	Transmission Coefficient
Cavity wall Front and Rear Facade	2x18,3 m^2	1,5 W/m^2K [0,15]
House Seperating Walls	2x 53 m^2	1,5 W/m^2K [0,15]
Ground Floor	48,8 m^2	2,5 W/m^2K [0,15]
Roof	59,8 m^2	2,6 W/m^2K [0,15]
Wooden Prefab Facade-Frames	2x 19,3m^2	1,7 W/m^2K [0,15]
Glass in Main Departments	13,4 m^2	5,7 W/m^2K [0,8]
Glass in Secondary Departments	10,7 m^2	5,7 W/m^2K [0,8]
Exterior Doors	2x2,4 m^2	3,0 W/m^2K [0,8]



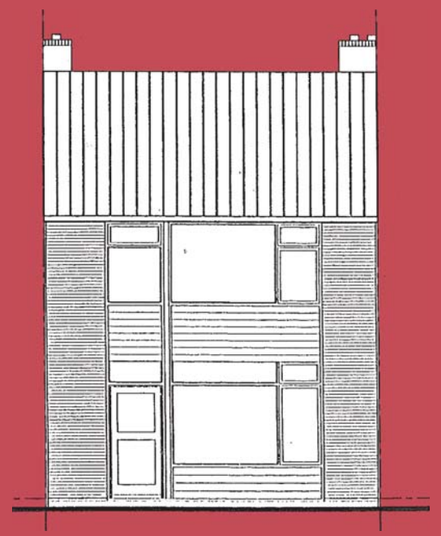
24) Ground Floor Plan

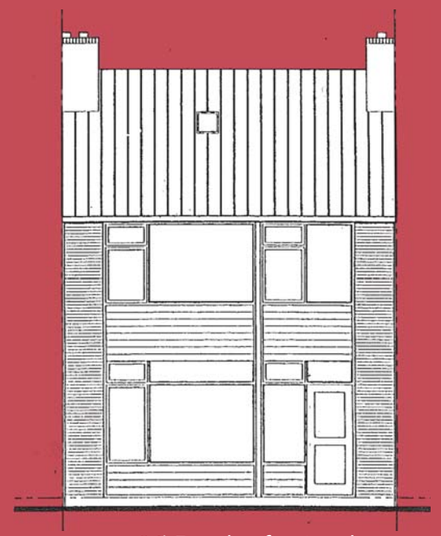


24) 1th Floor Plan



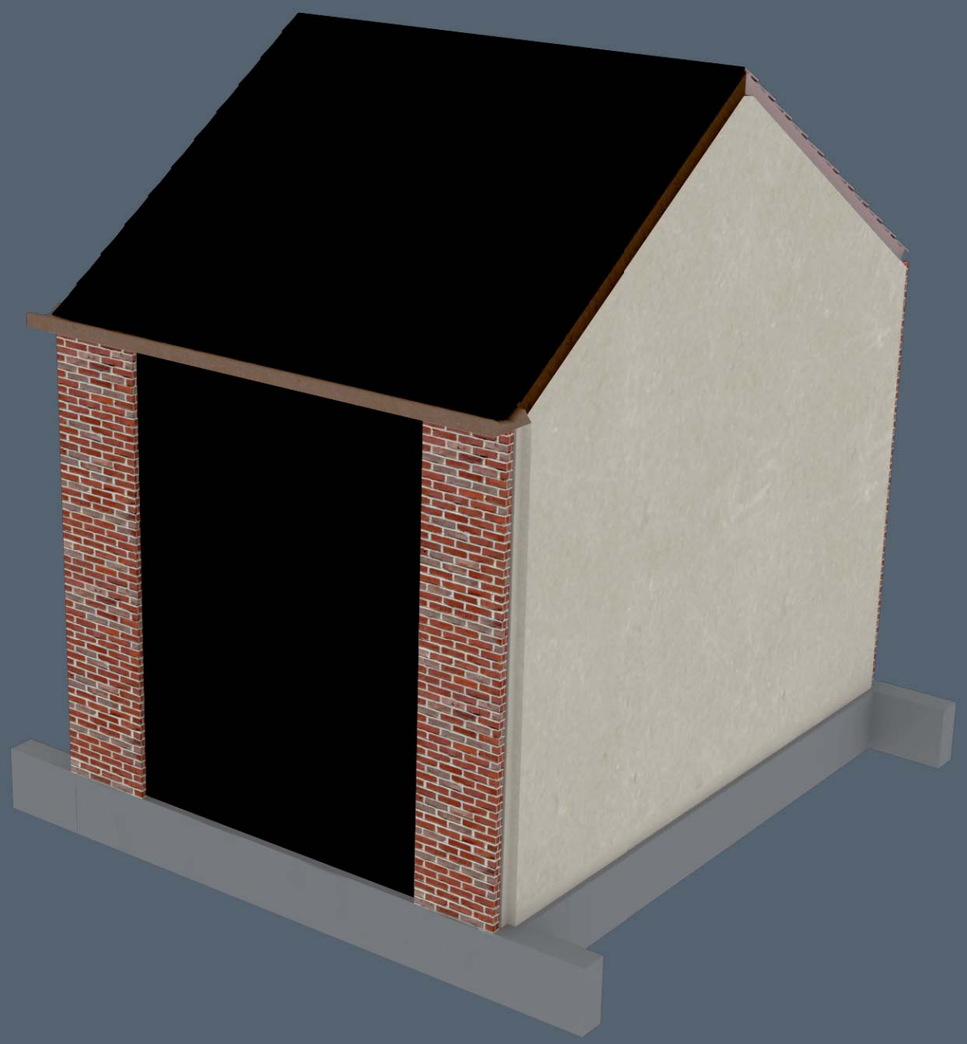
24) 2nd Floor Plan





24) Facades, front and rear

0: Starting Point



Dwelling in original state

1: Strip Existing Elements

Remove wooden prefab frames
Remove rooftiles
Remove wooden battens

2: Preparations

Excavate near foundation beam

Install custom made load bearing steel pillars to foundation beam

Install wooden beam on steel pillars to carry prefab facade elements

3: Install Prefab Elements

Prefab element consists of timber construction fram with glasswool and integrated ventilation ducts.

Ground floor facade element is resting on wooden beam with steel frames.

Facade element is vertically fixed to the cavity masonry wall by means of anchors

Facade element is fixed to concrete floor with steel angle anchors

3: Install Prefab Elements

Prefab element consists of timber construction frame with glasswool and integrated ventilation ducts. Crawl space insulation can be applied.

First floor facade element rests on ground floor facade element

Facade element is vertically fixed to the cavity masonry wall by means of anchors

Facade element is horizontally fixed to concrete floor with steel angle anchors

4: Add Installations

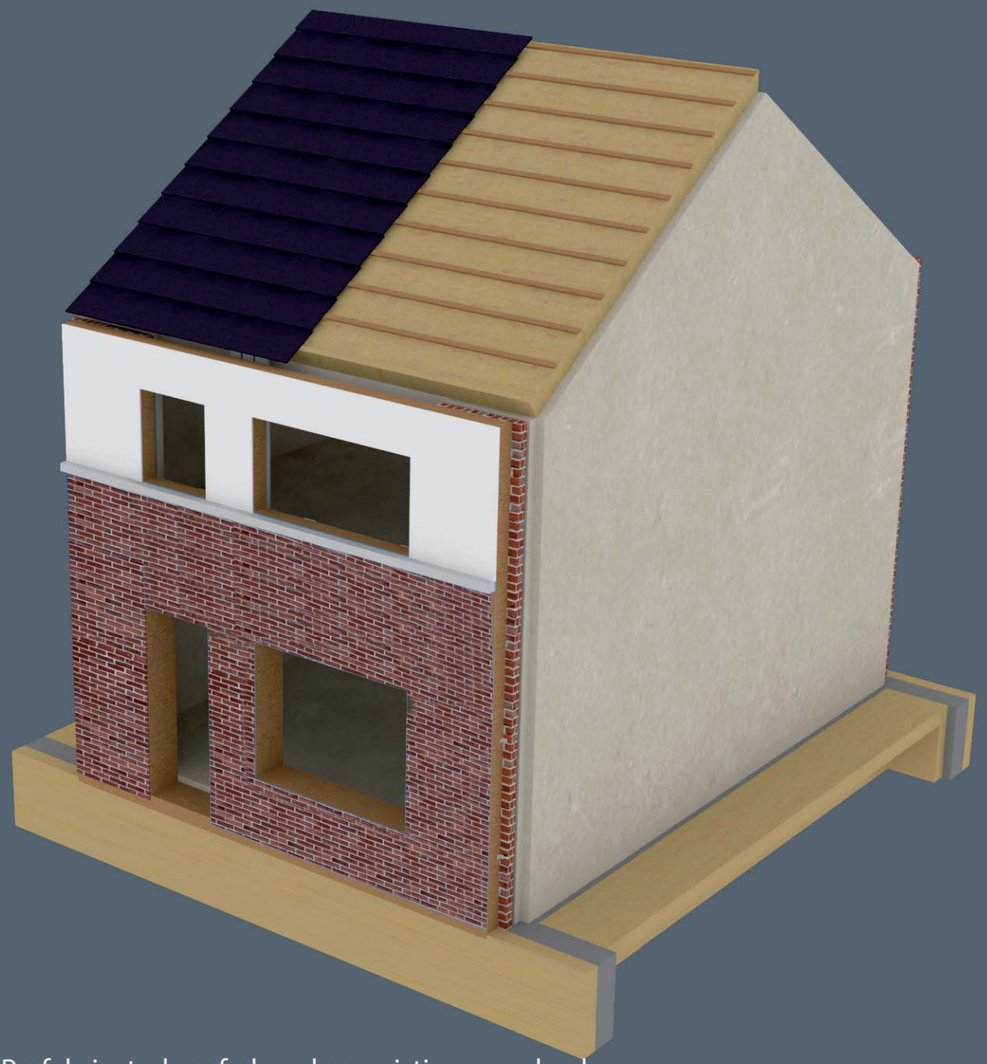
Installations are located in the attic. Mechanical ventilation with heat recovery installed and connected to built-in ventilation ducts in facade.

Optional with solar boiler on roof and tank in the attic

Optional solar PV panels on roof, with transformers installed under panels

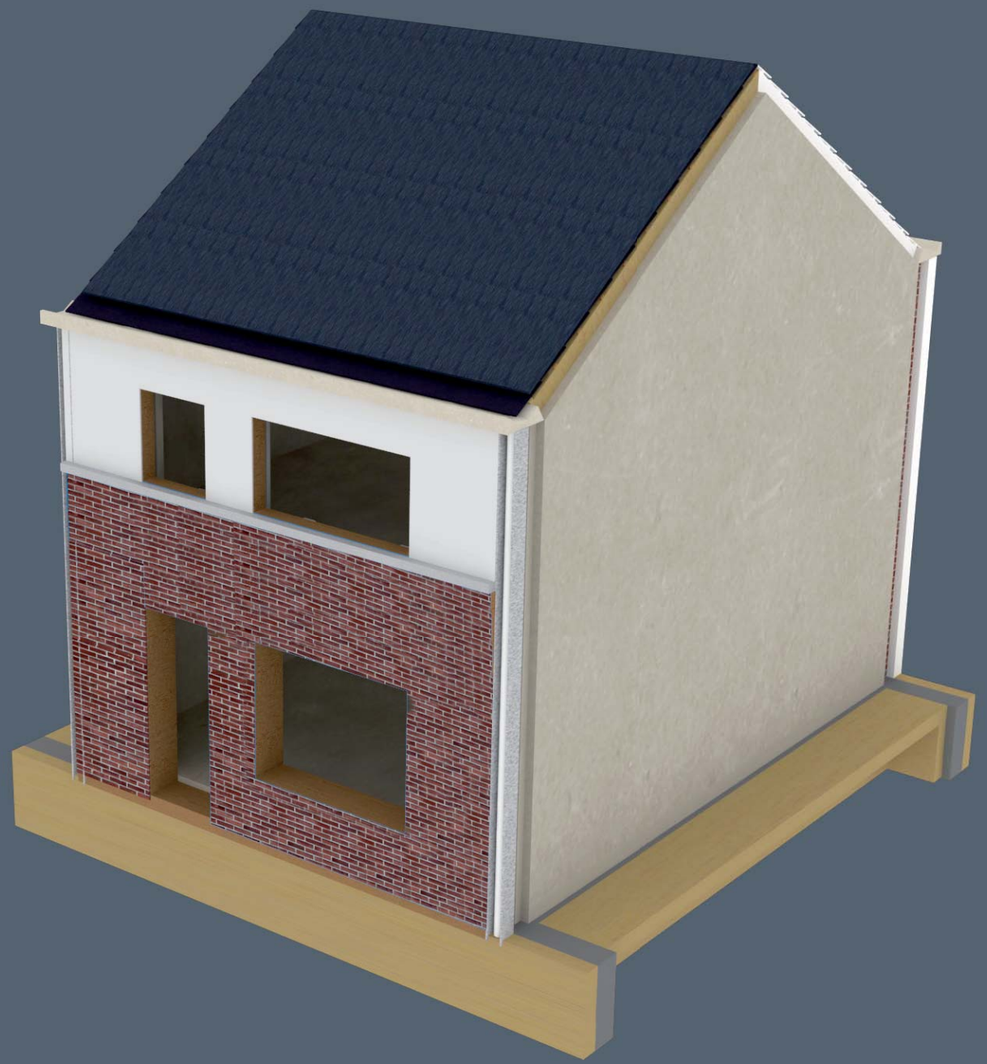
HR boiler replaces existing boiler. Reuse existing pipes and radiators.

5: Install Roof Module



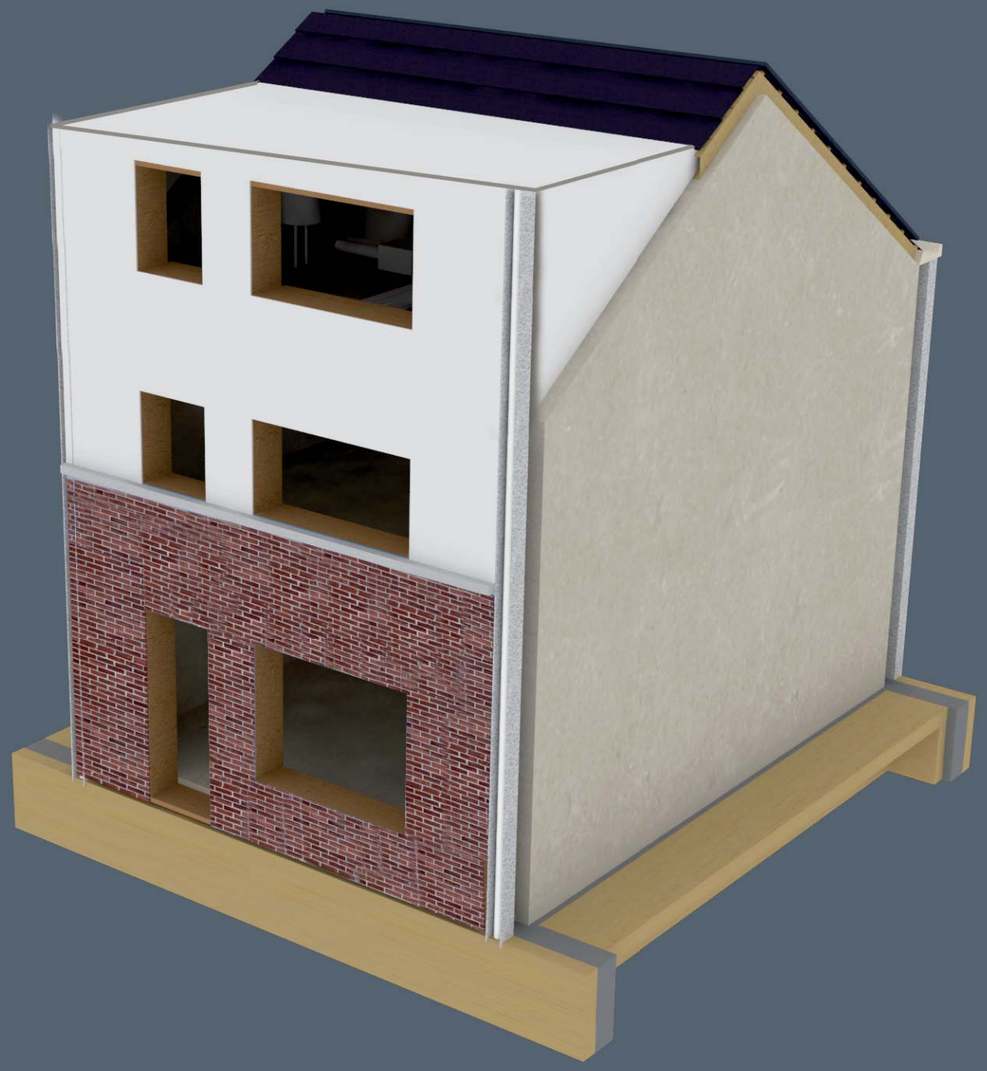
Prefabricated roof placed on existing wooden beams.
Connected to partition wall by means of angular anchors.
Horizontal finishing through separated prefabricated gutter (see next page)
Roof is factory equipped with ceramic tiles and solar panels.

6: Finishing



Finish by prefabricated wooden gutter construction with zinc gutter.
Vertical rainwater discharge through drainpipe (zinc) located in wooden frame.
Wooden frame also provides vertical finishing facade elements.

1: Add a Dormer



Create more living space and make the attic more liveable
Dormer consist of one prefab element
Existing wooden beams carrying old roof are removed

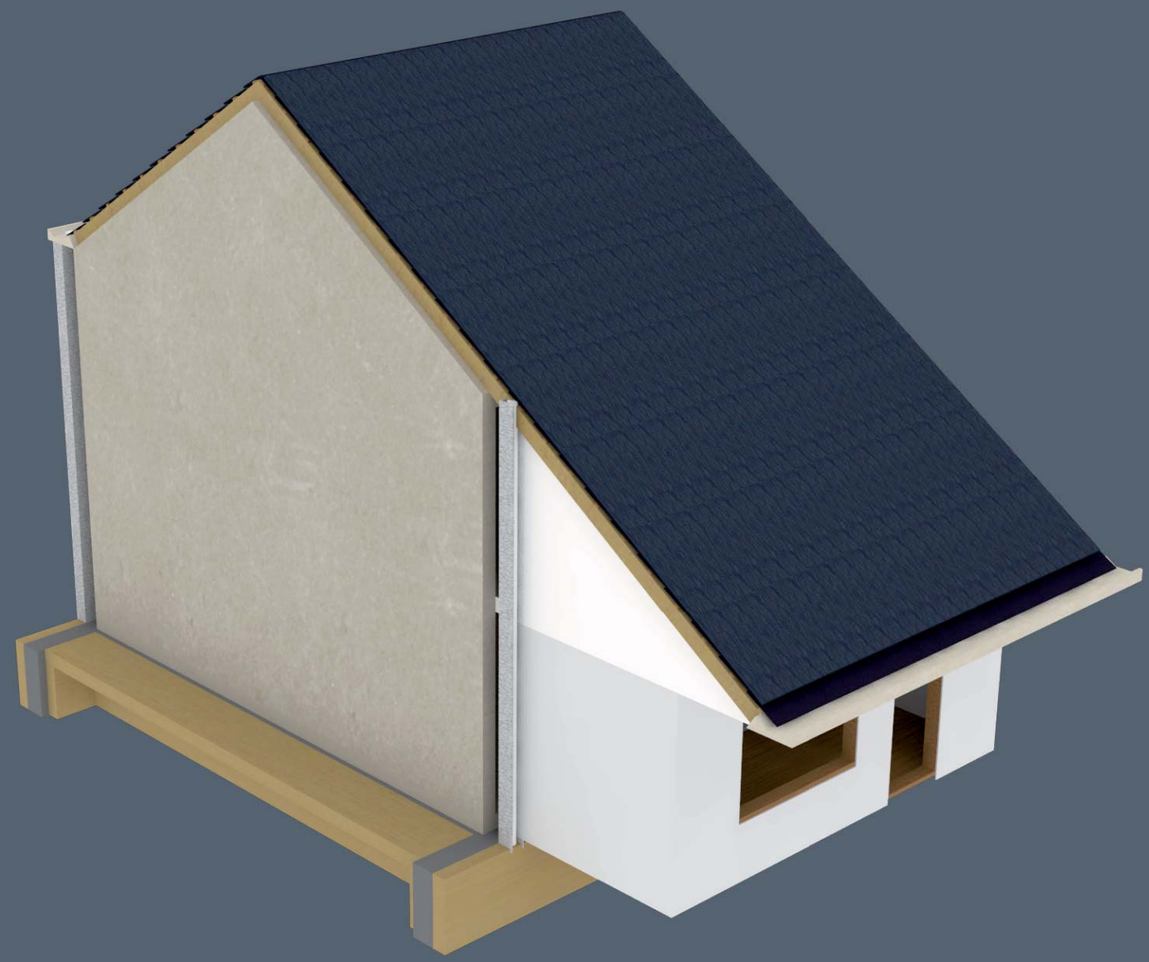
2: Make a Flat Roof

Create more living space and make the attic more liveable
Extension consist of two large dormers
Existing wooden beams carrying old roof are removed

3: Add an Extension

Create extra living space by adding 3D prefab extension
Two extra foundation beams are required
Roof could be used as terrace

4: Add an XL+ Extension



Create extra living space by adding 3D prefab extension + Roof module
Two extra foundation beams are required
More PV panels may be integrated

Chapter 3: Design
Design Details

Old Coat

Old coat contains load bearing concrete structure, wooden roof beams and facade cavity wall.
(Roof sheet shown for clarification roof boundaries)

New Coat

New coat contains pre-fab insulated elements with all necessary facilities such as ventilation ducts, window frames and window sills.
Installations positioned in the attic.

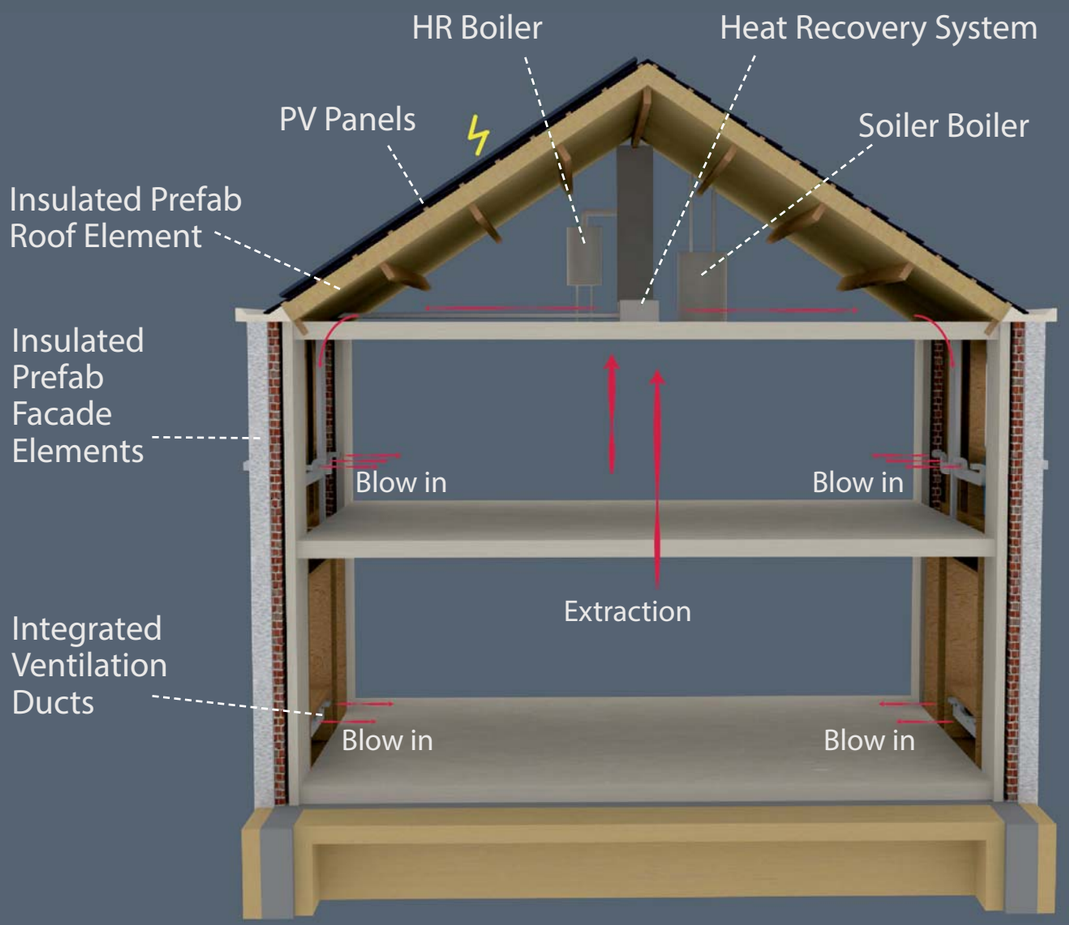
Coats Combined

Combination of the old and new coat ensures insulated energy saving home, tailerd to the needs of the residents.

Chapter 3: Design

Design Details

Section



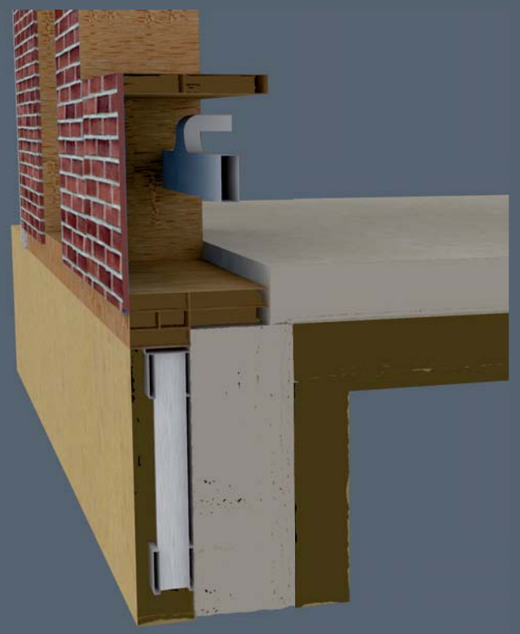
The wooden pefab facade elements contain integrated ventilation ducts which are connected to the heat recovery system located in the attic. Air blow in is done via the integrated ducts, extraction occurs due to existing channels in bathroom and kitchen, guiding to the heat recovery system. Residents' chosen configuration may contain a HR Boiler, PV Panels and a Solar Boiler as well.

1th Floor

Wooden facade element is horizontally fixed to concrete floor with extended angular steel anchors (insulation in wooden frame not shown). First floor element rests on ground floor element. Element is vertically fixed through the cavity wall into the load bearing concrete structure of the dwelling

Ground Floor

Wooden facade element is fixed to - and rests on - external construction (steel pillars with horizontal wooden beam) (insulation in wooden frame not shown). Insulation on the exterior-side of the foundation beam as well crawl space insulation is added. Finishing of wooden prefab elements is achieved by brickslips.



Chapter 4

Construction costs

Content & Structure

9 Cost calculations of Basic Renovation Model:

3 Insulation values:

- Rc 3,5
- Rc 4,5
- Rc 6,0

Combined with

3 Installation configurations:

- Basic
- Full Options
- Full Options + Geothermal Heatpump

The elaborated variant on the next pages is the Basic renovation model without extensions, an insulation value Rc = 4,5 and with a Full Option installation configuration.
The data and results of all other variants can be found in the reference list.

Main operations:

- Remove existing elements
- Preparings for prefab elements
- Installating prefab elements
- Adding installations

Cost sources:

ArchidatBouwkostenonline, 2014
Bouwkosten.nl, 2014

Databases with1000+suppliers
Updated monthly

Construction costs not in material costs, but in construction-parts costs

Including

- Man hours
- Materials
- Equipment

Excluding

- General Site Costs
- General Operating Costs
- Profit & Risk Margin (calculated afterwards)

Specific construction elements listed seperately by source and supplier

Before renovation

After renovation

Chapter 4

Construction costs

Stripping Existing Elements

Renovation Model: Standard
Insulation: Rc = 4.5
Installation: Full Option

Part	Price	Unit	Quantity	Costs
Remove wooden facade parts, incl. frames and windows	11,55	m2	44	€ 508
Remove rooftiles, incl. dispose with container	5	m2	58,6	€ 293
Remove parts sloping roof	19	m	12,2	€ 232
Remove rainwater drainage	19	m	10,7	€ 203
Subtotal				€ 1.236

Preparations

Renovation Model: Standard
Insulation: Rc = 4.5
Installation: Full Option

Part	Price	Unit	Quantity	Costs
Excavate ditch	4,63	m3	12,2	€ 56
Apply after-insulation crawl space (foam beads)	23,1	m2	47,2	€ 1.090
Appply after-insulation foundation beams (foam beads)	23,1	m2	32,4	€ 748
Installing steel support pillars (IPE100)	15,77	m	4	€ 63
Drill holes in steel pillars	5	hole	32	€ 160
Welding head plate	50	piece	4	€ 200
Attachment to foundation beams	42,27	hour	1	€ 42
Wooden beam on steel support pillars	3,33	m	18	€ 60
Wall plate anchors	2,13	piece	8	€ 17
Attachement to steel pillars	42,27	hour	1	€ 42
Subtotal				€ 2.480

Chapter 4

Construction costs

Prefab Facade Elements

Renovation Model: Standard
Insulation: Rc = 4.5
Installation: Full Option

Part	Price	Unit	Quantity	Costs
Prefab Timber Frame, Rc = 4.5	98,35	m2	48	€ 4.721
Brickslips	30,45	m2	48	€ 1.462
Brickslips, glue	3,95	m2	48	€ 190
Installing brickslips	65,6	m2	48	€ 3.149
Flexible ventilation ducts	5,1	m	28	€ 143
Ventilation strips	7,99	piece	10	€ 80
Facade decor strip (composite)	5,45	m	12	€ 65
Installing exterior door	1410	piece	2	€ 2.820
Window frame, incl. HR++ Glazing	797	piece	1	€ 797
	786	piece	2	€ 1.572
	1070	piece	1	€ 1.070
	876	piece	2	€ 1.752
Installing window sills	33,1	m	10	€ 331
Installing Prefab Roof elements, Rc = 4.5	42,3	m2	58,6	
Installing Prefab Roof elements, Rc = 4.5	53,37	m2	58,6	€ 3.127
Installing rooftiles (keramic)	35,05	m2	58,6	€ 2.054
	37,15	m	12,2	€ 453
	48,15	m	6,1	€ 294
Installing wooden gutter frame	125	m	12,2	€ 1.525
Installing water drainage	110	m	10,7	€ 1.177
Installing wooden frame water drainage	20,5	m	10,7	€ 219
Subtotal				€ 26.734

Installations

Renovation Model: Standard
Insulation: Rc = 4.5
Installation: Full Option

Part	Price	Unit	Quantity	Costs
Installing HR Boiler	1975	Piece	1	€ 1.975
Installing Geothermal heat pump	17320	Piece	0	€ 0
Installing Solar boiler	1800	Piece	1	€ 1.800
Installing Ventilation unit (heat recovery)	1985	Piece	1	€ 1.985
Installing PV panels	5692	Set	1	€ 5.692
Installing Sunscreen	725	Piece	1	€ 725
Subtotal				€ 12.177

Chapter 4

Construction costs

Total costs

Renovation Model: Standard
Insulation: Rc = 4.5
Installation: Full Option

Costs	Part
Removing existing elements	€ 1.236
Preparations	€ 2.480
Installing prefab skin	€ 26.734
Installations	€ 12.177
Subtotal	€ 46.627
General Site Costs	€ 2.558
General Operating Costs	€ 2.259
Profit & Risk	€ 1.423
Total	€ 48.867

Construction Costs: Alternatives

Zero - Alternative (€28.000)

Principles:

House needs complete maintenance

House is in original state

Includes replacement costs for roof, gutters, drainpipes, facade cladding, window frames and doors, and installing new boiler

Zero - Alternative + Energy upgrade (€33.000)

Principles:

Principles of Zero-Alternative

+ Apply after insulation in crawl space

+ Apply after insulation in cavity wall

+ Apply after insulation in roof

+ Apply wall insulation system behind wooden frames and battens

Traditional concept (€43.000)

Principles:

Traditional refurbishment concept according to Toolkit Existing Housing (2012)

Concept 113ZCT, most promising concept value for money

Includes HR boiler, Sun boiler, mechanical ventilation, new window frames, facade and crawl space insulation

Chapter 4
Construction Costs
Overview

Basic, Rc = 3.5

Basic, Rc = 3.5	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€26.120
Installations	€3.960
Subtotal	€34.016
General Site Costs	€2.041
General Operating Costs	€1.803
Profit & Risk	€1.136
Total	**€38.995**

Basic, Rc = 3.5, Full Options	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€26.120
Installations	€12.177
Subtotal	€42.014
General Site Costs	€2.521
General Operating Costs	€2.227
Profit & Risk	€1.403
Total	**€48.164**

Basic, Rc = 3.5, Full Options + Pump	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€26.120
Installations	€29.497
Subtotal	€59.334
General Site Costs	€3.560
General Operating Costs	€3.145
Profit & Risk	€1.981
Total	**€68.019**

Basic, Rc = 4,5

Basic, Rc = 4.5	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€26.734
Installations	€3.960
Subtotal	€34.629
General Site Costs	€2.078
General Operating Costs	€1.835
Profit & Risk	€1.156
Total	**€39.699**

Basic, Rc = 4.5, Full Options	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€26.734
Installations	€12.177
Subtotal	€42.627
General Site Costs	€2.558
General Operating Costs	€2.259
Profit & Risk	€1.423
Total	**€48.867**

Basic, Rc = 4.5, Full Options + Pump	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€26.734
Installations	€29.497
Subtotal	€59.947
General Site Costs	€3.597
General Operating Costs	€3.177
Profit & Risk	€2.002
Total	**€68.722**

Basic, Rc = 6,0

Basic, Rc = 6.0	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€27.584
Installations	€3.960
Subtotal	€35.480
General Site Costs	€2.129
General Operating Costs	€1.880
Profit & Risk	€1.185
Total	**€40.674**

Basic, Rc = 6.0, Full Options	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€27.584
Installations	€12.177
Subtotal	€43.477
General Site Costs	€2.609
General Operating Costs	€2.304
Profit & Risk	€1.452
Total	**€49.842**

Basic, Rc = 6.0, Full Options + Pump	
Remove existing elements	€1.236
Preparations	€2.480
Installing prefab skin	€27.584
Installations	€29.497
Subtotal	€60.797
General Site Costs	€3.648
General Operating Costs	€3.222
Profit & Risk	€2.030
Total	**€69.698**

Alternatives

Zero Alternative	
Subtotal	€24.149
General Site Costs	€1.449
General Operating Costs	€1.280
Profit & Risk	€806
Total	**€27.684**

Zero Alternative + Energy Upgrade	
Necessary Maintenance	€24.149
Energy Upgrade	€5.297
Subtotal	€29.445
General Site Costs	€1.767
General Operating Costs	€1.561
Profit & Risk	€983
Total	**€33.756**

Traditional, Concept 1113ZCT	
Total	**€42.918**

Interim results

Basic Renovation

Costs: ca. €40.000

No major difference in extra costs for extra thick insulation package.

refered to insulation value Rc = 3.5:
+€700 for Rc = 4.5
+€1700 for Rc = 6.0

Basic Renovation + Full Option

Costs: ca. €50.000

More installations are installed and a significant increase in construction costs occur. Instead of installation costs of €4.000, now €12.000.

Basic Renovation + Full Option + Geothermal Heapump

Costs: ca. €70.000

When a heat pump is added, the HR Boiler is unnecessary and substracted.
Installtion cost rise to ca. €30.000.

In the next chaper will be calculted whether the thicker insulation packages and different installation configurations for energy saving measures will pay themself back.

The Zero-Alternative, in which only maintenance is performed, still brings a lot of costs with it: €28.000 (full maintenance needed). Additional Energy Saving Upgrades adds ca. €5000.

The Traditional Renovation concept 113ZCT has a starting price of €43.000.

Chapter 5

Energy performance

Content & Structure

9 Performance calculations of Basic Renovation Model:

3 Insulation values:

Rc 3,5

Rc 4,5

Rc 6,0

Combined with

3 Installation configurations:

Basic

Full Options

Full Options + Geothermal Heatpump

Used software:

EPG & Costs

Similar to the previous chapter, the elaborated variant on the next pages is the Basic renovation model without extensions, an insulation value Rc = 4,5 and with a Full Option installation configuration.
The data and results of all other variants can be found in the references.

EPG & Costs

'For indiciative EPC calculation for housing sector, and comparing energy saving measure packages.'

Developed by DGMR Consulting engineers, commissioned by AgentschapNL and Ministry of National Affairs (2012)

EPG Result in Gas and Elektricity consumption. Units: CO_2 emission (kg) and energy consumption (MJ).

25) CO_2 footprint

26) Energy labeling

Chapter 5

Energy Performance

Parameters EPG & Costs

On the right page you find the entered parameters of the Basic renovation model with an insulation value of Rc = 4,5. The geometric values correspond to the PeGe structure as analyzed in Chapter 2.

The difference in entered parameters for the different installation configurations as they occur in respectively the 'Basic', 'Full Options' and 'Full Options + Geothermal Heat Pump' variants, are also included in the table on the right.

Because a geothermal heat pump is not yet found profitable at this time, the heat pump does not include the 'Full Options' variant. However the geothermal heat pump variant is still examined to identify possible energy savings, and thus gains its own designated "Full Options + Geothermal Heat Pump"-tag.

In order to get insight in the effect of a thicker insulation package in facades, ground floor and roof, on the energy performance, an analysis has been performed by creating just one variable; the insulation value. Different insulation variables tested are Rc = 3.5 , Rc = 4.5 , and Rc = 6.0.

An overview of the results of all calculations will be presentated on the next pages.

For the full calculations, including those of the design variants 'Dormer', 'Flat Roof', 'Extension' and 'Extenstion XL', the reference list can be consulted.

Reference Type	Basic	Full Options	Full Options + Heat Pump
In Between / Row house			
Geometry			
Living surface	114,5	114,5	114,5
Ground floor	47,2	47,2	47,2
Roof	58,6	58,6	58,6
Front Facade	24,45	24,45	24,45
Rear Facade	24,45	24,45	24,45
Left Facade	0	0	0
Right Facade	0	0	0
Windows Front Facade	6,7 (8)	6,7 (8)	6,7 (8)
Windows Rear Facade	9,1	9,1	9,1
Windows Left Facade	0	0	0
Windows Right Facade	0	0	0
Windows Roof	0	0	0
Doors	2,4	2,4	2,4
Number of dwellings	1	1	1
Structural			
Orientation	North	North	North
Rc value Facade	4.5	4.5	4.5
Rc value Ground Floor	4.5	4.5	4.5
Rc value Roof	4.5	4.5	4.5
Uw Glazing	1,6	1,6	1,6
Sunscreen	Absent	Present	Present
Thermal capacity	Half-and-Half	Half-and-Half	Half-and-Half
Detailing	Forfaitair	Forfaitair	Forfaitair
Installations			
Heating	HR-combi	HR-combi	Geothermal Heat Pump
Heat delivery	Radiators	Radiators	Radiatoren
Warm water	HR-combi	HR-combi	HR-combi
Douche Heat recovery	Absent	Absent	Absent
Ventilation	Balanced type D	Balanced type D	Balanced type D
Ventilation system	With bypass	With bypass	With bypass
Ventilator	Alternating Current	Alternating Current	Alternating Current
Heat recovery	Rendement 95%	Rendement 95%	Rendement 95%
Cooling	Absent	Absent	Absent
Sun-energy			
Solar boiler	Absent	2,4 m2	2,4 m2
Pv Panels	Absent	20 m2	20 m2

Chapter 5

Energy Performance

Energy bills

The design variant 'Basic' with insulation value Rc = 4.5 is elaborated. For the performed calculations of the other variants can be refered to the reference list.

The software tool EPG & Costs presents the results of the calculations in energy usage (MJ) and CO_2 emissions (kG). Within the energy result, electricity and gas consumption are binded together while electricty and gas consumption is seperated in the CO_2 results (see upper table on the right page).
To calculate the theoretical energy bill the results have to be converted to kWh (elektricty) and m^3 (gas usage). Because the CO_2 emissions are seperated for the elektricty and gas usage, the calculation can be made using the following data:

CO_2 emission per generated kWh: 0,56kg (CBS, 2014a)

CO_2 emission per burned m3 gas: 1,8 kg (CBS, 2014a)

To check the reliability of the data an extra loop is made by using:

Energy per kWh: 8,2 MJ (CBS, 2014a)

Energy per m3 gas: 31,65 MJ (CBS, 2014a)

The total amount of elektricity usage and gas consumption is now available. The result of the extra loop is a 4% off, which may occur due to developement of a more efficiency energy generation in 2014, in comparison with 2012 when the EPG & Costs software is released (CBS, 2014a)

To calculate the energy bill the following energy prices are used:

Elektricity price: €0,23/kWh (European Commission, 2014)

Gas price: €0,72/m^3 (European Commission, 2014)

The design variant 'Basic' with insulation value Rc = 4.5 is elaborated on the right page, also an overview with all energy bills per renovation model can be found on the right. The full calculations of all renovation models can be found in the reference list.

Example EPG calculation Results

Basic Rc 4.5								
Results EPG Calculation				**Calculation**		**Costs**		
	Energy (MJ)	**CO_2-elektricity (kg)**	**CO_2-gas (kg)**	**Elektricity (kWh)**	**Gas (m3)**	**Elektricity**	**Gas**	**Total**
Heating	12.960	126	552	225	307	€ 52	€ 221	€ 273
Warm water	16.656	0	843	0	468	€ 0	€ 337	€ 337
Cooling	0	0	0	0	0	€ 0	€ 0	€ 0
Summer comfort	1.056	65	0	116	0	€ 27	€ 0	€ 27
Fans	7.525	461	0	823	0	€ 189	€ 0	€ 189
Lighting	5.276	323	0	577	0	€ 133	€ 0	€ 133
Subtotal	43.473	975	1.395	1.741	775	€ 400	€ 558	€ 958
Produced	0							
Total	43.473	975	1.395	1.741	775	€ 400	€ 558	€ 958

Overview energy bill per renovation model

Renovation Model	**Investment**	**Energy cost year 1**		
		Gas	**Elektricity**	**Total**
Basic				
Basic Rc 3.5	€ 39.001	€ 597	€ 400	€ 997
Basic Rc 4.5	€ 39.704	€ 558	€ 400	€ 958
Basic Rc 6.0	€ 40.679	€ 538	€ 401	€ 939
Basic Rc 3.5 Full Options	€ 52.176	€ 497	€ 223	€ 720
Basic Rc 4.5 Full Options	€ 52.879	€ 458	€ 221	€ 679
Basic Rc 6.0 Full Options	€ 53.853	€ 438	€ 221	€ 659
Basic Rc 3.5 Full Options + Geothermal heat pump	€ 69.767	€ 0	€ 649	€ 649
Basic Rc 4.5 Full Options + Geothermal heat pump	€ 70.470	€ 0	€ 621	€ 621
Basic Rc 6.0 Full Options + Geothermal heat pump	€ 71.444	€ 0	€ 607	€ 607
Variants				
Dormer Rc 4.5 Standard	€ 44.783	€ 538	€ 416	€ 954
Dormer Rc 4.5 Full options	€ 57.957	€ 455	€ 251	€ 705
Double Dormer Rc 4.5 Standard	€ 49.861	€ 562	€ 432	€ 994
Double Dormer Rc 4.5 Full options	€ 63.036	€ 430	€ 260	€ 689
Extension Rc 4.5 Standard	€ 63.103	€ 577	€ 430	€ 1.006
Extension Rc 4.5 Full options	€ 76.277	€ 445	€ 257	€ 702
Extension XL+ Rc 4.5 Standard	€ 68.884	€ 604	€ 460	€ 1.064
Extension XL+ Rc 4.5 Full options	€ 82.059	€ 464	€ 292	€ 756
Alternatives				
Only necessary maintenance	€ 27.548	€ 1.873	€ 805	€ 2.678
Necessary maintenance + Energy upgrade	€ 33.831	€ 936	€ 805	€ 1.741
Traditional renovation concept 113ZCT	€ 42.919	€ 530	€ 285	€ 815

Chapter 5

Energy Performance

Savings & Payback time

The energy bills are calculated for the next 40 years by using the results from previous chapter. Calculating the net present value over the next 40 years, the value of the energy bill at this moment can be calculated. Comparing the different renovation models with a 'no renovation strategy' (a dwelling in original state), the energy savings can be calculated.

The following key indicators are used:

Annual increase elektricity price: 5,4% (CBS, 2014b, average 1996 - 2013)

Annual increase gas price: 3,6% (CBS, 2014b, average 1996 - 2013)

Elektricity usage reference: 3500 kWh (Otter, 2008)

Gas usage reference: 2600 m^3 (Otter, 2008)

Inflation: 1,75% (average past 10 years, inflation.eu, 2014)

With the results the payback time of each individual renovation model can be calculated.

Below you find an overview for each renovation model, including the investment costs, the payback time, the savings on the energy bills after 40 years, and the profit after 40 years.

On the right page you find the energy bill development in the next 40 years for the renovation model 'Basic' with insulation value Rc = 4.5. Full calculations of each renovation model can be found in the reference list.

Renovation Model	Investment	Payback time	Savings 40 year	Profit 40 year
Basic				
Basic Rc 3.5	€ 39.001	22	€ 83.543	€ 44.542
Basic Rc 4.5	€ 39.704	22	€ 85.239	€ 45.535
Basic Rc 6.0	€ 40.479	22	€ 83.529	€ 43.050
Basic Rc 3.5 Full Options	€ 52.176	24	€ 99.924	€ 47.748
Basic Rc 4.5 Full Options	€ 52.879	24	€ 101.787	€ 48.909
Basic Rc 6.0 Full Options	€ 53.853	24	€ 102.677	€ 48.824
Basic Rc 3.5 Full Options + Geothermal heat pump	€ 69.767	32	€ 92.951	€ 23.185
Basic Rc 4.5 Full Options + Geothermal heat pump	€ 70.470	32	€ 94.844	€ 24.374
Basic Rc 6.0 Full Options + Geothermal heat pump	€ 71.444	32	€ 95.790	€ 24.345
Variants				
Dormer Rc 4.5 Standard	€ 44.783	19	€ 85.072	€ 40.289
Dormer Rc 4.5 Full options	€ 57.957	22	€ 99.935	€ 41.978
Double Dormer Rc 4.5 Standard	€ 49.861	17	€ 82.939	€ 33.077
Double Dormer Rc 4.5 Full options	€ 63.036	20	€ 100.431	€ 37.396
Extension Rc 4.5 Standard	€ 63.103	24	€ 82.437	€ 19.334
Extension Rc 4.5 Full options	€ 76.277	26	€ 99.940	€ 23.663
Extension XL+ Rc 4.5 Standard	€ 68.884	25	€ 79.209	€ 10.325
Extension XL+ Rc 4.5 Full options	€ 82.059	21	€ 96.748	€ 14.689
Alternatives				
Only necessary maintenance	€ 27.548	0	€ 0	-€ 27.548
Necessary maintenance + Energy upgrade	€ 33.831	35	€ 40.699	€ 6.868
Traditional renovation concept 113ZCT	€ 42.919	22	€ 94.298	€ 51.379

Energy bill, Savings, Net present value (Model: Basic Rc=4.5)

Basic, Rc = 4.5 Investment: €39.704					
Year	Gas	Elektricity	Total	NCW	Besparing NCW
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 3.447
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 5.185
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 6.933
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 8.693
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 10.465
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 12.249
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 14.048
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 15.861
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 17.690
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 19.536
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 21.399
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 23.280
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 25.181
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 27.103
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 29.046
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 31.011
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 33.000
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 35.014
20	€ 15.943	€ 13.815	€ 29.758	€ 21.402	€ 37.054
21	€ 17.075	€ 14.961	€ 32.037	€ 22.644	€ 39.120
22	**€ 18.248**	**€ 16.170**	**€ 34.418**	**€ 23.909**	**€ 41.215**
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 43.338
24	€ 20.721	€ 18.786	€ 39.507	€ 26.508	€ 45.493
25	€ 22.025	€ 20.201	€ 42.226	€ 27.845	€ 47.679
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 49.898
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 52.152
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 54.441
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 56.768
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 59.132
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 61.537
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 63.984
33	€ 34.297	€ 34.646	€ 68.943	€ 39.572	€ 66.473
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 69.007
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 71.587
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 74.215
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 76.892
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 79.621
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 82.403
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 85.239

The payback time of often 20 years or more is still too long. Residents are not waiting for a long time loan or contract, as it is described in the problem statement as largest barrier to participate in energy saving measures (Welzen, 2014). In the next chapter research in reducing the payback time is presented.

Chapter 6

Reduce Payback Time

Content & Structure

Using property value comparisons through Funda.nl (2014), this chapter gives insight in the affect of the renovation models on the housing porperty value. The effect can be substracted in the construction costs to reduce the investment costs and payback time.

To generate reliable results the dwellings are compared to eachother per municipality and per district. Only the municipalities with at least a property tax assement 'properly' have been assigned (Rijksoverheid, 2013)

The following method using Funda.nl has been used:

1. Obtain general information from 'Characteristics'

2. Read the description 'Particulars'

3. Check pictures to note any abnormalities

The following criteria have been used to find simliar homes as the PeGe building structure:

Building typology:	House
Property type:	Single Family
Variant:	In between
Construction type:	Resale
Construction period:	1960 - 1970
	1970 - 1980

Nine comparable dwellings in the neigborhood 'Verzetstrijdersbuurt, Delft' and eleven dwellings in 'Meerzicht-west, Zoetermeer' are investigated to find the impact of energy saving measures and extension of living space, on the housing property value. The results are presented on the following pages.

funda

27.

Gemeente Delft

28.

gemeente Zoetermeer

29.

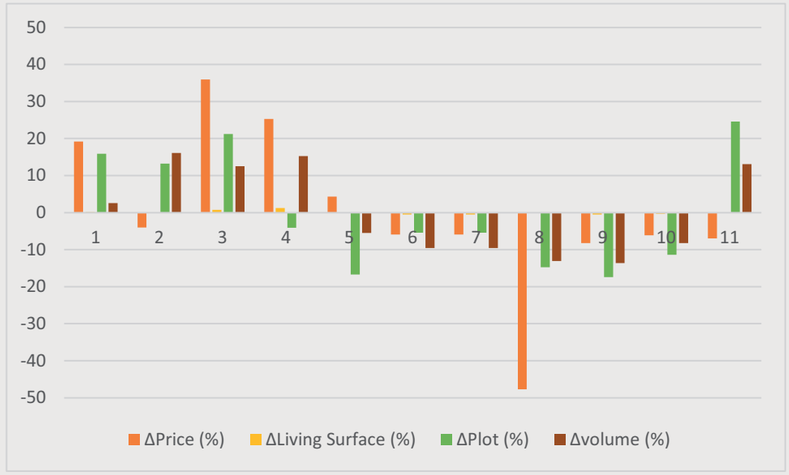
Chapter 6

Reduce Payback Time

Property Value

Municipality: Delft													
District: Verzetstrijdersbuurt				Specifications					Energy				
Address	Asking Price	State	Available since	Construction year	Living Surface	Additional Surface	Plot	Volume	Energy label	Insulation	Heating	Warm Water	Facilities
Gebbenlaan 8	285.000	Available	4 Weeks	1972	128 m2	12 m2	174 m2	380 m3	-	-	Central, Combi	Combi Boiler	Dormer, Sunscreen
Gebbenlaan 10	229.500	Sold	3 Weeks	1970	125 m2	6 m2	170 m2	430 m3	-	Double Glazing	Central, Combi	Combi Boiler	Dormer
~~Gebbenlaan 27~~	~~325.000~~	~~Sold~~	~~19,5 Months~~	~~1970~~	~~140 m2~~	~~9 m2~~	~~182 m2~~	~~417 m3~~	-	~~Double Glazing~~	~~Central, Combi~~	~~Combi Boiler~~	~~Dormer, Extension~~
Schijflaan 12	299.500	Sold with Reservation	4 Months	1976	150 m2	17 m2	144 m2	427 m3	-	Roof, Wall, DG	Central, Boiler	Electric Boiler	Sunscreen
Schijflaan 13	249.500	Available	4 Weeks	1975	125 m2	5 m2	125 m2	350 m3	-	Roof, Wall, Floor, DG	Central, Boiler	Electric Boiler	Mechanical Ventilation, Sunscreen
Van der Kamlaan 43	225.000	Sold	5 Months	1971	115 m2	5 m2	142 m2	335 m3	-	-	Central, Combi	Combi Boiler	
Van der Kamlaan 45	225.000	Available	6+ Months	1971	115 m2	5 m2	142 m2	335 m3	-	-	Central, Combi	Combi Boiler	Dormer
~~Van der Kamlaan 54~~	~~125.000~~	~~Sold~~	~~7 Weeks~~	~~1970~~	~~122 m2~~	~~5 m2~~	~~128 m2~~	~~322 m3~~	-	-	~~Central, Combi~~	~~Combi Boiler~~	~~Dormer~~
Van der Kamlaan 70	219.500	Sold with Reservation	3 Months	1970	115 m2	12 m2	124 m2	320 m3	-	Double Glazing	Central, Combi	Combi Boiler	Dormer
Wilhelminalaan 172	224.500	Available	6 Weeks	1969	120 m2	9 m2	133 m2	340 m3	-	Roof, Wall, DG	Central, Combi	Combi Boiler	Dormer, Sunscreen
Wilhelminalaan 65	222.500	Sold	3,5 Months	1970	125 m2	6 m2	187 m2	419 m3	-	Double Glazing	Central, Combi	Combi Boiler	Dormer
Average	239.000			1971	125	8 m2	150 m2	370 m3					

Municipality: Delft				
District: Verzetstrijdersbuurt				
Address	ΔPrice (%)	ΔLiving Surface (%)	ΔPlot (%)	Δvolume (%)
Gebbenlaan 8	19,20	0,13	15,93	2,58
Gebbenlaan 10	-4,01	-0,02	13,26	16,07
~~Gebbenlaan 27~~	~~35,93~~	~~0,74~~	~~21,26~~	~~12,56~~
Schijflaan 12	25,27	1,25	-4,06	15,26
Schijflaan 13	4,35	-0,02	-16,72	-5,52
Van der Kamlaan 43	-5,89	-0,53	-5,39	-9,57
Van der Kamlaan 45	-5,89	-0,53	-5,39	-9,57
~~Van der Kamlaan 54~~	~~-47,72~~	~~-0,18~~	~~-14,72~~	~~-13,08~~
Van der Kamlaan 70	-8,19	-0,53	-17,38	-13,62
Wilhelminalaan 172	-6,10	-0,28	-11,39	-8,22
Wilhelminalaan 65	-6,94	-0,02	24,59	13,10
Average	€ 239.000	125m2	150m2	370m3



Search results

11 similar homes of which 2 are not suitable for analysis:

Gebbenlaan 27
Extreme high asking price
(+80.000 Euro)

Van der kamlaan 54:
Extreme low asking price
(-110.000 Euro, auction item)

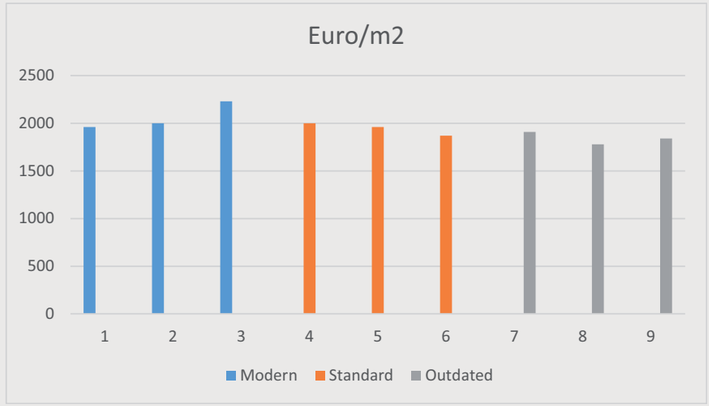
Too many variables provide ambiguous relationships between property asking prices and facilities.

Chapter 6

Reduce Payback Time

Property Value

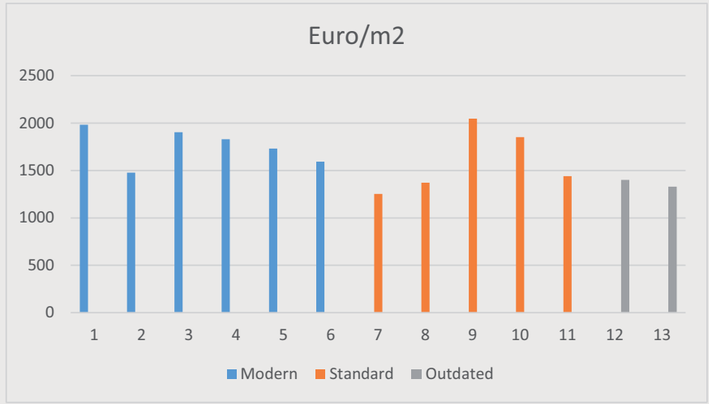
Municipality: Delft								
District: Verzetstrijdersbuurt						State of Maintenance		
Address	Asking price	ΔPrice	Living Surface	ΔLiving Surface	Euro/m2	Kitchen	Bathroom	General
Van der Kamlaan 43	€ 225.000	-€ 14.000	115 m2	-10 m2	€ 1.960	0	+	+
Schijflaan 13	€ 249.500	€ 10.000	125 m2	0 m2	€ 2.000	+	+	0
Gebbenlaan 8	€ 285.000	€ 46.000	128 m2	3 m2	€ 2.230	+	+	+
Schijflaan 12	€ 299.500	€ 60.000	150 m2	25 m2	€ 2.000	0	0	+
Van der Kamlaan 45	€ 225.000	-€ 14.000	115 m2	-10 m2	€ 1.960	0	0	0
Wilhelminalaan 172	€ 224.500	-€ 15.000	120 m2	-5 m2	€ 1.870	0	0	0
Van der Kamlaan 70	€ 219.500	-€ 20.000	115 m2	-10 m2	€ 1.910	0	-	-
Wilhelminalaan 65	€ 222.500	-€ 17.000	125 m2	0 m2	€ 1.780	-	-	-
Gebbenlaan 10	€ 229.500	-€ 10.000	125 m2	0 m2	€ 1.840	-	-	-
Averages	€ 240.000	€ 240.000	124 m2	124 m2	€ 1.950			



Averages

Status:	costs/m²:
Modern	€2059
Standard	€1941
Outdated	€1841

Municipality: Zoetermeer								
District: Meerzicht-West						State of Maintenance		
Address	Asking price	ΔPrice	Living Surface	ΔLiving Surface	Euro/m2	Kitchen	Bathroom	General
Tijberg 28	€ 238.000	€ 35.000	120 m2	-6 m2	€ 1.980	+	+	+
Herikerberg 60	€ 200.000	-€ 3.000	105 m2	-21 m2	€ 1.900	0	+	+
Tijberg 62	€ 219.500	€ 16.500	120 m2	-6 m2	€ 1.830	+	0	+
Fivelingo 98	€ 225.000	€ 22.000	130 m2	4 m2	€ 1.730	+	0	+
Zijlberg 29	€ 215.000	€ 12.000	135 m2	9 m2	€ 1.590	+	0	+
Zijlberg 22	€ 169.000	-€ 34.000	135 m2	9 m2	€ 1.250	0	0	+
Zijlberg 24	€ 185.000	-€ 18.000	135 m2	9 m2	€ 1.370	+	0	0
Kozakkenberg 9	€ 200.000	-€ 3.000	108 m2	-18 m2	€ 1.850	0	-	0
Zijlberg 35	€ 194.500	-€ 8.500	135 m2	9 m2	€ 1.440	0	-	0
Wildenberg 46	€ 189.000	-€ 14.000	135 m2	9 m2	€ 1.400	-	-	-
Zijlberg 67	€ 179.500	-€ 23.500	135 m2	9 m2	€ 1.330	-	-	-
Average	€ 200.000	€ 200.000	127 m2	127 m2	€ 1.610			



Averages

Status:	costs/m²:
Modern	€1753
Standard	€1592
Outdated	€1365

Chapter 6

Reduce Payback Time
Property Value

Conclusion

Through research via Funda.nl there is no direct link between extra - Energy saving - facilities or installations, and the estimated house value. This is also admitted by literature (Dekker, 2014) In the remainder of this study energy saving measures will therefore not be included in a change in property value, the measures "only" count as energy saving measure in the calculations.

The results do clearly show that the square meter price is depended on the maintenance status of the dwelling. The renovation modules which expand the living space do increase the property value. The additional value will be calculated by the average square meter price based on both examined municipalities. The weakest squaremeter price (thus the square meter price labeled 'outdated') will be implemented due to the fact the used renovation concept in this research has no influence on the intior and thus the total rate of dwelling could still be assigned a 'outdated' status.

Integrate subsidies

Subsidies are financial supports by the government. Delft municipality had until August 2014 an interesting subsidy policy, in which the municipality met the residents for investments in energy-saving measures. This could lead to a maximum of €1100 subsidy for investment in sustainable energy upgrades to the PeGe renovation.

After this period Delft municipallity spreads loans at very low interest rates. The interest rate is 4% below market rate (compared to the average market rate for a loan for 10 years), with a minimum of 1.5%.

The European Commission has adopted policies for the development and strengthening of the economy. Every seven years, money is made available for all Member States. For the period 2014 - 2020 new policies are still under development (RVO.nl, 2014a)

There are four funds for which money is made available. In the European Fund for Regional Development (ERDF), €507 million is made available for the Netherlands. The policy is still in development and therefore it is not clear how the amount is divided and can be applied in a private renovation concept as in this study.

For the rental sector however, subsidies are already announced in the STEP-program (RVO.nl, 2014b) Housing associations can apply grants when dwellings improve to at least an energy label B. For a realization of three energy label improvements is set free €2,000, €2,600 for 4 label steps, €3,500 for 5 steps and €4,500 euro for 6 energy label improvements

Unfortunately subsidies can only be applied for purchases of products or services into private ownership (Traverse, 2014), yet there are no possibilities to gain subsidies for leased or rented objects and services.

Conclusion

The payback period of the renovation can not be reduced by applying subsidies -at this moment.

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Chapter 7

Lease

Content & Structure

In this chapter the results are presented whether through the use of a lease construction, the investment costs can be decreased and thus the payback time of the renovations models can be lowered.

There are two main types of lease: financial lease and operational lease. Both of them are first explained by literature, than a consideration can be made which lease construction offers the most potential in this research to reduce investment costs for the client, the residents.

The lease type 'Sale and Lease back' is neglected in this thesis because this type is not applicable, since the lease company does not have the goal to sell its own products and to lease them back for use in their own company.

Lease is a type of credit in which the lessor (owner) buys equipment, assets or consumer products and makes them available for the lessee (user) for a limited time and for a fixed fee.

(Hees, 1998)

Chapter 7

Lease

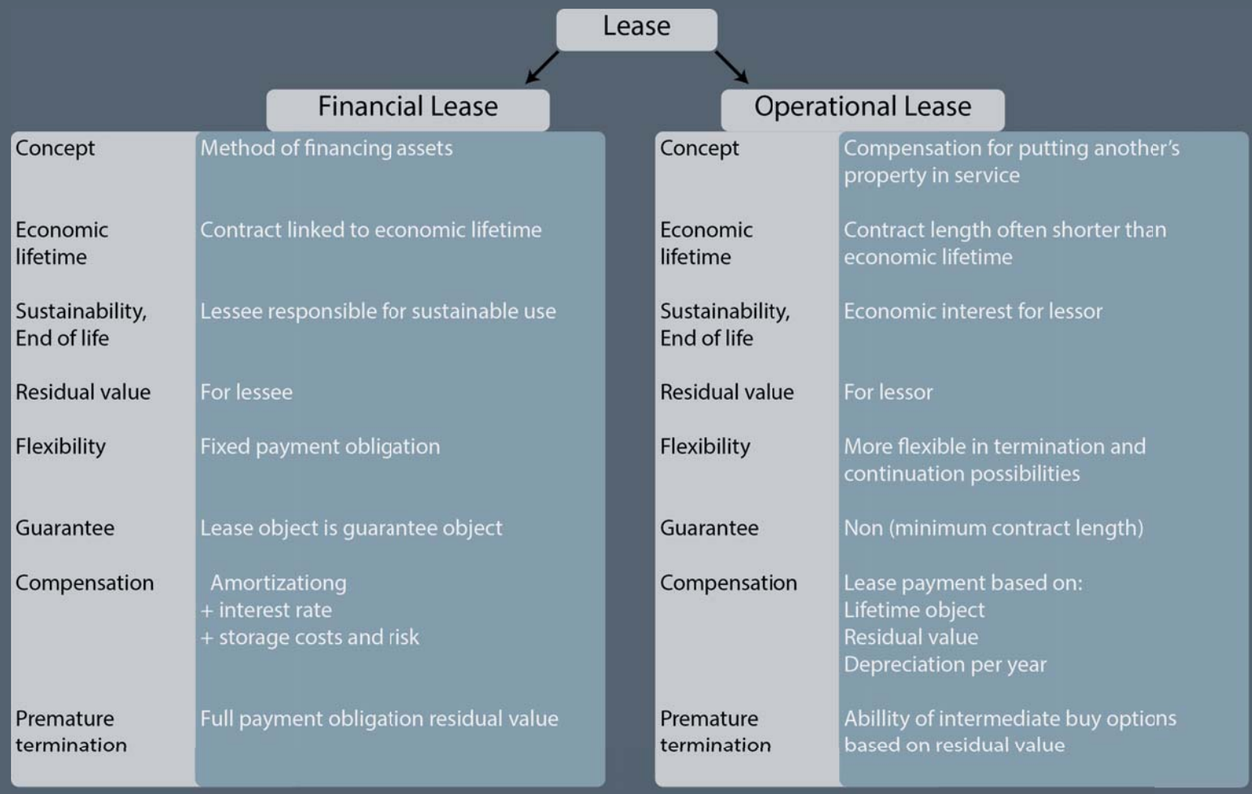
Financial Lease

With financial leasing, the lessor (owner / lease company) only remains legal owner while the full economic ownership (assurance, maintenance) will be transferred to the lessee (user / resident). This means that the lessee takes risk over the value and depreciation of the objects, but he or she does become owner at the end of the contract (Bierman, 1982).

The contract length and charges are linked to the economic lifetime of the elements thus the payment obligation and periods are predetermined by a fixed amount. The full investment costs made by the lease company are fully repaid by the occupant, including an interest rate and costs for storage and risk (Bierman, 1982).

Because finance lease is similar to hire and purchase, it seems logical to link the prefab facade elements from the renovation concept to a financial lease contract. After all, when a occupant has to hand in these prefab elements (which is the case with operational lease), his home will have two open facades and roof. The housing law even prohibits this appearance in the street scene (Wamelink, 2007) and according to the building regulations it certainly is not allowed to live in such dwelling (Bouwbesluit 2012)

The financial lease act as a mortgage loan which can be upgraded by service and maintenance contracts. The additional costs for service and maintenance however, brings additional costs on top of the already high basic price, and previous studies of Welzen (2014) already show that the long-term loan and the high investment costs are the largest barriers for residents to participate in a renovation process. The focus should therefore lie on reducing the investment cost of the renovation and reducing the amount and terms of lease payments. Therefore financial lease will not be favorable to incorporate within this research.



Operational Lease

With operation lease the lessee (user / resident) pays a (monthly) fee for the use of the elements while the lessor (owner / lease company) remains legal owner of the elements. The elements will return to the company at the end of the contract (Bierman, 1982).

The risk of higher than normal loss in depreciation is addressed to the leasing company. The company benefits from the residual values of the elements, but at the same time the company is dependent on the residents' handling with their elements. Service and maintenance contracts are implemented to take care of all burdens, and gives the company more certainty about the residual value (Bierman, 1982).

The costs and terms of the lease contract is based on an estimation of the economic lifetime, depreciation, and residual values of the elements (Bierman, 1982)

Compared to the prefabricated shell around the dwelling, installations and facilities are easier to detach, replace and upgrade, thus operational lease seems more in place here. The installations are kept in the possession of the company and residual values are returned to the company. By integrating the residual values, the initial investment which is passed to the residents lowers and the related (monthly) lease payments are decreasing with it. Regarding the previously stated large barriers for residents to participate in a sustainable renovation (long term loan and high investment barriers, Welzen, 2014), operational lease seems more attractive.

Chapter 7

Lease
Financial vs. Operational Lease

To give residents more influence and take care of all the burdens, residents may choose from different maintenance and service contracts. The different contracts could be 1) a preventive package (planned maintenance), 2) a corrective package (planned maintenance + repairing defects) or 3) an all-inclusive replacement package (planned maintenance + repairing defects + renewal and upgrading to new technologies and modules when available).

The financial or operational lease contract combined with the chosen service and maintenance package come together in a Service Level Agreement (Zijlstra, 2006). The SLA states among others; the involved stakeholders, the functionality of the modules, the performance requirements (key performance indicators and restrictions), the length of the contract, the amount of payments, and a regulation concerning renewal or pre-termination of the contract.

Conclusion

The focus should lie on reducing the cost of the renovation. Within financial lease constructions the investment costs will remain at best equal due to the similarity with a hire and purchase structure plus extra costs for service and maintenance contracts. With operational leases the residual value of the components belong to the lessor (the leasing company). The lease company can substract the financial benefits - gained by the residual values - from the investment costs which is passed to the residents, and reuse the recovered components or materials in other projects. The residents can be offered a reduced contract making the renovation financially more attractive.

The actions residents can take at end of the operational lease contract are:

1. Residents covers full contract period and

    i. Return elements
        a. Lease new elements with new contract
            (updated installations, extend living space, create new up-to-date appearance)
        b. Renovation via traditional method
            (contact lease company fully disconnected)
        c. Dwelling on sale, new resident chooses new elements
            (temporary lease contract involved)
        d. Demolition dwelling
            (still gained profit on total living costs and comfort)
        e. Return, remain open dwelling
            (not permitted by housing law)

    ii. Continues lease plan
        a. Present residual values are calculated to extend operational lease contract
            (very cheap monthly costs because always presented 'investment loss' is already paid back)
        b. Present residual value is calculated and contract is changed to financial lease
            (Monthly fee to redeem, resident become owner)

    iii. Directly buys elements
        (Resident pays residual value at once and becomes owner)

2. Resident resigns contract premature

    i. Redeem
        (Resident pays residual value and becomes owner)
    ii. Take-over
        (Residents sells contract to new resident)
    iii. Upgrade
        (Resident changes configuration, extra new investment costs applied)
    iv. Interim cancel
        (Resident pays lost in income for leasing company, substracted with extra residual value)

Chapter 7
Lease
Integrate residual values

The depreciation and residual values are calculated according to their lifetime expectancies and their initial material costs. Below are first the materials presented which can be reused and thus have actual residual value. Underneath, the remaining materials are listed which can only be recycled to raw materials and thus have no residual value. On the right page the result of the different elements and materials can be found.

The elements that can be reused are:

Components:
- Window frames
- Doors
- Window sills
- Gutters
- Drainpipes
- Rooftiles
- Ventilation ducts

Installations:
- Heat recovery Unit
- Boiler
- PV Panels
- Sun boiler
- Sunscreen

The elements which can be recycled are:
- Wooden / Timber frame
- Insulation
- Brickslips
- Cladding boards
- Plasterboards

Source:
Vissering, 2011 (SBR)

Depreciation and Residual Values

Elements	Investment	Life Time Expectancy	Depreciation per year	Residual value after: 5 years	10 years	15 years	20 years
Re-Use							
Window frames	€5191	37	€140	€4490	€3788	€3087	€2385
Doors	€2820	37	€76	€2439	€2058	€1677	€1296
Window sills	€331	30	€11	€256	€221	€166	€110
Gutters	€1525	41	€37	€1339	€1153	€967	€781
Drainpipes	€1177	41	€29	€1033	€890	€746	€603
Rooftiles	€2800	50	€56	€2521	€2240	€1961	€1681
Ventilation ducts	€223	25	€9	€178	€134	€89	€45
Dormer	€4430	37	€120	€3832	€3233	€2634	€2035
Extension	€21020	37	€568	€18183	€15342	€12500	€9660
Heat recovery Unit	€1985	17	€117	€1401	€817	€234	€0
Boiler	€1975	15	€132	€1317	€658	€0	€0
PV Panels	€5690	25	€228	€4554	€3415	€2277	€1138
Solar Boiler	€5075	30	€169	€4229	€3383	€2538	€1692
Sunscreen	€725	15	€48	€483	€242	€0	€0
Re-Cycle							
Wood/Timber frame	Var.	50	0	0	0	0	0
Insulation	Var.	36	0	0	0	0	0
Brickslips	Var.	66	0	0	0	0	0
Rabbat finishing	Var.	30	0	0	0	0	0
Plasterboard	Var.	39	0	0	0	0	0

Chapter 7
Lease
Results

In the table below the results for entering a 10 year Operational Lease contract is elaborated. The table also includes for all renovation variants; the investment costs, energy bill first year, payback time, monthly costs for 10 year Financial Lease contracts, and all net living costs for 5, 10, 15, and 20 year Operational Lease contracts. For fully detailed calculations is referred to the reference list.

The investment cost for the renovation model "Basic with Rc = 4.5", is reduced with ca. €11.000 euro when the residual values are integrated in the 10-year operational lease contract. This leads to a difference in monthly fees ranging from € 330 euros for financial leases (thus excluding the integration of the residual values), to € 240 for operational lease (including the integration of the residual values). When also the energy savings are included and deducted from the monthly fee, the extra net living cost for this renovation is lowered to €95/month

The longer the contract is held the cheaper the monthly costs. This is due to the fact that there is always a certain loss in investment costs and due to the assumption of rising energy prices. When a contract is entered for 5 years instead of 15 years, there is a difference of 10 years in which the loss in investment and materials must be repaid. The differences in net living costs can be found in the table below.

Results: Overview

				10 Year Contract
				Financial
Renovation Model	Investment	Energy Bill	Payback time	Lease
Basic Rc 4.5	€ 40.000	€ 960	22	€ 330
Basic Rc 4.5 Full Options	€ 50.000	€ 680	24	€ 440
Basic Rc 4.5 Full Options + Geothermal heat pump	€ 70.000	€ 620	32	€ 590
Dormer Rc 4.5 Standard	€ 45.000	€ 950	19 (24)	€ 370
Dormer Rc 4.5 Full options	€ 58.000	€ 710	22 (26)	€ 480
Double Dormer Rc 4.5 Standard	€ 50.000	€ 990	17 (27)	€ 420
Double Dormer Rc 4.5 Full options	€ 63.000	€ 690	20 (28)	€ 530
Extension Rc 4.5 Standard	€ 63.000	€ 1.010	24 (33)	€ 530
Extension Rc 4.5 Full options	€ 76.000	€ 700	26 (33)	€ 640
Extension XL+ Rc 4.5 Standard	€ 69.000	€ 1.060	25 (36)	€ 570
Extension XL+ Rc 4.5 Full options	€ 82.000	€ 760	21 (36)	€ 680
Alternatives				
Only necessary maintenance	€ 28.000	€ 2.680	0	€ 230
Necessary maintenance + Energy upgrade	€ 34.000	€ 1.740	35	€ 280
Traditional renovation concept 113ZCT	€ 43.000	€ 820	19	€ 300

10 Year Contract					Operational Lease		
Operational Lease	Recalculated	Monthly			5 Year	15 Year	20 Year
Residual value	Investment	Payment	Energy saving	Net Costs	Net Costs	Net Costs	Net Costs
€ 11.000	€ 29.000	€ 240	€ 145	€ 95	€ 290	€ 20	-€ 20
€ 19.000	€ 31.000	€ 280	€ 165	€ 115	€ 310	€ 40	€ 0
€ 18.000	€ 52.000	€ 430	€ 170	€ 260	€ 620	€ 140	€ 75
€ 14.000	€ 31.000	€ 250	€ 145	€ 105	€ 310	€ 35	-€ 5
€ 22.000	€ 36.000	€ 300	€ 165	€ 135	€ 330	€ 55	€ 15
€ 18.000	€ 32.000	€ 270	€ 140	€ 130	€ 335	€ 50	€ 10
€ 25.000	€ 38.000	€ 310	€ 170	€ 140	€ 350	€ 70	€ 25
€ 26.000	€ 37.000	€ 310	€ 140	€ 170	€ 380	€ 85	€ 45
€ 34.000	€ 42.000	€ 350	€ 165	€ 185	€ 400	€ 105	€ 60
€ 30.000	€ 39.000	€ 330	€ 135	€ 195	€ 420	€ 110	€ 65
€ 38.000	€ 44.000	€ 370	€ 160	€ 210	€ 430	€ 130	€ 80
				€ 0			
€ 0	€ 28.000	€ 230	€ 0	€ 230	€ 460	€ 155	€ 115
€ 0	€ 34.000	€ 280	€ 80	€ 200	€ 490	€ 115	€ 65
€ 0	€ 43.000	€ 300	€ 155	€ 145	€ 440	€ 35	-€ 20

Chapter 7
Lease
Maintenance

The average maintenance costs housing corporations spend each year are €1464,-, split into

- €906 euro for plannend maintenance
- €354 euro for complaint maintenance
- €203 euro for mutation maintenance

(Ministry of National Affairs, 2013a)

Plannend maintenance is scheduled maintenance to prevent failures of the dwellings in a later stadium. Plannend maintenance is among others covered by exterior paintwork, replacement of window frames and boiler maintenance. Complaint maintenance is based on complaints indicated by the residents. Mutation maintenance is the necessary maintenance to prepare the house for a new tenant when moving out (Adeas, 2014)

The assumption is made that higher maintenance costs may appear at a certain new and innovative renovation design as described in this thesis. It is therefore that the reference of €1464,- for yearly maintenance is fully adopted in the upcoming calculations, instead of taking out the €203,- for mutation maintenance which only occurs at the rental sector. Thereby due to the large scale approach, instead of maintenance at one house at a time, an extra 7% in maintenance costs (van den Berge, 2013) is taken in the calculation of the solely alternative renovations (the 'Traditional Renovation' model, the 'Only Maintenance', and 'Maintenance + Energy Saving Upgrades' variants which do not include a lease contract and are not participating in a large scale approach).

See below a indication of the maintenance structure, and see next page for a more elaborated maintenance check list by Bouwgarant (2014)

Element	Each '#' year	Costs
Paintwork	6	€46/m2
Rooftiles	50	€118/m2
Masonry joints	30	€62/m2
Gutters	30	€56/m2
Chimney	60	€768/piece
Rainwater drainage	30	€31/m
Gutter- and roofboarding	30	€53/m
Window frames	30	€555/m2
Door frames	30	€594m2
Double glazing	25	€150m2
Central heating boiler	20	€1880/piece

(Vereniging Eigen Huis, 2014)

Roof
Check leaks roofdeck
Check connection rooftiles
Check for damage / missing tiles
Remove algae and moss growth
Remove bird nests under ridge and pans
Replace rooftiles

Dormers
Clean / wash
Check for leaks
Check window operation
Check en clean gutter around skylight
Check joints pans - gutter
Check condition seals and weather stripping
Repair parts

Gutters
Clean gutters
Check for leaks and damages
Check drainage
Repair parts

Gutter Paneling
Clean / wash paintwork
Check for dry rot
Check for damp spots and leaks
Check for cracks and warping
Check finishing condition
Necessary paintwork
Repair parts

Drainpipes
Check for damage, cracks
Check connection gutter - outlet
Check fixings, loose, rusted or broken
Repair parts

Facades
Clean
Check for cracks, warping
Check for open connections
Check finishing condition (flaking, algae, cracking, loss of gloss, blistering, damages)
Necessary paintwork
Repair parts

Masonry
Check for cracks
Check for damp spots
Check for gaps
Check joints, loose or fallen
Repair parts

Window Frames
Clean / wash
Check glazing beads for cracks, warping
Check window sills for damages
Check rotating parts
Check for loose screws in locks and hinges
Check draughtproofing for damage
Check moisture / condensation betweend double glazing
Check glue edges
Clean vents
Necessary paintwork
Repair parts

Installations
Heating installation
Check water pressure
Check compression fittings for leaks
Clean convectors
Check gas line for rust spots
Repair boiler parts

Mechanical Ventilation System
Clean fan
Repair parts

Energy Generation
Check operation PV Panels
Repair PV components
Check operation Solar boiler
Repair Solar boiler parts
Check operation thermal heatpump
Repair thermal heatpump parts

Sunscreens
Clean and check screen
Repair screen

(Bouwgarant, 2014)

Chapter 8

Results

Content & Structure

In this chapter the results for the lease calculation are presented.

The results include the renovation model “Basic with Rc Value = 4,5” and the three renovation variants “Only Maintenance”, “Maintenance + Energy Saving Upgrades” and the tradional renovation concept.

At the end of the chapter the results will be compared to eachother and conclusions regarding costs, payback periods, feasibility and energy performance performed.

The presented lease contracts for the Basic RC =4.5 renovation include all a 10 year contract, with variations at continuation at the end of the contract. The different lease contracts presented for the prefab renovation model are:

10 Year Operational Lease, with after 10 years:
- New Contract (gain new elements)
- Extend Contract (keep elements, pay off residual value occording lifetime expectancy)
- Redeem elements (keep elements, pay off residual value in 10 years)
- Directly buy elements (pay residual value at once)

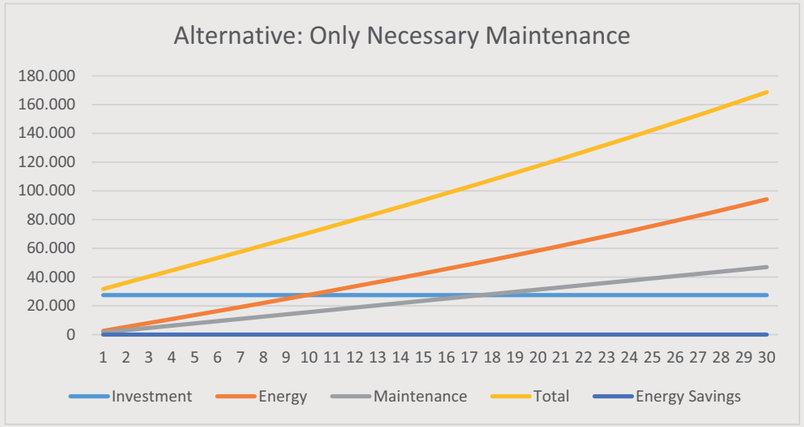
10 Year Financial Lease
- Elements are paid off

Chapter 8: Results

Renovation model: Alternative, Only Necessary Maintenance

Electricity: 3500 kWh

Gas: 2600 m³

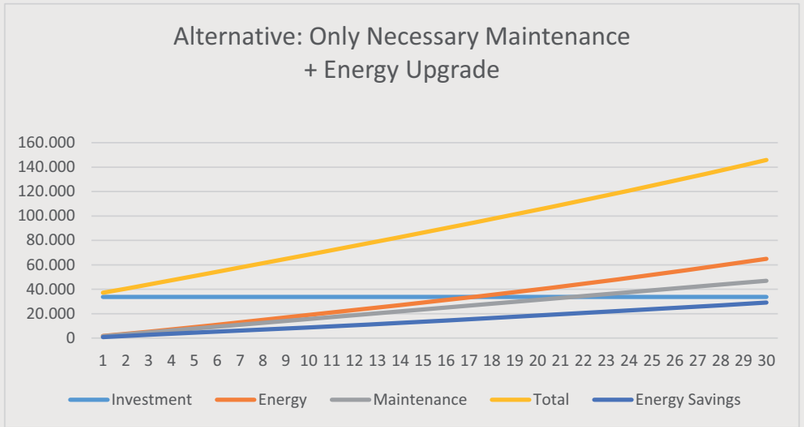


Alternative: Only Necessary Maintenance					Including Loan 5,5%	
Year	Investment	Energy usage	Maintenance	Total	Investment	Total
1	€ 27.548	€ 2.678	€ 1.566	€ 31.792	€ 3.564	€ 7.808
2	€ 27.548	€ 5.372	€ 3.133	€ 36.053	€ 7.128	€ 15.633
3	€ 27.548	€ 8.085	€ 4.699	€ 40.332	€ 10.692	€ 23.477
4	€ 27.548	€ 10.818	€ 6.266	€ 44.631	€ 14.256	€ 31.340
5	€ 27.548	€ 13.571	€ 7.832	€ 48.951	€ 17.820	€ 39.223
6	€ 27.548	€ 16.347	€ 9.399	€ 53.294	€ 21.384	€ 47.130
7	€ 27.548	€ 19.147	€ 10.965	€ 57.660	€ 24.948	€ 55.060
8	€ 27.548	€ 21.972	€ 12.532	€ 62.052	€ 28.512	€ 63.016
9	€ 27.548	€ 24.825	€ 14.098	€ 66.471	€ 32.076	€ 70.999
10	€ 27.548	€ 27.706	€ 15.665	€ 70.918	€ 35.640	€ 79.011
11	€ 27.548	€ 30.617	€ 17.231	€ 75.396	€ 35.640	€ 83.488
12	€ 27.548	€ 33.560	€ 18.798	€ 79.905	€ 35.640	€ 87.997
13	€ 27.548	€ 36.536	€ 20.364	€ 84.448	€ 35.640	€ 92.540
14	€ 27.548	€ 39.548	€ 21.931	€ 89.026	€ 35.640	€ 97.118
15	€ 27.548	€ 42.596	€ 23.497	€ 93.641	€ 35.640	€ 101.733
16	€ 27.548	€ 45.683	€ 25.064	€ 98.294	€ 35.640	€ 106.387
17	€ 27.548	€ 48.811	€ 26.630	€ 102.988	€ 35.640	€ 111.081
18	€ 27.548	€ 51.981	€ 28.197	€ 107.725	€ 35.640	€ 115.817
19	€ 27.548	€ 55.195	€ 29.763	€ 112.506	€ 35.640	€ 120.598
20	€ 27.548	€ 58.455	€ 31.330	€ 117.333	€ 35.640	€ 125.425
21	€ 27.548	€ 61.764	€ 32.896	€ 122.208	€ 35.640	€ 130.300
22	€ 27.548	€ 65.123	€ 34.463	€ 127.134	€ 35.640	€ 135.226
23	€ 27.548	€ 68.535	€ 36.029	€ 132.112	€ 35.640	€ 140.204
24	€ 27.548	€ 72.001	€ 37.596	€ 137.145	€ 35.640	€ 145.237
25	€ 27.548	€ 75.525	€ 39.162	€ 142.234	€ 35.640	€ 150.327
26	€ 27.548	€ 79.107	€ 40.728	€ 147.383	€ 35.640	€ 155.475
27	€ 27.548	€ 82.751	€ 42.295	€ 152.593	€ 35.640	€ 160.686
28	€ 27.548	€ 86.458	€ 43.861	€ 157.867	€ 35.640	€ 165.960
29	€ 27.548	€ 90.233	€ 45.428	€ 163.208	€ 35.640	€ 171.301
30	€ 27.548	€ 94.076	€ 46.994	€ 168.618	€ 35.640	€ 176.710

Renovation model: Alternative, Necessary maintenance + Energy upgrade

Electricity: 3500 kWh

Gas: 1300 m³



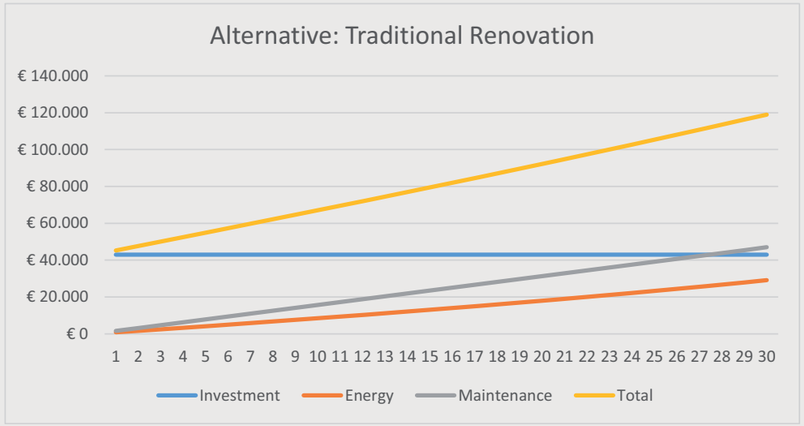
Alternative: Necessary maintenance + Energy upgrades					Including Loan 5,5%	
Year	Investment	Energy usage	Maintenance	Total	Investment	Total
1	€ 33.831	€ 1.741	€ 1.566	€ 37.139	€ 4.380	€ 7.688
2	€ 33.831	€ 3.515	€ 3.133	€ 40.480	€ 8.760	€ 15.408
3	€ 33.831	€ 5.323	€ 4.699	€ 43.854	€ 13.140	€ 23.163
4	€ 33.831	€ 7.167	€ 6.266	€ 47.265	€ 17.520	€ 30.953
5	€ 33.831	€ 9.049	€ 7.832	€ 50.713	€ 21.900	€ 38.781
6	€ 33.831	€ 10.970	€ 9.399	€ 54.201	€ 26.280	€ 46.649
7	€ 33.831	€ 12.933	€ 10.965	€ 57.730	€ 30.660	€ 54.558
8	€ 33.831	€ 14.939	€ 12.532	€ 61.303	€ 35.040	€ 62.511
9	€ 33.831	€ 16.991	€ 14.098	€ 64.921	€ 39.420	€ 70.509
10	€ 33.831	€ 19.090	€ 15.665	€ 68.586	€ 43.800	€ 78.555
11	€ 33.831	€ 21.028	€ 17.231	€ 72.091	€ 43.800	€ 82.059
12	€ 33.831	€ 22.994	€ 18.798	€ 75.623	€ 43.800	€ 85.592
13	€ 33.831	€ 24.990	€ 20.364	€ 79.186	€ 43.800	€ 89.154
14	€ 33.831	€ 27.016	€ 21.931	€ 82.779	€ 43.800	€ 92.747
15	€ 33.831	€ 29.075	€ 23.497	€ 86.404	€ 43.800	€ 96.372
16	€ 33.831	€ 31.168	€ 25.064	€ 90.063	€ 43.800	€ 100.032
17	€ 33.831	€ 33.296	€ 26.630	€ 93.758	€ 43.800	€ 103.726
18	€ 33.831	€ 35.461	€ 28.197	€ 97.489	€ 43.800	€ 107.457
19	€ 33.831	€ 37.664	€ 29.763	€ 101.259	€ 43.800	€ 111.227
20	€ 33.831	€ 39.908	€ 31.330	€ 105.069	€ 43.800	€ 115.037
21	€ 33.831	€ 42.193	€ 32.896	€ 108.920	€ 43.800	€ 118.889
22	€ 33.831	€ 44.522	€ 34.463	€ 112.816	€ 43.800	€ 122.784
23	€ 33.831	€ 46.896	€ 36.029	€ 116.756	€ 43.800	€ 126.725
24	€ 33.831	€ 49.317	€ 37.596	€ 120.744	€ 43.800	€ 130.712
25	€ 33.831	€ 51.787	€ 39.162	€ 124.781	€ 43.800	€ 134.749
26	€ 33.831	€ 54.309	€ 40.728	€ 128.869	€ 43.800	€ 138.837
27	€ 33.831	€ 56.883	€ 42.295	€ 133.010	€ 43.800	€ 142.978
28	€ 33.831	€ 59.513	€ 43.861	€ 137.206	€ 43.800	€ 147.174
29	€ 33.831	€ 62.200	€ 45.428	€ 141.459	€ 43.800	€ 151.427
30	€ 33.831	€ 64.946	€ 46.994	€ 145.772	€ 43.800	€ 155.740

Chapter 8: Results

Renovation model: Alternative, Traditional Renovation

Electricity: 3500 kWh

Gas: 700 m³

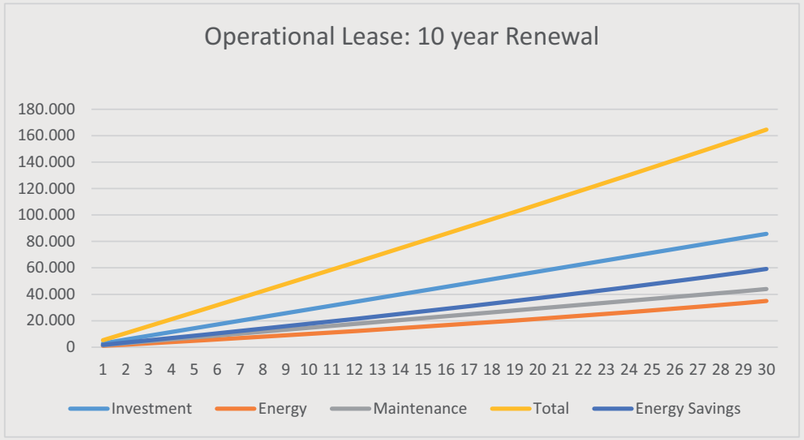


Alternative: Traditional renovation					Including Loan 5,5%	
Year	Investment	Energy usage	Maintenance	Total	Investment	Total
1	€ 42.918	€ 815	€ 1.566	€ 45.299	€ 5.556	€ 7.937
2	€ 42.918	€ 1.636	€ 3.133	€ 47.687	€ 11.112	€ 15.881
3	€ 42.918	€ 2.463	€ 4.699	€ 50.080	€ 16.668	€ 23.830
4	€ 42.918	€ 3.296	€ 6.266	€ 52.480	€ 22.224	€ 31.786
5	€ 42.918	€ 4.137	€ 7.832	€ 54.888	€ 27.780	€ 39.750
6	€ 42.918	€ 4.986	€ 9.399	€ 57.303	€ 33.336	€ 47.721
7	€ 42.918	€ 5.843	€ 10.965	€ 59.726	€ 38.892	€ 55.700
8	€ 42.918	€ 6.708	€ 12.532	€ 62.158	€ 44.448	€ 63.688
9	€ 42.918	€ 7.583	€ 14.098	€ 64.599	€ 50.004	€ 71.685
10	€ 42.918	€ 8.467	€ 15.665	€ 67.049	€ 55.560	€ 79.691
11	€ 42.918	€ 9.361	€ 17.231	€ 69.510	€ 55.560	€ 82.152
12	€ 42.918	€ 10.266	€ 18.798	€ 71.982	€ 55.560	€ 84.624
13	€ 42.918	€ 11.182	€ 20.364	€ 74.465	€ 55.560	€ 87.107
14	€ 42.918	€ 12.110	€ 21.931	€ 76.959	€ 55.560	€ 89.601
15	€ 42.918	€ 13.051	€ 23.497	€ 79.466	€ 55.560	€ 92.108
16	€ 42.918	€ 14.004	€ 25.064	€ 81.986	€ 55.560	€ 94.628
17	€ 42.918	€ 14.971	€ 26.630	€ 84.519	€ 55.560	€ 97.161
18	€ 42.918	€ 15.952	€ 28.197	€ 87.067	€ 55.560	€ 99.709
19	€ 42.918	€ 16.948	€ 29.763	€ 89.629	€ 55.560	€ 102.271
20	€ 42.918	€ 17.960	€ 31.330	€ 92.207	€ 55.560	€ 104.849
21	€ 42.918	€ 18.987	€ 32.896	€ 94.801	€ 55.560	€ 107.443
22	€ 42.918	€ 20.032	€ 34.463	€ 97.412	€ 55.560	€ 110.054
23	€ 42.918	€ 21.094	€ 36.029	€ 100.041	€ 55.560	€ 112.683
24	€ 42.918	€ 22.174	€ 37.596	€ 102.687	€ 55.560	€ 115.329
25	€ 42.918	€ 23.273	€ 39.162	€ 105.353	€ 55.560	€ 117.995
26	€ 42.918	€ 24.392	€ 40.728	€ 108.039	€ 55.560	€ 120.681
27	€ 42.918	€ 25.532	€ 42.295	€ 110.745	€ 55.560	€ 123.387
28	€ 42.918	€ 26.693	€ 43.861	€ 113.472	€ 55.560	€ 126.114
29	€ 42.918	€ 27.876	€ 45.428	€ 116.222	€ 55.560	€ 128.864
30	€ 42.918	€ 29.082	€ 46.994	€ 118.994	€ 55.560	€ 131.636

Renovation model: Operational Lease, 10 year Renewal + Each 10 year new elements

Electricity: 1750 kWh

Gas: 775 m³



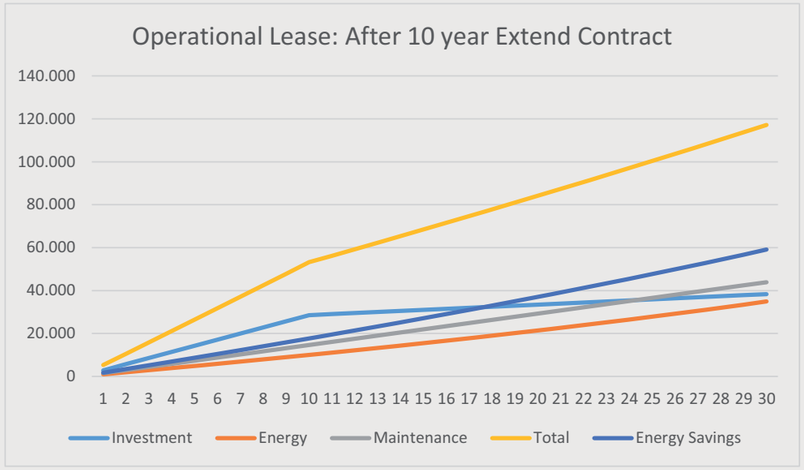
Operational Lease - Each 10 year new elements					Including 2,07% Interest	
Year	Investment	Energy usage	Maintenance	Total	Investment	Total
1	€ 2.856	€ 958	€ 1.464	€ 5.279	€ 3.156	€ 5.578
2	€ 5.712	€ 1.925	€ 2.928	€ 10.565	€ 6.312	€ 11.165
3	€ 8.569	€ 2.900	€ 4.392	€ 15.861	€ 9.468	€ 16.760
4	€ 11.425	€ 3.884	€ 5.856	€ 21.165	€ 12.624	€ 22.364
5	€ 14.281	€ 4.878	€ 7.320	€ 26.479	€ 15.780	€ 27.978
6	€ 17.137	€ 5.882	€ 8.784	€ 31.804	€ 18.936	€ 33.602
7	€ 19.993	€ 6.898	€ 10.248	€ 37.139	€ 22.092	€ 39.238
8	€ 22.850	€ 7.925	€ 11.712	€ 42.486	€ 25.248	€ 44.885
9	€ 25.706	€ 8.964	€ 13.176	€ 47.846	€ 28.404	€ 50.544
10	€ 28.562	€ 10.016	€ 14.640	€ 53.218	€ 31.560	€ 56.216
11	€ 31.418	€ 11.081	€ 16.104	€ 58.604	€ 34.716	€ 61.901
12	€ 34.274	€ 12.161	€ 17.568	€ 64.004	€ 37.872	€ 67.601
13	€ 37.131	€ 13.256	€ 19.032	€ 69.419	€ 41.028	€ 73.316
14	€ 39.987	€ 14.366	€ 20.496	€ 74.849	€ 44.184	€ 79.046
15	€ 42.843	€ 15.493	€ 21.960	€ 80.296	€ 47.340	€ 84.793
16	€ 45.699	€ 16.637	€ 23.424	€ 85.761	€ 50.496	€ 90.557
17	€ 48.556	€ 17.799	€ 24.888	€ 91.243	€ 53.652	€ 96.339
18	€ 51.412	€ 18.980	€ 26.352	€ 96.744	€ 56.808	€ 102.140
19	€ 54.268	€ 20.181	€ 27.816	€ 102.265	€ 59.964	€ 107.961
20	€ 57.124	€ 21.402	€ 29.280	€ 107.806	€ 63.120	€ 113.802
21	€ 59.980	€ 22.644	€ 30.744	€ 113.369	€ 66.276	€ 119.664
22	€ 62.837	€ 23.909	€ 32.208	€ 118.953	€ 69.432	€ 125.549
23	€ 65.693	€ 25.197	€ 33.672	€ 124.561	€ 72.588	€ 131.457
24	€ 68.549	€ 26.508	€ 35.136	€ 130.193	€ 75.744	€ 137.388
25	€ 71.405	€ 27.845	€ 36.600	€ 135.851	€ 78.900	€ 143.345
26	€ 74.261	€ 29.209	€ 38.064	€ 141.534	€ 82.056	€ 149.329
27	€ 77.118	€ 30.599	€ 39.528	€ 147.244	€ 85.212	€ 155.339
28	€ 79.974	€ 32.017	€ 40.992	€ 152.983	€ 88.368	€ 161.377
29	€ 82.830	€ 33.465	€ 42.456	€ 158.751	€ 91.524	€ 167.445
30	€ 85.686	€ 34.943	€ 43.920	€ 164.550	€ 94.680	€ 173.543

Chapter 8: Results

Renovation model: Opeartional Lease, 10 year Contract + Extend Contract

Electricity: 1750 kWh

Gas: 775 m³

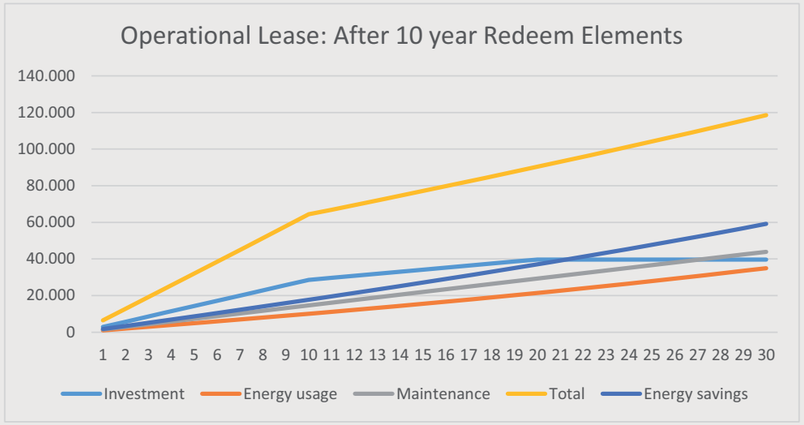


Operational Lease - After 10 year, Extend Contract						Including 2,07% Interest	
Year	Investment	Energy usage	Maintenance	Pay Residual V.	Total	Investment	Total
1	€ 2.856	€ 958	€ 1.464	€ 0	€ 5.279	€ 3.156	€ 5.578
2	€ 5.712	€ 1.925	€ 2.928	€ 0	€ 10.565	€ 6.312	€ 11.165
3	€ 8.569	€ 2.900	€ 4.392	€ 0	€ 15.861	€ 9.468	€ 16.760
4	€ 11.425	€ 3.884	€ 5.856	€ 0	€ 21.165	€ 12.624	€ 22.364
5	€ 14.281	€ 4.878	€ 7.320	€ 0	€ 26.479	€ 15.780	€ 27.978
6	€ 17.137	€ 5.882	€ 8.784	€ 0	€ 31.804	€ 18.936	€ 33.602
7	€ 19.993	€ 6.898	€ 10.248	€ 0	€ 37.139	€ 22.092	€ 39.238
8	€ 22.850	€ 7.925	€ 11.712	€ 0	€ 42.486	€ 25.248	€ 44.885
9	€ 25.706	€ 8.964	€ 13.176	€ 0	€ 47.846	€ 28.404	€ 50.544
10	€ 28.562	€ 10.016	€ 14.640	€ 0	€ 53.218	€ 31.560	€ 56.216
11	€ 28.562	€ 11.081	€ 16.104	€ 490	€ 56.237	€ 32.060	€ 59.245
12	€ 28.562	€ 12.161	€ 17.568	€ 980	€ 59.271	€ 32.581	€ 62.310
13	€ 28.562	€ 13.256	€ 19.032	€ 1.470	€ 62.320	€ 33.113	€ 65.401
14	€ 28.562	€ 14.366	€ 20.496	€ 1.960	€ 65.385	€ 33.655	€ 68.518
15	€ 28.562	€ 15.493	€ 21.960	€ 2.450	€ 68.466	€ 34.209	€ 71.663
16	€ 28.562	€ 16.637	€ 23.424	€ 2.940	€ 71.564	€ 34.775	€ 74.836
17	€ 28.562	€ 17.799	€ 24.888	€ 3.430	€ 74.680	€ 35.352	€ 78.039
18	€ 28.562	€ 18.980	€ 26.352	€ 3.920	€ 77.815	€ 35.941	€ 81.273
19	€ 28.562	€ 20.181	€ 27.816	€ 4.410	€ 80.969	€ 36.542	€ 84.539
20	€ 28.562	€ 21.402	€ 29.280	€ 4.900	€ 84.144	€ 37.156	€ 87.838
21	€ 28.562	€ 22.644	€ 30.744	€ 5.390	€ 87.341	€ 37.782	€ 91.170
22	€ 28.562	€ 23.909	€ 32.208	€ 5.880	€ 90.559	€ 38.421	€ 94.538
23	€ 28.562	€ 25.197	€ 33.672	€ 6.371	€ 93.801	€ 39.074	€ 97.943
24	€ 28.562	€ 26.508	€ 35.136	€ 6.861	€ 97.067	€ 39.740	€ 101.385
25	€ 28.562	€ 27.845	€ 36.600	€ 7.351	€ 100.358	€ 40.420	€ 104.865
26	€ 28.562	€ 29.209	€ 38.064	€ 7.841	€ 103.675	€ 41.114	€ 108.386
27	€ 28.562	€ 30.599	€ 39.528	€ 8.331	€ 107.020	€ 41.822	€ 111.949
28	€ 28.562	€ 32.017	€ 40.992	€ 8.821	€ 110.392	€ 42.545	€ 115.554
29	€ 28.562	€ 33.465	€ 42.456	€ 9.311	€ 113.794	€ 43.283	€ 119.204
30	€ 28.562	€ 34.943	€ 43.920	€ 9.801	€ 117.226	€ 44.036	€ 122.900

Renovation model: Operational Lease, 10 year Contract +Redeem Elements

Electricity: 1750 kWh

Gas: 775 m³



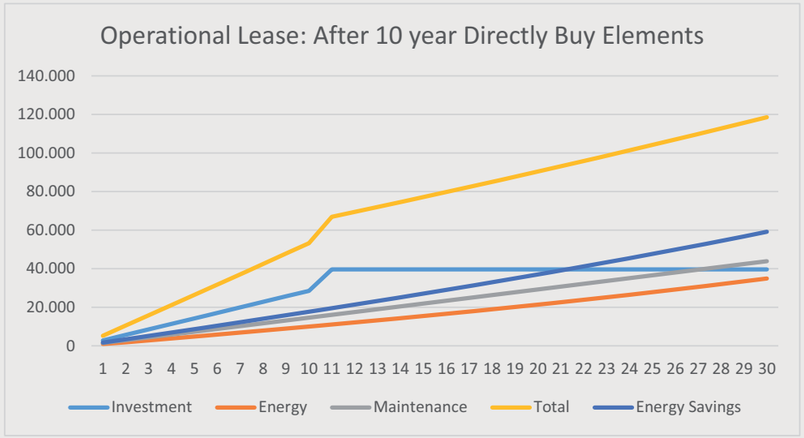
Operational Lease - After 10 year, Redeem Residual Value in 10 years						Including 2,07% Interest	
Year	Investment	Energy usage	Maintenance	Pay Residual V.	Total	Investment	Total
1	€ 2.856	€ 958	€ 1.464	€ 0	€ 5.279	€ 3.156	€ 5.578
2	€ 5.712	€ 1.925	€ 2.928	€ 0	€ 10.565	€ 6.312	€ 11.165
3	€ 8.569	€ 2.900	€ 4.392	€ 0	€ 15.861	€ 9.468	€ 16.760
4	€ 11.425	€ 3.884	€ 5.856	€ 0	€ 21.165	€ 12.624	€ 22.364
5	€ 14.281	€ 4.878	€ 7.320	€ 0	€ 26.479	€ 15.780	€ 27.978
6	€ 17.137	€ 5.882	€ 8.784	€ 0	€ 31.804	€ 18.936	€ 33.602
7	€ 19.993	€ 6.898	€ 10.248	€ 0	€ 37.139	€ 22.092	€ 39.238
8	€ 22.850	€ 7.925	€ 11.712	€ 0	€ 42.486	€ 25.248	€ 44.885
9	€ 25.706	€ 8.964	€ 13.176	€ 0	€ 47.846	€ 28.404	€ 50.544
10	€ 28.562	€ 10.016	€ 14.640	€ 0	€ 53.218	€ 31.560	€ 56.216
11	€ 28.562	€ 11.081	€ 16.104	€ 1.114	€ 56.862	€ 32.697	€ 59.883
12	€ 28.562	€ 12.161	€ 17.568	€ 2.228	€ 60.520	€ 33.882	€ 63.611
13	€ 28.562	€ 13.256	€ 19.032	€ 3.343	€ 64.193	€ 35.091	€ 67.378
14	€ 28.562	€ 14.366	€ 20.496	€ 4.457	€ 67.881	€ 36.324	€ 71.187
15	€ 28.562	€ 15.493	€ 21.960	€ 5.571	€ 71.586	€ 37.584	€ 75.037
16	€ 28.562	€ 16.637	€ 23.424	€ 6.685	€ 75.309	€ 38.869	€ 78.931
17	€ 28.562	€ 17.799	€ 24.888	€ 7.800	€ 79.049	€ 40.182	€ 82.869
18	€ 28.562	€ 18.980	€ 26.352	€ 8.914	€ 82.808	€ 41.521	€ 86.853
19	€ 28.562	€ 20.181	€ 27.816	€ 10.028	€ 86.587	€ 42.888	€ 90.885
20	€ 28.562	€ 21.402	€ 29.280	€ 11.142	€ 90.386	€ 44.283	€ 94.965
21	€ 28.562	€ 22.644	€ 30.744	€ 11.142	€ 93.092	€ 44.283	€ 97.671
22	€ 28.562	€ 23.909	€ 32.208	€ 11.142	€ 95.821	€ 44.283	€ 100.400
23	€ 28.562	€ 25.197	€ 33.672	€ 11.142	€ 98.573	€ 44.283	€ 103.152
24	€ 28.562	€ 26.508	€ 35.136	€ 11.142	€ 101.349	€ 44.283	€ 105.928
25	€ 28.562	€ 27.845	€ 36.600	€ 11.142	€ 104.150	€ 44.283	€ 108.729
26	€ 28.562	€ 29.209	€ 38.064	€ 11.142	€ 106.977	€ 44.283	€ 111.556
27	€ 28.562	€ 30.599	€ 39.528	€ 11.142	€ 109.831	€ 44.283	€ 114.410
28	€ 28.562	€ 32.017	€ 40.992	€ 11.142	€ 112.714	€ 44.283	€ 117.292
29	€ 28.562	€ 33.465	€ 42.456	€ 11.142	€ 115.625	€ 44.283	€ 120.204
30	€ 28.562	€ 34.943	€ 43.920	€ 11.142	€ 118.568	€ 44.283	€ 123.146

Chapter 8: Results

Renovation model: Opeartional Lease, 10 year Contract + Directly Buy

Electricity: 1750 kWh

Gas: 775 m³

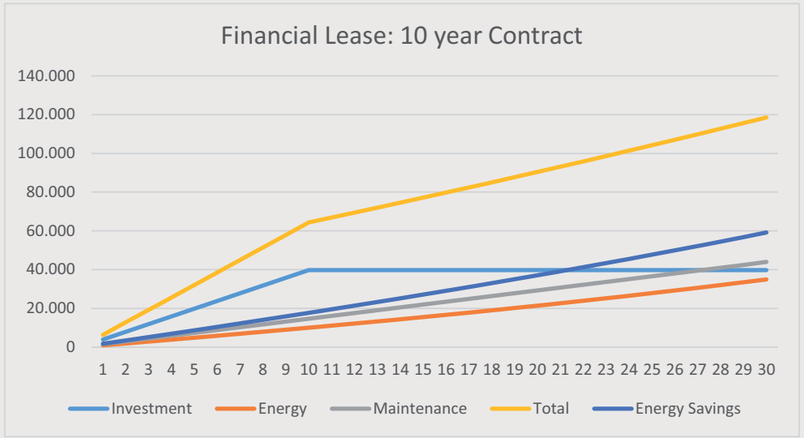


Operational Lease - After 10 year, Directly Buy Elements						Including 2,07% Interest	
Year	Investment	Energy usage	Maintenance	Pay Residual V.	Total	Investment	Total
1	€ 2.856	€ 958	€ 1.464	€ 0	€ 5.279	€ 3.156	€ 5.578
2	€ 5.712	€ 1.925	€ 2.928	€ 0	€ 10.565	€ 6.312	€ 11.165
3	€ 8.569	€ 2.900	€ 4.392	€ 0	€ 15.861	€ 9.468	€ 16.760
4	€ 11.425	€ 3.884	€ 5.856	€ 0	€ 21.165	€ 12.624	€ 22.364
5	€ 14.281	€ 4.878	€ 7.320	€ 0	€ 26.479	€ 15.780	€ 27.978
6	€ 17.137	€ 5.882	€ 8.784	€ 0	€ 31.804	€ 18.936	€ 33.602
7	€ 19.993	€ 6.898	€ 10.248	€ 0	€ 37.139	€ 22.092	€ 39.238
8	€ 22.850	€ 7.925	€ 11.712	€ 0	€ 42.486	€ 25.248	€ 44.885
9	€ 25.706	€ 8.964	€ 13.176	€ 0	€ 47.846	€ 28.404	€ 50.544
10	€ 28.562	€ 10.016	€ 14.640	€ 0	€ 53.218	€ 31.560	€ 56.216
11	€ 28.562	€ 11.081	€ 16.104	€ 11.142	€ 66.890	€ 42.702	€ 69.887
12	€ 28.562	€ 12.161	€ 17.568	€ 11.142	€ 69.433	€ 42.702	€ 72.431
13	€ 28.562	€ 13.256	€ 19.032	€ 11.142	€ 71.992	€ 42.702	€ 74.990
14	€ 28.562	€ 14.366	€ 20.496	€ 11.142	€ 74.567	€ 42.702	€ 77.565
15	€ 28.562	€ 15.493	€ 21.960	€ 11.142	€ 77.158	€ 42.702	€ 80.155
16	€ 28.562	€ 16.637	€ 23.424	€ 11.142	€ 79.766	€ 42.702	€ 82.764
17	€ 28.562	€ 17.799	€ 24.888	€ 11.142	€ 82.392	€ 42.702	€ 85.390
18	€ 28.562	€ 18.980	€ 26.352	€ 11.142	€ 85.037	€ 42.702	€ 88.035
19	€ 28.562	€ 20.181	€ 27.816	€ 11.142	€ 87.701	€ 42.702	€ 90.699
20	€ 28.562	€ 21.402	€ 29.280	€ 11.142	€ 90.386	€ 42.702	€ 93.384
21	€ 28.562	€ 22.644	€ 30.744	€ 11.142	€ 93.092	€ 42.702	€ 96.090
22	€ 28.562	€ 23.909	€ 32.208	€ 11.142	€ 95.821	€ 42.702	€ 98.819
23	€ 28.562	€ 25.197	€ 33.672	€ 11.142	€ 98.573	€ 42.702	€ 101.571
24	€ 28.562	€ 26.508	€ 35.136	€ 11.142	€ 101.349	€ 42.702	€ 104.347
25	€ 28.562	€ 27.845	€ 36.600	€ 11.142	€ 104.150	€ 42.702	€ 107.148
26	€ 28.562	€ 29.209	€ 38.064	€ 11.142	€ 106.977	€ 42.702	€ 109.975
27	€ 28.562	€ 30.599	€ 39.528	€ 11.142	€ 109.831	€ 42.702	€ 112.829
28	€ 28.562	€ 32.017	€ 40.992	€ 11.142	€ 112.714	€ 42.702	€ 115.711
29	€ 28.562	€ 33.465	€ 42.456	€ 11.142	€ 115.625	€ 42.702	€ 118.623
30	€ 28.562	€ 34.943	€ 43.920	€ 11.142	€ 118.568	€ 42.702	€ 121.565

Renovation model: Financial Lease, 10 year Contract

Electricity: 1750 kWh

Gas: 775 m³



Financial Lease - 10 year Contract					Including 2,07% Interest	
Year	Investment	Energy usage	Maintenance	Total	Investment	Total
1	€ 3.970	€ 958	€ 1.464	€ 6.393	€ 4.392	€ 6.814
2	€ 7.941	€ 1.925	€ 2.928	€ 12.794	€ 8.784	€ 13.637
3	€ 11.911	€ 2.900	€ 4.392	€ 19.203	€ 13.176	€ 20.468
4	€ 15.882	€ 3.884	€ 5.856	€ 25.622	€ 17.568	€ 27.308
5	€ 19.852	€ 4.878	€ 7.320	€ 32.050	€ 21.960	€ 34.158
6	€ 23.823	€ 5.882	€ 8.784	€ 38.489	€ 26.352	€ 41.018
7	€ 27.793	€ 6.898	€ 10.248	€ 44.939	€ 30.744	€ 47.890
8	€ 31.763	€ 7.925	€ 11.712	€ 51.400	€ 35.136	€ 54.773
9	€ 35.734	€ 8.964	€ 13.176	€ 57.874	€ 39.528	€ 61.668
10	€ 39.704	€ 10.016	€ 14.640	€ 64.360	€ 43.920	€ 68.576
11	€ 39.704	€ 11.081	€ 16.104	€ 66.890	€ 43.920	€ 71.105
12	€ 39.704	€ 12.161	€ 17.568	€ 69.433	€ 43.920	€ 73.649
13	€ 39.704	€ 13.256	€ 19.032	€ 71.992	€ 43.920	€ 76.208
14	€ 39.704	€ 14.366	€ 20.496	€ 74.567	€ 43.920	€ 78.782
15	€ 39.704	€ 15.493	€ 21.960	€ 77.158	€ 43.920	€ 81.373
16	€ 39.704	€ 16.637	€ 23.424	€ 79.766	€ 43.920	€ 83.981
17	€ 39.704	€ 17.799	€ 24.888	€ 82.392	€ 43.920	€ 86.607
18	€ 39.704	€ 18.980	€ 26.352	€ 85.037	€ 43.920	€ 89.252
19	€ 39.704	€ 20.181	€ 27.816	€ 87.701	€ 43.920	€ 91.917
20	€ 39.704	€ 21.402	€ 29.280	€ 90.386	€ 43.920	€ 94.602
21	€ 39.704	€ 22.644	€ 30.744	€ 93.092	€ 43.920	€ 97.308
22	€ 39.704	€ 23.909	€ 32.208	€ 95.821	€ 43.920	€ 100.037
23	€ 39.704	€ 25.197	€ 33.672	€ 98.573	€ 43.920	€ 102.789
24	€ 39.704	€ 26.508	€ 35.136	€ 101.349	€ 43.920	€ 105.564
25	€ 39.704	€ 27.845	€ 36.600	€ 104.150	€ 43.920	€ 108.365
26	€ 39.704	€ 29.209	€ 38.064	€ 106.977	€ 43.920	€ 111.193
27	€ 39.704	€ 30.599	€ 39.528	€ 109.831	€ 43.920	€ 114.047
28	€ 39.704	€ 32.017	€ 40.992	€ 112.714	€ 43.920	€ 116.929
29	€ 39.704	€ 33.465	€ 42.456	€ 115.625	€ 43.920	€ 119.841
30	€ 39.704	€ 34.943	€ 43.920	€ 118.568	€ 43.920	€ 122.783

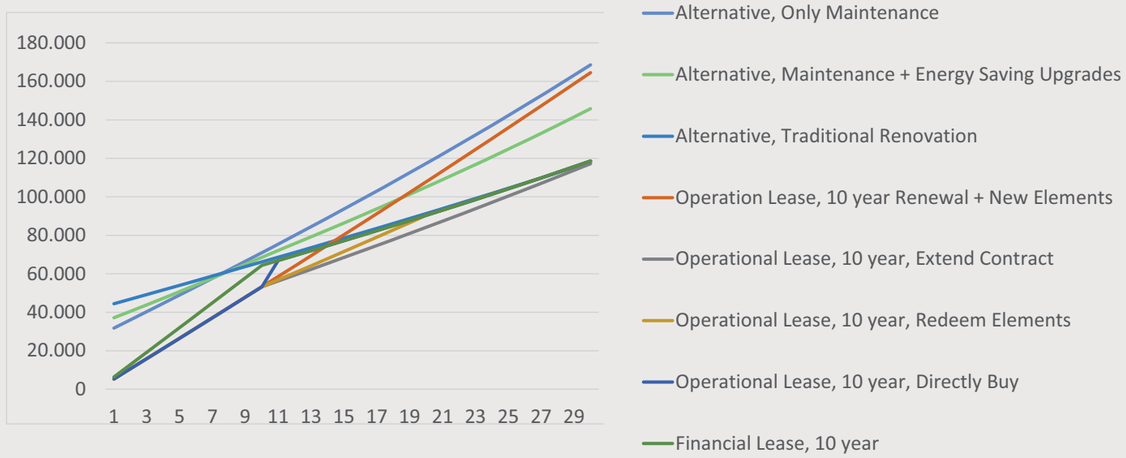
Chapter 8
Results
Conclusion

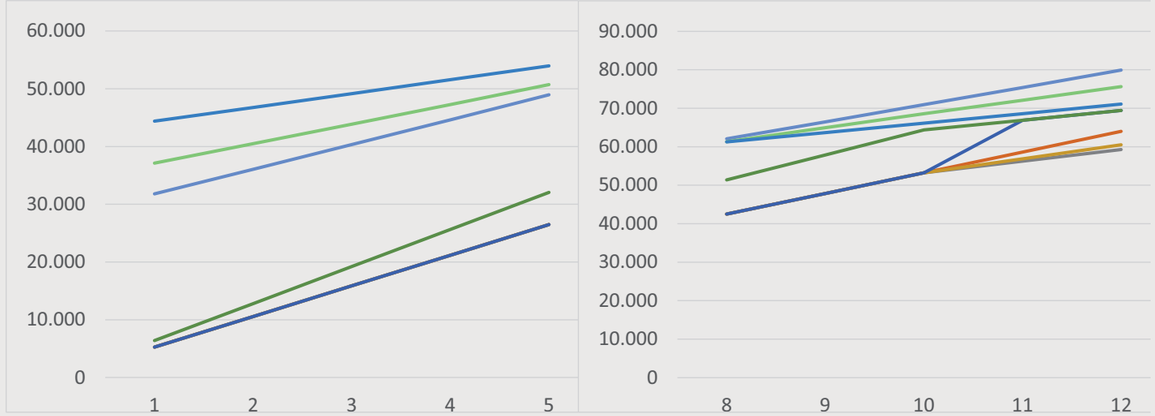
On this page several important conclusions are elaborated from the comparison of the different renovation strategies and different lease strategies (see graphs on the page to the right). It is assumed that residents are able to pay for the investment themeselves, so interest rates are excluded in the renovation variants "Only Maintenance", "Maintenance + Energy Saving Upgrades" and the "Traditional Renovation" strategy. In the next chapter the sensitivity is examined regarding the integration of loans and interest rates.

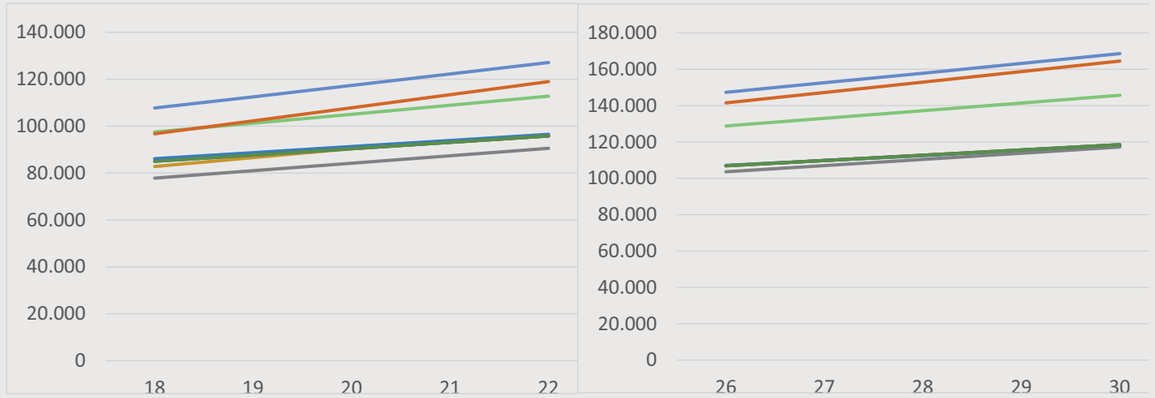
Conclusions:
- "Only Maintenance" has less investment cost than "Maintenance + Energy Saving Upgrades", however within 6 years the energy saving upgrades as well as the extra costs for the traditional renovation strategy has already paid back due to the energy savings on the energy bill.

- The 10 year Operational Lease Contracts have no initial large investment costs;
- however, when renewing the contract and gaing new elements each 10 years, this variant becomes within 19 year the most expensive renovation strategy, excluding the "Only Maintenance" strategy. This is due to the large investment costs which have to paid back each time new renovation components are installed. Withing 12 years it already becomes more expensive than the "Traditional Renovation" concept.
- whether you choose to end your contract and pay off your elements at once ("Directly Buy"), extend your contract and redeem the elements in 10 years ("Redeem Elements"), or extend the contract for the next 20 years and only pay for the depreciation of elements ("Extend Contract"), the difference of the strategies differs just about €1000,- at the end of 30 years.

- The 10 year Financial Lease Contract has larger inital monthly payments due to the integrated redeem of elements, and becomes more expensive the first 10 years, however, at the long term the result is about similar with the Operational Lease construction because elements are already in private ownership in an earlier stage.







Chapter 8
Results
Conclusion

Excluding interest rates and private loans, compared with the Traditional Renovation model, the Prefab Operational Lease concepts have large financial advantages in the first 10 years. The financial advantages will eventually come to each other and will be negligible (see tables below).
The "Maintenance" and "Maintenance + Energy Saving Upgrade" variants become more expensive each year. Starting at a difference of relatively €4.500 and €2.000 compared with the Traditional Renovation strategy, emerging to a difference of €50.000 and €27.000 within 30 years.

Interim conclusion:
If the largest motivating factor for residents is a financial benefit on the short-term, an Operational Lease Contract with Prefab Facade elements will be the best option, comparing to the Tradtional Renovation model, the resident saves €13.000 in the first 10 years. However if the resident is motivated by a long-term strategy the benefits from a operational lease strategy are negligible. A more expensive renovation model demonstrates that the financial benefits in the short-term are less large, and in the long run due to the combination of larger investment costs combined with a relatively less higher energy saving bill, there is even a slight disadvantages compared to the operational lease model elaborated before.

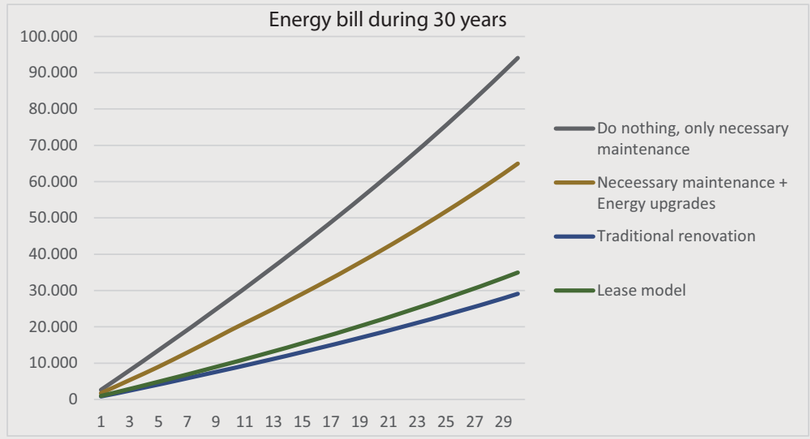
Model 10 year	Investment	Energy	Maintenance	Total
Maintenance	€ 27.500	€ 27.700	€ 15.700	€ 70.900
Maintenance + Energy Saving Upgrades	€ 33.800	€ 19.000	€ 15.700	€ 68.500
Traditional Renovation	€ 42.000	€ 8.500	€ 15.700	€ 66.200
Prefab Lease Renovation	€ 28.600	€ 10.000	€ 14.600	€ 53.200

Model 20 year	Investment	Energy	Maintenance	Total
Maintenance	€ 27.500	€ 58.500	€ 31.300	€ 117.300
Maintenance + Energy Saving Upgrades	€ 33.800	€ 39.900	€ 31.300	€ 105.000
Traditional Renovation	€ 42.000	€ 18.000	€ 31.300	€ 91.300
Prefab Lease Renovation	€ 37.300	€ 21.400	€ 29.300	€ 88.000

Model 30 year	Investment	Energy	Maintenance	Total
Maintenance	€ 27.500	€ 94.000	€ 47.000	€ 168.500
Maintenance + Energy Saving Upgrades	€ 33.800	€ 64.900	€ 47.000	€ 145.700
Traditional Renovation	€ 42.000	€ 29.000	€ 47.000	€ 118.000
Prefab Lease Renovation	€ 39.700	€ 34.900	€ 43.900	€ 118.500

Exclusive Renovation Model	Investment	Energy	Maintenance	Total
Total in 10 years	€ 32.300	€ 7.000	€ 14.600	€ 53.900
Total in 20 years	€ 44.965	€ 14.900	€ 29.300	€ 89.165
Total in 30 years	€ 52.900	€ 24.000	€ 43.900	€ 120.800

Next to the total costs of each renovation concept it should be noticed that the cheapest renovation strategy is not always the most prefered one. Besides barriers as nuisance during the renovation at certain renovation concepts, the condition of the sustainable character should be taken into account. In the graph below the different energy bills for the different renovation models are presented. In this example the "Traditional Renovation" model has the best energy performance, which may be a reason to choose for a more expensive renovation.



Chapter 9

Sensitivity Analysis

Content & Structure

Due to the fact that the used figures in this report are based on figures with a certain tolerance, on several averages and on assumptions, a sensitivy analysis will make clear which key elements are critical for the result.

First a sensitivy analysis is presented by implementing different interest rates, providing insight in the impact of loans and equity capital.

Thereafter, a sensitivity analysis is performed for miscalculations in construction costs, energy savings, and financial aspects.

The first part includes the integration of a loan with an interest rates of 5,5% for residents when participating in the alternative renovation models. The rate corresponds with the average interest rate of the past 10 years (Current Rates, 2014a).

Also a 2,07% rate is introduced for missed interest income for the lease company (Current Rates, 2014b)

The second part includes an analysis of 10 different models:

- 10% more construction costs
- 10% less construction costs
- 1% extra annual energy price increase
- 1% less annual energy price increase
- 1,3% annual missed interest savings for residents integrated
- 2,07% annual missed interest savings for residents integrated
- €1000 subsidy at start
- €2500 subsidy at start
- 90% initial energy demand reference
- 75% initial energy demand reference

Chapter 9
Sensitivity Analysis
Interest Rates

In the previous chapter is assumed that residents are able to pay for the entire investment themselves, no loan is included. When the investment has been built by entering a loan, figures do change. The interest rate for the loan is set to 5,5% which corresponds to the average loan for a 10 year loan at this moment (Current Rates, 2014a). There is also an interest rate implemented in the lease strategies, due to the missing interest savings the lease company would gain if it put their money in the bank instead of investing it in the renovation. This interest rate is set to 2,07% which corresponds to the average current savings rate (Current Rates, 2014b)
In the graphs on the right and tables below the results are presented.

- The "Traditional Renovation" total costs increase with €13.000 in the first10 years and becomes financially more less attractive than the 10 year operational lease contracts, with an exception of the lease variant "Renewal, each 10 year new elements".

- At the end of year 30, the "Traditional Renovation" is about €9.000 more expensive than the lease strategies, ending in €132.000 at the end of year 30

- The lease strategies only differ about €1.000 at the end of year 30, including the Financial Lease strategy. Costs at the end are about €123.000

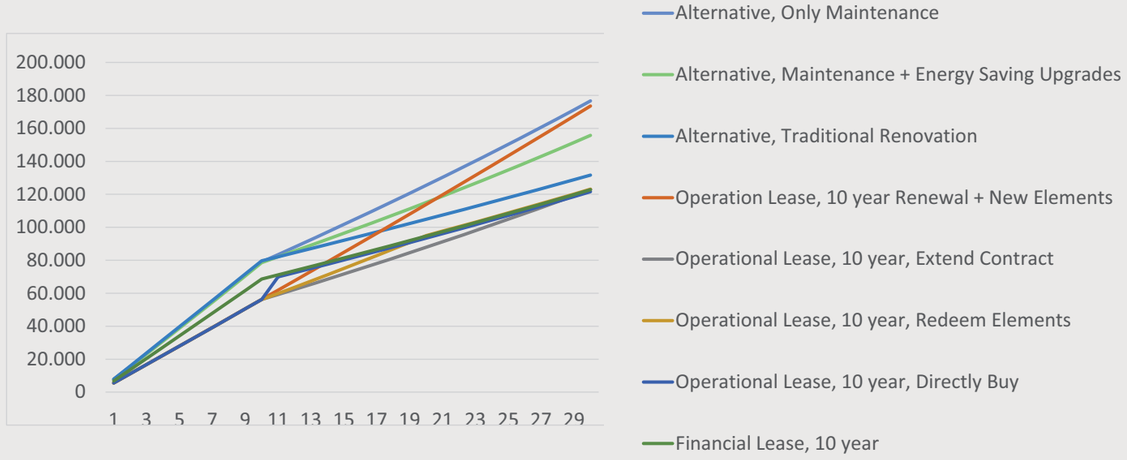
- The costs for doing nothing but "Maintenance" will eventually rise to €176.000 in 30 years
- The costs for "Maintenance" + Energy Saving Upgrades" will end in 30 years to €156.000

Conclusion
Including personal loans and interest rates, lease contracts become considerably more attractive during all years. The financial differences will reduce after the first 10 years and after 30 years the difference is €9.000, which corresponds with less than €30/month. This is explained by the fact residents do own their traditional renovation after 10 years, while residents still have to pay for the residual value in the operational lease structure.

Model 10 year incl. interest rate	Investment	Energy	Maintenance	Total
Maintenance	€ 35.600	€ 27.700	€ 15.700	€ 79.000
Maintenance + Energy Saving Upgrades	€ 43.800	€ 19.000	€ 15.700	€ 78.500
Traditional Renovation	€ 55.600	€ 8.500	€ 15.700	€ 79.800
Prefab Lease Renovation	€ 31.600	€ 10.000	€ 14.600	€ 56.200

Model 20 year incl. interest rate	Investment	Energy	Maintenance	Total
Maintenance	€ 35.600	€ 58.500	€ 31.300	€ 125.400
Maintenance + Energy Saving Upgrades	€ 43.800	€ 39.900	€ 31.300	€ 115.000
Traditional Renovation	€ 55.600	€ 18.000	€ 31.300	€ 104.900
Prefab Lease Renovation	€ 40.000	€ 21.400	€ 29.300	€ 90.700

Model 30 year incl. interest rate	Investment	Energy	Maintenance	Total
Maintenance	€ 35.600	€ 94.000	€ 47.000	€ 176.600
Maintenance + Energy Saving Upgrades	€ 43.800	€ 64.900	€ 47.000	€ 155.700
Traditional Renovation	€ 55.600	€ 29.000	€ 47.000	€ 131.600
Prefab Lease Renovation	€ 44.000	€ 34.900	€ 43.900	€ 122.800



Chapter 9

Sensitivity Analysis

Net Living Costs

The second part includes an analysis in 10 different models:

- 10% more construction costs
- 10% less construction costs
- 1% extra annual energy price increase
- 1% less annual energy price increase
- 1,3% annual missed interest savings for residents integrated
- 2,07% annual missed interest savings for residents integrated
- €1000 subsidy at start
- €2500 subsidy at start
- 90% initial energy demand reference
- 75% initial energy demand reference

Each analysis is presented with the following figures:

- Investment cost
- Payback Time
- Energy bill first year
- Energy savings first year
- Monthly Payment Financial Lease 10 years contract
- Monthly Payment Operational Lease 10 year contract
- Monthly Net living costs

At the end of the chapter the results are summarized and several conclusions are drawn.

Initial result (reference)

Basic Model, Rc = 4.5
Investment: € 40.000

Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 3.447
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 5.185
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 6.933
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 8.693
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 10.465
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 12.249
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 14.048
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 15.861
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 17.690
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 19.536
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 21.399
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 23.280
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 25.181
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 27.103
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 29.046
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 31.011
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 33.000
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 35.014
20	€ 15.943	€ 13.815	€ 29.758	€ 21.402	€ 37.054
21	€ 17.075	€ 14.961	€ 32.037	€ 22.644	€ 39.120
22	**€ 18.248**	**€ 16.170**	**€ 34.418**	**€ 23.909**	**€ 41.215**
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 43.338
24	€ 20.721	€ 18.786	€ 39.507	€ 26.508	€ 45.493
25	€ 22.025	€ 20.201	€ 42.226	€ 27.845	€ 47.679
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 49.898
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 52.152
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 54.441
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 56.768
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 59.132
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 61.537
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 63.984
33	€ 34.297	€ 34.646	€ 68.943	€ 39.572	€ 66.473
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 69.007
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 71.587
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 74.215
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 76.892
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 79.621
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 82.403
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 85.239

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 662	€ 13.592	€ 26.112	€ 435	€ 145	€ 290
10 Years	€ 331	€ 11.142	€ 28.562	€ 238	€ 147	€ 91
15 Years	€ 221	€ 8.692	€ 31.012	€ 172	€ 151	€ 22
20 Years	€ 165	€ 6.900	€ 32.804	€ 137	€ 154	-€ 18

Investment cost: €40.000

Payback Time: 22 years

Energy bill first year: €958

Energy savings first year: €1719

Monthly Payment Financial Lease 10 year contract: €331

Monthly Payment Operational Lease 10 year contract: €238

Monthly Net living costs: €91

Chapter 9
Sensitivity Analysis

Sensitivity: +10% construction cost

Basic Model, Rc = 4.5					
Investment:	€ 44.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 3.447
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 5.185
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 6.933
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 8.693
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 10.465
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 12.249
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 14.048
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 15.861
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 17.690
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 19.536
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 21.399
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 23.280
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 25.181
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 27.103
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 29.046
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 31.011
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 33.000
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 35.014
20	€ 15.943	€ 13.815	€ 29.758	€ 21.402	€ 37.054
21	€ 17.075	€ 14.961	€ 32.037	€ 22.644	€ 39.120
22	€ 18.248	€ 16.170	€ 34.418	€ 23.909	€ 41.215
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 43.338
24	**€ 20.721**	**€ 18.786**	**€ 39.507**	**€ 26.508**	**€ 45.493**
25	€ 22.025	€ 20.201	€ 42.226	€ 27.845	€ 47.679
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 49.898
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 52.152
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 54.441
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 56.768
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 59.132
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 61.537
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 63.984
33	€ 34.297	€ 34.646	€ 68.943	€ 39.572	€ 66.473
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 69.007
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 71.587
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 74.215
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 76.892
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 79.621
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 82.403
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 85.239

Investment cost: €44.000

Payback Time: 24 years

Energy bill first year: €958

Energy savings first year: €1719

Monthly Payment Financial
Lease 10 year contract: €364

Monthly Payment Operational
Lease 10 year contract: €271

Monthly Net living costs: €124

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 728	€ 13.592	€ 30.082	€ 501	€ 145	€ 356
10 Years	€ 364	€ 11.142	€ 32.533	€ 271	€ 147	€ 124
15 Years	€ 243	€ 8.692	€ 34.983	€ 194	€ 151	€ 44
20 Years	€ 182	€ 6.900	€ 36.775	€ 153	€ 154	-€ 1

Sensitivity: -10% construction cost

Basic Model, Rc = 4.5					
Investment:	€ 36.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 3.447
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 5.185
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 6.933
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 8.693
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 10.465
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 12.249
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 14.048
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 15.861
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 17.690
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 19.536
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 21.399
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 23.280
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 25.181
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 27.103
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 29.046
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 31.011
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 33.000
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 35.014
20	**€ 15.943**	**€ 13.815**	**€ 29.758**	**€ 21.402**	**€ 37.054**
21	€ 17.075	€ 14.961	€ 32.037	€ 22.644	€ 39.120
22	€ 18.248	€ 16.170	€ 34.418	€ 23.909	€ 41.215
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 43.338
24	€ 20.721	€ 18.786	€ 39.507	€ 26.508	€ 45.493
25	€ 22.025	€ 20.201	€ 42.226	€ 27.845	€ 47.679
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 49.898
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 52.152
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 54.441
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 56.768
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 59.132
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 61.537
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 63.984
33	€ 34.297	€ 34.646	€ 68.943	€ 39.572	€ 66.473
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 69.007
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 71.587
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 74.215
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 76.892
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 79.621
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 82.403
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 85.239

Investment cost: €36.000

Payback Time: 20 years

Energy bill first year: €958

Energy savings first year: €1719

Monthly Payment Financial
Lease 10 year contract: €298

Monthly Payment Operational
Lease 10 year contract: €205

Monthly Net living costs: €58

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 596	€ 13.592	€ 22.141	€ 369	€ 145	€ 224
10 Years	€ 298	€ 11.142	€ 24.592	€ 205	€ 147	€ 58
15 Years	€ 199	€ 8.692	€ 27.042	€ 150	€ 151	€ 0
20 Years	€ 149	€ 6.900	€ 28.834	€ 120	€ 154	-€ 34

Chapter 9
Sensitivity Analysis

Sensitivity: 1% extra annual increase in energy price

Basic Model, Rc = 4.5					
Investment:	€ 40.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.142	€ 827	€ 1.968	€ 1.934	€ 3.464
3	€ 1.752	€ 1.280	€ 3.032	€ 2.929	€ 5.236
4	€ 2.391	€ 1.762	€ 4.153	€ 3.942	€ 7.037
5	€ 3.059	€ 2.275	€ 5.334	€ 4.977	€ 8.868
6	€ 3.757	€ 2.822	€ 6.579	€ 6.032	€ 10.731
7	€ 4.488	€ 3.403	€ 7.891	€ 7.111	€ 12.627
8	€ 5.253	€ 4.021	€ 9.274	€ 8.213	€ 14.558
9	€ 6.052	€ 4.679	€ 10.731	€ 9.340	€ 16.526
10	€ 6.889	€ 5.378	€ 12.267	€ 10.494	€ 18.533
11	€ 7.764	€ 6.123	€ 13.887	€ 11.675	€ 20.579
12	€ 8.679	€ 6.915	€ 15.594	€ 12.885	€ 22.668
13	€ 9.636	€ 7.758	€ 17.394	€ 14.125	€ 24.802
14	€ 10.637	€ 8.655	€ 19.293	€ 15.397	€ 26.981
15	€ 11.685	€ 9.610	€ 21.294	€ 16.703	€ 29.209
16	€ 12.780	€ 10.625	€ 23.405	€ 18.043	€ 31.487
17	€ 13.926	€ 11.706	€ 25.632	€ 19.419	€ 33.818
18	€ 15.125	€ 12.855	€ 27.980	€ 20.833	€ 36.204
19	€ 16.378	€ 14.079	€ 30.457	€ 22.288	€ 38.647
20	**€ 17.690**	**€ 15.380**	**€ 33.070**	**€ 23.784**	**€ 41.150**
21	€ 19.061	€ 16.765	€ 35.826	€ 25.323	€ 43.716
22	€ 20.496	€ 18.238	€ 38.734	€ 26.908	€ 46.346
23	€ 21.997	€ 19.806	€ 41.803	€ 28.540	€ 49.045
24	€ 23.567	€ 21.474	€ 45.041	€ 30.221	€ 51.814
25	€ 25.209	€ 23.249	€ 48.458	€ 31.955	€ 54.656
26	€ 26.927	€ 25.137	€ 52.064	€ 33.742	€ 57.575
27	€ 28.723	€ 27.146	€ 55.870	€ 35.586	€ 60.574
28	€ 30.603	€ 29.284	€ 59.887	€ 37.489	€ 63.656
29	€ 32.568	€ 31.559	€ 64.127	€ 39.453	€ 66.825
30	€ 34.624	€ 33.979	€ 68.603	€ 41.481	€ 70.083
31	€ 36.775	€ 36.554	€ 73.329	€ 43.576	€ 73.435
32	€ 39.025	€ 39.294	€ 78.319	€ 45.740	€ 76.884
33	€ 41.378	€ 42.209	€ 83.587	€ 47.978	€ 80.434
34	€ 43.839	€ 45.311	€ 89.150	€ 50.291	€ 84.090
35	€ 46.414	€ 48.611	€ 95.025	€ 52.683	€ 87.856
36	€ 49.107	€ 52.123	€ 101.230	€ 55.157	€ 91.735
37	€ 51.924	€ 55.859	€ 107.783	€ 57.718	€ 95.733
38	€ 54.870	€ 59.835	€ 114.705	€ 60.368	€ 99.853
39	€ 57.952	€ 64.064	€ 122.017	€ 63.112	€ 104.102
40	€ 61.176	€ 68.565	€ 129.741	€ 65.953	€ 108.484

Investment cost: €40.000

Payback Time: 20 years

Energy bill 2nd year: €976*

Energy savings 2nd year: €1745

Monthly Payment Financial Lease 10 year contract: €331

Monthly Payment Operational Lease 10 year contract: €238

Monthly Net living costs: €84

*The first year the increase in energy price is fixed at the initial value

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 662	€ 13.592	€ 26.112	€ 435	€ 148	€ 287
10 Years	€ 331	€ 11.142	€ 28.562	€ 238	€ 154	€ 84
15 Years	€ 221	€ 8.692	€ 31.012	€ 172	€ 162	€ 10
20 Years	€ 165	€ 6.900	€ 32.804	€ 137	€ 171	-€ 35

Sensitivity: 1% less annual increase in energy price

Basic Model, Rc = 4.5					
Investment:	€ 40.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.131	€ 819	€ 1.949	€ 1.915	€ 3.430
3	€ 1.718	€ 1.255	€ 2.973	€ 2.871	€ 5.134
4	€ 2.321	€ 1.711	€ 4.031	€ 3.827	€ 6.831
5	€ 2.939	€ 2.186	€ 5.125	€ 4.782	€ 8.521
6	€ 3.573	€ 2.683	€ 6.256	€ 5.736	€ 10.205
7	€ 4.224	€ 3.201	€ 7.426	€ 6.692	€ 11.883
8	€ 4.892	€ 3.743	€ 8.635	€ 7.647	€ 13.557
9	€ 5.577	€ 4.308	€ 9.885	€ 8.604	€ 15.226
10	€ 6.280	€ 4.898	€ 11.178	€ 9.562	€ 16.891
11	€ 7.002	€ 5.514	€ 12.515	€ 10.522	€ 18.552
12	€ 7.742	€ 6.157	€ 13.899	€ 11.484	€ 20.211
13	€ 8.501	€ 6.828	€ 15.329	€ 12.448	€ 21.867
14	€ 9.280	€ 7.529	€ 16.809	€ 13.415	€ 23.521
15	€ 10.079	€ 8.261	€ 18.340	€ 14.385	€ 25.173
16	€ 10.899	€ 9.025	€ 19.924	€ 15.359	€ 26.824
17	€ 11.741	€ 9.822	€ 21.563	€ 16.336	€ 28.475
18	€ 12.604	€ 10.655	€ 23.259	€ 17.318	€ 30.126
19	€ 13.490	€ 11.524	€ 25.014	€ 18.305	€ 31.778
20	€ 14.398	€ 12.432	€ 26.830	€ 19.296	€ 33.431
21	€ 15.331	€ 13.379	€ 28.710	€ 20.293	€ 35.085
22	€ 16.287	€ 14.368	€ 30.656	€ 21.295	€ 36.741
23	€ 17.269	€ 15.401	€ 32.670	€ 22.304	€ 38.400
24	**€ 18.276**	**€ 16.479**	**€ 34.755**	**€ 23.320**	**€ 40.063**
25	€ 19.309	€ 17.605	€ 36.914	€ 24.342	€ 41.729
26	€ 20.369	€ 18.780	€ 39.149	€ 25.372	€ 43.399
27	€ 21.456	€ 20.006	€ 41.463	€ 26.410	€ 45.074
28	€ 22.572	€ 21.287	€ 43.860	€ 27.456	€ 46.755
29	€ 23.717	€ 22.624	€ 46.342	€ 28.511	€ 48.441
30	€ 24.892	€ 24.020	€ 48.912	€ 29.575	€ 50.134
31	€ 26.097	€ 25.478	€ 51.575	€ 30.648	€ 51.834
32	€ 27.334	€ 26.999	€ 54.333	€ 31.732	€ 53.542
33	€ 28.602	€ 28.587	€ 57.190	€ 32.826	€ 55.258
34	€ 29.904	€ 30.246	€ 60.150	€ 33.931	€ 56.983
35	€ 31.239	€ 31.977	€ 63.216	€ 35.048	€ 58.717
36	€ 32.610	€ 33.784	€ 66.394	€ 36.176	€ 60.461
37	€ 34.015	€ 35.671	€ 69.687	€ 37.317	€ 62.216
38	€ 35.458	€ 37.641	€ 73.099	€ 38.472	€ 63.982
39	€ 36.938	€ 39.698	€ 76.636	€ 39.639	€ 65.759
40	€ 38.456	€ 41.845	€ 80.301	€ 40.821	€ 67.550

Investment cost: €40.000

Payback Time: 24 years

Energy bill 2nd year: €957*

Energy savings 2nd year: €1711

Monthly Payment Financial Lease 10 year contract: €331

Monthly Payment Operational Lease 10 year contract: €238

Monthly Net living costs: €97

*The first year the increase in energy price is fixed at the initial value

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 662	€ 13.592	€ 26.112	€ 435	€ 142	€ 293
10 Years	€ 331	€ 11.142	€ 28.562	€ 238	€ 141	€ 97
15 Years	€ 221	€ 8.692	€ 31.012	€ 172	€ 140	€ 32
20 Years	€ 165	€ 6.900	€ 32.804	€ 137	€ 139	-€ 3

Chapter 9
Sensitivity Analysis

Sensitivity: +1,31% missed annual interest savings

Basic Model, Rc = 4.5					
Investment:	€ 40.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.900	€ 3.404
3	€ 1.735	€ 1.267	€ 3.002	€ 2.827	€ 5.054
4	€ 2.355	€ 1.736	€ 4.092	€ 3.738	€ 6.672
5	€ 2.998	€ 2.230	€ 5.229	€ 4.635	€ 8.259
6	€ 3.664	€ 2.751	€ 6.416	€ 5.518	€ 9.816
7	€ 4.354	€ 3.300	€ 7.654	€ 6.388	€ 11.344
8	€ 5.069	€ 3.879	€ 8.948	€ 7.246	€ 12.845
9	€ 5.809	€ 4.489	€ 10.298	€ 8.092	€ 14.318
10	€ 6.576	€ 5.132	€ 11.708	€ 8.927	€ 15.766
11	€ 7.371	€ 5.809	€ 13.181	€ 9.751	€ 17.190
12	€ 8.195	€ 6.524	€ 14.718	€ 10.565	€ 18.590
13	€ 9.048	€ 7.276	€ 16.324	€ 11.369	€ 19.967
14	€ 9.931	€ 8.070	€ 18.001	€ 12.165	€ 21.323
15	€ 10.847	€ 8.906	€ 19.753	€ 12.953	€ 22.659
16	€ 11.795	€ 9.787	€ 21.582	€ 13.732	€ 23.974
17	€ 12.778	€ 10.716	€ 23.494	€ 14.505	€ 25.271
18	€ 13.796	€ 11.695	€ 25.491	€ 15.271	€ 26.550
19	€ 14.851	€ 12.727	€ 27.578	€ 16.030	€ 27.812
20	€ 15.943	€ 13.815	€ 29.758	€ 16.784	€ 29.058
21	€ 17.075	€ 14.961	€ 32.037	€ 17.532	€ 30.289
22	€ 18.248	€ 16.170	€ 34.418	€ 18.276	€ 31.505
23	€ 19.463	€ 17.443	€ 36.906	€ 19.016	€ 32.708
24	€ 20.721	€ 18.786	€ 39.507	€ 19.752	€ 33.897
25	€ 22.025	€ 20.201	€ 42.226	€ 20.484	€ 35.074
26	€ 23.376	€ 21.692	€ 45.068	€ 21.214	€ 36.240
27	€ 24.776	€ 23.264	€ 48.040	€ 21.941	€ 37.396
28	€ 26.226	€ 24.920	€ 51.146	€ 22.666	€ 38.541
29	€ 27.728	€ 26.667	€ 54.395	€ 23.390	€ 39.677
30	**€ 29.284**	**€ 28.507**	**€ 57.791**	**€ 24.113**	**€ 40.805**
31	€ 30.896	€ 30.447	€ 61.343	€ 24.835	€ 41.924
32	€ 32.567	€ 32.491	€ 65.058	€ 25.557	€ 43.037
33	€ 34.297	€ 34.646	€ 68.943	€ 26.279	€ 44.143
34	€ 36.090	€ 36.918	€ 73.008	€ 27.002	€ 45.243
35	€ 37.947	€ 39.312	€ 77.259	€ 27.726	€ 46.338
36	€ 39.871	€ 41.835	€ 81.706	€ 28.451	€ 47.429
37	€ 41.864	€ 44.495	€ 86.359	€ 29.178	€ 48.515
38	€ 43.930	€ 47.298	€ 91.227	€ 29.908	€ 49.598
39	€ 46.069	€ 50.252	€ 96.321	€ 30.641	€ 50.679
40	€ 48.285	€ 53.366	€ 101.652	€ 31.376	€ 51.757

Investment cost: €40.000

Payback Time: 30 years

Energy bill first year: €958

Energy savings first year: €1719

Monthly Payment Financial Lease 10 year contract: €331

Monthly Payment Operational Lease 10 year contract: €238

Monthly Net living costs: €107

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 662	€ 13.592	€ 26.112	€ 435	€ 138	€ 298
10 Years	€ 331	€ 11.142	€ 28.562	€ 238	€ 131	€ 107
15 Years	€ 221	€ 8.692	€ 31.012	€ 172	€ 126	€ 46
20 Years	€ 165	€ 6.900	€ 32.804	€ 137	€ 121	€ 16

Sensitivity: +2,07% missed annual interest savings

Basic Model, Rc = 4.5					
Investment:	€ 40.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.887	€ 3.379
3	€ 1.735	€ 1.267	€ 3.002	€ 2.785	€ 4.980
4	€ 2.355	€ 1.736	€ 4.092	€ 3.656	€ 6.527
5	€ 2.998	€ 2.230	€ 5.229	€ 4.501	€ 8.020
6	€ 3.664	€ 2.751	€ 6.416	€ 5.319	€ 9.462
7	€ 4.354	€ 3.300	€ 7.654	€ 6.113	€ 10.855
8	€ 5.069	€ 3.879	€ 8.948	€ 6.883	€ 12.201
9	€ 5.809	€ 4.489	€ 10.298	€ 7.630	€ 13.501
10	€ 6.576	€ 5.132	€ 11.708	€ 8.355	€ 14.757
11	€ 7.371	€ 5.809	€ 13.181	€ 9.060	€ 15.972
12	€ 8.195	€ 6.524	€ 14.718	€ 9.745	€ 17.146
13	€ 9.048	€ 7.276	€ 16.324	€ 10.410	€ 18.282
14	€ 9.931	€ 8.070	€ 18.001	€ 11.057	€ 19.381
15	€ 10.847	€ 8.906	€ 19.753	€ 11.687	€ 20.444
16	€ 11.795	€ 9.787	€ 21.582	€ 12.299	€ 21.472
17	€ 12.778	€ 10.716	€ 23.494	€ 12.896	€ 22.468
18	€ 13.796	€ 11.695	€ 25.491	€ 13.478	€ 23.433
19	€ 14.851	€ 12.727	€ 27.578	€ 14.044	€ 24.367
20	€ 15.943	€ 13.815	€ 29.758	€ 14.597	€ 25.272
21	€ 17.075	€ 14.961	€ 32.037	€ 15.137	€ 26.150
22	€ 18.248	€ 16.170	€ 34.418	€ 15.663	€ 27.001
23	€ 19.463	€ 17.443	€ 36.906	€ 16.178	€ 27.826
24	€ 20.721	€ 18.786	€ 39.507	€ 16.681	€ 28.627
25	€ 22.025	€ 20.201	€ 42.226	€ 17.173	€ 29.404
26	€ 23.376	€ 21.692	€ 45.068	€ 17.654	€ 30.159
27	€ 24.776	€ 23.264	€ 48.040	€ 18.126	€ 30.893
28	€ 26.226	€ 24.920	€ 51.146	€ 18.588	€ 31.606
29	€ 27.728	€ 26.667	€ 54.395	€ 19.041	€ 32.299
30	€ 29.284	€ 28.507	€ 57.791	€ 19.486	€ 32.974
31	€ 30.896	€ 30.447	€ 61.343	€ 19.922	€ 33.631
32	€ 32.567	€ 32.491	€ 65.058	€ 20.351	€ 34.271
33	€ 34.297	€ 34.646	€ 68.943	€ 20.773	€ 34.894
34	€ 36.090	€ 36.918	€ 73.008	€ 21.188	€ 35.502
35	€ 37.947	€ 39.312	€ 77.259	€ 21.597	€ 36.095
36	€ 39.871	€ 41.835	€ 81.706	€ 22.000	€ 36.674
37	€ 41.864	€ 44.495	€ 86.359	€ 22.397	€ 37.240
38	€ 43.930	€ 47.298	€ 91.227	€ 22.789	€ 37.792
39	€ 46.069	€ 50.252	€ 96.321	€ 23.176	€ 38.333
40	€ 48.285	€ 53.366	€ 101.652	€ 23.559	€ 38.862

Investment cost: €40.000

Payback Time: >40 years

Energy bill first year: €958

Energy savings first year: €1719

Monthly Payment Financial Lease 10 year contract: €331

Monthly Payment Operational Lease 10 year contract: €238

Monthly Net living costs: €115

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 662	€ 13.592	€ 26.112	€ 435	€ 134	€ 302
10 Years	€ 331	€ 11.142	€ 28.562	€ 238	€ 123	€ 115
15 Years	€ 221	€ 8.692	€ 31.012	€ 172	€ 114	€ 59
20 Years	€ 165	€ 6.900	€ 32.804	€ 137	€ 105	€ 31

Chapter 9
Sensitivity Analysis

Sensitivity: +€1000 subsidy at start

Basic Model, Rc = 4.5					
Investment:	€ 39.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 3.447
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 5.185
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 6.933
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 8.693
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 10.465
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 12.249
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 14.048
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 15.861
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 17.690
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 19.536
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 21.399
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 23.280
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 25.181
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 27.103
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 29.046
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 31.011
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 33.000
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 35.014
20	€ 15.943	€ 13.815	€ 29.758	€ 21.402	€ 37.054
21	**€ 17.075**	**€ 14.961**	**€ 32.037**	**€ 22.644**	**€ 39.120**
22	€ 18.248	€ 16.170	€ 34.418	€ 23.909	€ 41.215
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 43.338
24	€ 20.721	€ 18.786	€ 39.507	€ 26.508	€ 45.493
25	€ 22.025	€ 20.201	€ 42.226	€ 27.845	€ 47.679
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 49.898
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 52.152
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 54.441
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 56.768
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 59.132
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 61.537
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 63.984
33	€ 34.297	€ 34.646	€ 68.943	€ 39.572	€ 66.473
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 69.007
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 71.587
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 74.215
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 76.892
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 79.621
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 82.403
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 85.239

Investment cost: €39.000

Payback Time: 21 years

Energy bill first year: €958

Energy savings first year: €1719

Monthly Payment Financial
Lease 10 year contract: €323

Monthly Payment Operational
Lease 10 year contract: €230

Monthly Net living costs: €82

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 645	€ 13.592	€ 25.112	€ 419	€ 145	€ 274
10 Years	€ 323	€ 11.142	€ 27.562	€ 230	€ 147	€ 82
15 Years	€ 215	€ 8.692	€ 30.012	€ 167	€ 151	€ 16
20 Years	€ 161	€ 6.900	€ 31.804	€ 133	€ 154	-€ 22

Sensitivity: +€2500 subsidy at start

Basic Model, Rc = 4.5					
Investment:	€ 37.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.719
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 3.447
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 5.185
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 6.933
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 8.693
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 10.465
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 12.249
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 14.048
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 15.861
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 17.690
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 19.536
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 21.399
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 23.280
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 25.181
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 27.103
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 29.046
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 31.011
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 33.000
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 35.014
20	**€ 15.943**	**€ 13.815**	**€ 29.758**	**€ 21.402**	**€ 37.054**
21	€ 17.075	€ 14.961	€ 32.037	€ 22.644	€ 39.120
22	€ 18.248	€ 16.170	€ 34.418	€ 23.909	€ 41.215
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 43.338
24	€ 20.721	€ 18.786	€ 39.507	€ 26.508	€ 45.493
25	€ 22.025	€ 20.201	€ 42.226	€ 27.845	€ 47.679
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 49.898
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 52.152
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 54.441
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 56.768
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 59.132
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 61.537
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 63.984
33	€ 34.297	€ 34.646	€ 68.943	€ 39.572	€ 66.473
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 69.007
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 71.587
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 74.215
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 76.892
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 79.621
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 82.403
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 85.239

Investment cost: €37.000

Payback Time: 20 years

Energy bill first year: €958

Energy savings first year: €1719

Monthly Payment Financial
Lease 10 year contract: €310

Monthly Payment Operational
Lease 10 year contract: €217

Monthly Net living costs: €70

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 620	€ 13.592	€ 23.612	€ 394	€ 145	€ 249
10 Years	€ 310	€ 11.142	€ 26.062	€ 217	€ 147	€ 70
15 Years	€ 207	€ 8.692	€ 28.512	€ 158	€ 151	€ 8
20 Years	€ 155	€ 6.900	€ 30.304	€ 126	€ 154	-€ 28

Chapter 9
Sensitivity Analysis

Sensitivity: 90% initial energy demand reference

Basic Model, Rc = 4.5					
Investment:	€ 40.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.452
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 2.910
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 4.377
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 5.852
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 7.336
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 8.830
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 10.335
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 11.851
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 13.379
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 14.919
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 16.474
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 18.043
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 19.627
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 21.226
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 22.843
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 24.477
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 26.130
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 27.802
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 29.494
20	€ 15.943	€ 13.815	€ 29.758	€ 21.402	€ 31.208
21	€ 17.075	€ 14.961	€ 32.037	€ 22.644	€ 32.944
22	€ 18.248	€ 16.170	€ 34.418	€ 23.909	€ 34.702
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 36.485
24	€ 20.721	€ 18.786	€ 39.507	€ 26.508	€ 38.293
25	**€ 22.025**	**€ 20.201**	**€ 42.226**	**€ 27.845**	**€ 40.127**
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 41.988
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 43.877
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 45.795
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 47.744
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 49.725
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 51.738
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 53.786
33	€ 34.297	€ 34.646	€ 68.943	€ 39.572	€ 55.868
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 57.988
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 60.145
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 62.341
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 64.578
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 66.858
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 69.180
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 71.548

Investment cost: €40.000

Payback Time: 25 years

Energy bill first year: €958

Energy savings first year: €1452

Monthly Payment Financial Lease 10 year contract: €331

Monthly Payment Operational Lease 10 year contract: €238

Monthly Net living costs: €114

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 662	€ 13.592	€ 26.112	€ 435	€ 122	€ 313
10 Years	€ 331	€ 11.142	€ 28.562	€ 238	€ 124	€ 114
15 Years	€ 221	€ 8.692	€ 31.012	€ 172	€ 127	€ 45
20 Years	€ 165	€ 6.900	€ 32.804	€ 137	€ 130	€ 7

Sensitivity: 75% initial energy demand reference

Basic Model, Rc = 4.5					
Investment:	€ 40.000				
Year	Gas	Elektricity	Total	NPV	Savings NPV
1	€ 558	€ 400	€ 958	€ 958	€ 1.050
2	€ 1.136	€ 823	€ 1.959	€ 1.925	€ 2.104
3	€ 1.735	€ 1.267	€ 3.002	€ 2.900	€ 3.164
4	€ 2.355	€ 1.736	€ 4.092	€ 3.884	€ 4.229
5	€ 2.998	€ 2.230	€ 5.229	€ 4.878	€ 5.300
6	€ 3.664	€ 2.751	€ 6.416	€ 5.882	€ 6.378
7	€ 4.354	€ 3.300	€ 7.654	€ 6.898	€ 7.462
8	€ 5.069	€ 3.879	€ 8.948	€ 7.925	€ 8.555
9	€ 5.809	€ 4.489	€ 10.298	€ 8.964	€ 9.655
10	€ 6.576	€ 5.132	€ 11.708	€ 10.016	€ 10.764
11	€ 7.371	€ 5.809	€ 13.181	€ 11.081	€ 11.881
12	€ 8.195	€ 6.524	€ 14.718	€ 12.161	€ 13.009
13	€ 9.048	€ 7.276	€ 16.324	€ 13.256	€ 14.146
14	€ 9.931	€ 8.070	€ 18.001	€ 14.366	€ 15.294
15	€ 10.847	€ 8.906	€ 19.753	€ 15.493	€ 16.454
16	€ 11.795	€ 9.787	€ 21.582	€ 16.637	€ 17.625
17	€ 12.778	€ 10.716	€ 23.494	€ 17.799	€ 18.808
18	€ 13.796	€ 11.695	€ 25.491	€ 18.980	€ 20.005
19	€ 14.851	€ 12.727	€ 27.578	€ 20.181	€ 21.215
20	€ 15.943	€ 13.815	€ 29.758	€ 21.402	€ 22.440
21	€ 17.075	€ 14.961	€ 32.037	€ 22.644	€ 23.679
22	€ 18.248	€ 16.170	€ 34.418	€ 23.909	€ 24.934
23	€ 19.463	€ 17.443	€ 36.906	€ 25.197	€ 26.205
24	€ 20.721	€ 18.786	€ 39.507	€ 26.508	€ 27.493
25	€ 22.025	€ 20.201	€ 42.226	€ 27.845	€ 28.798
26	€ 23.376	€ 21.692	€ 45.068	€ 29.209	€ 30.122
27	€ 24.776	€ 23.264	€ 48.040	€ 30.599	€ 31.464
28	€ 26.226	€ 24.920	€ 51.146	€ 32.017	€ 32.827
29	€ 27.728	€ 26.667	€ 54.395	€ 33.465	€ 34.209
30	€ 29.284	€ 28.507	€ 57.791	€ 34.943	€ 35.614
31	€ 30.896	€ 30.447	€ 61.343	€ 36.453	€ 37.040
32	€ 32.567	€ 32.491	€ 65.058	€ 37.996	€ 38.489
33	**€ 34.297**	**€ 34.646**	**€ 68.943**	**€ 39.572**	**€ 39.962**
34	€ 36.090	€ 36.918	€ 73.008	€ 41.184	€ 41.459
35	€ 37.947	€ 39.312	€ 77.259	€ 42.833	€ 42.982
36	€ 39.871	€ 41.835	€ 81.706	€ 44.519	€ 44.531
37	€ 41.864	€ 44.495	€ 86.359	€ 46.245	€ 46.108
38	€ 43.930	€ 47.298	€ 91.227	€ 48.012	€ 47.713
39	€ 46.069	€ 50.252	€ 96.321	€ 49.821	€ 49.347
40	€ 48.285	€ 53.366	€ 101.652	€ 51.674	€ 51.011

Investment cost: €40.000

Payback Time: 33 years

Energy bill first year: €958

Energy savings first year: €1050

Monthly Payment Financial Lease 10 year contract: €331

Monthly Payment Operational Lease 10 year contract: €238

Monthly Net living costs: €148

Contract	Financial Lease	Operational lease				
	Monthly payment	Salvage value	Recalculated investment	Monthly payment	Energy saving	Net Costs
5 Years	€ 662	€ 13.592	€ 26.112	€ 435	€ 88	€ 347
10 Years	€ 331	€ 11.142	€ 28.562	€ 238	€ 90	€ 148
15 Years	€ 221	€ 8.692	€ 31.012	€ 172	€ 91	€ 81
20 Years	€ 165	€ 6.900	€ 32.804	€ 137	€ 93	€ 43

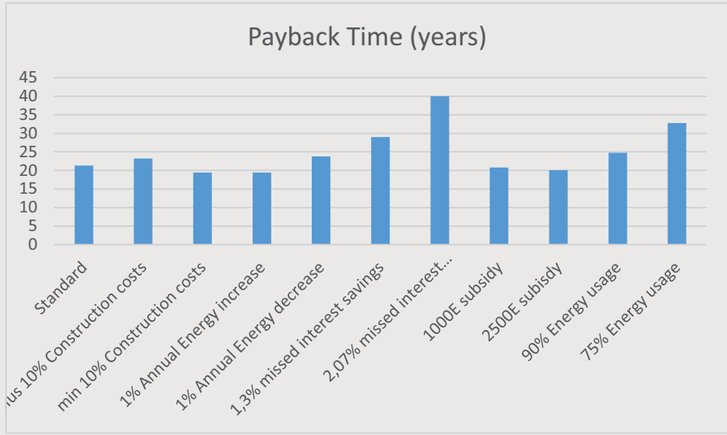
Chapter 9
Sensitivity Analysis
Conclusion

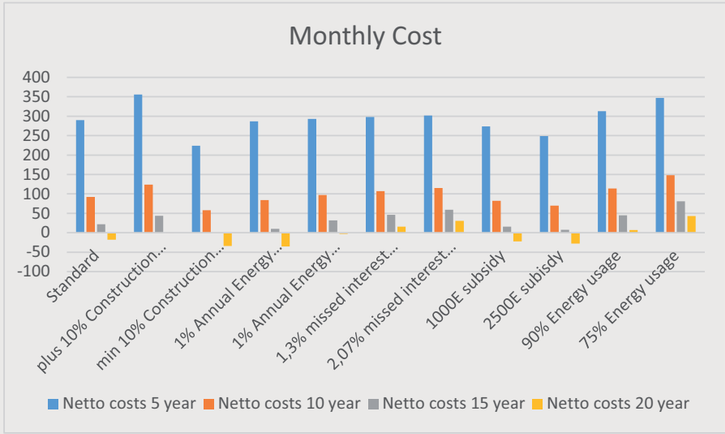
A crucial element is the initial energy reference. Two scenarios are elaborated in which the dwelling is not in its original state, but had already some energy saving upgrades such as insulation in crawl spaces, facades and roof. These energy references are fixed at 90% and 75% of the initial 100% energy usage of the dwellings in original state. The results are almost shocking as the payback period increases by 3.5 and 11.5 years respectively. This is a significant increase and the leasing concept will therefore be much less attractive if the property is already partly renovated. This also reflects in the monthly contract costs which rise from € 290 / month to € 347 / month in a 5 year contract, and from € -18 / month to € 43 / month for 20 years (see table on the right page)

Also noteworthy is the large increase in paybacktime when taking into account that residents could also put their money in the bank to generate interest savings, instead of invest in their dwelling. If they are able to pay the renovation from their own pockets, the payback period increases from 21.3 years to 29 years at an interest rate of 1.31% (average interest rate November 2014). When calculated with an interest rate of 2.07% (the average interest rate of the past 10 years), the payback period even rises to over 40 years. The monthly fees also increases by € 12 / month for a 5 year contract and even € 49 / month for a contract with a term of 20 years. It may be concluded that the lease model is not financially attractive and it is better to put your money in the bank instead of invest it in the renovation. However, there will always be maintenance taken place to preserve the value of the dwelling. At least these costs should be substracted from the private funds.

A 10% fluctuation in construction costs are reflected in a difference in the payback period of about 2 years, and a large difference of monthly expenses of € 66 / month for a 5 year lease contract, and € 17 / month for a 20 year contract. If the annual energy price increase each year 1% more than calculated in the reference, there is an additional paybacktime of 2 years. 1000 euro or 2500 euro subsidy affects the payback the least; respectively 0.5 and 1.2 years.

Model	Paybacktime	Nett cost			
	(year)	5 Year	10 Year	15 Year	20 Year
Standard	21,3	290	92	22	-18
plus 10% Construction costs	23,2	356	124	44	-1
min 10% Construction costs	19,4	224	58	0	-34
1% Annual Energy increase	19,4	287	84	10	-35
1% Annual Energy decrease	23,8	293	97	32	-3
1,3% missed interest savings	29	298	107	46	16
2,07% missed interest savings	40	302	115	59	31
1000E subsidy	20,8	274	82	16	-22
2500E subisdy	20,1	249	70	8	-28
90% Energy usage	24,8	313	114	45	7
75% Energy usage	32,8	347	148	81	43





Chapter 10

Residents' Interests

Content & Structure

In this chapter the residents are put central. This part attempts to give an insight in the behavior of residents, their willingness to pay, what are motivating factors and what are barriers.

A research is included based on discussions with professionals and residents. Next to this an literature study is performed and presented on the next pages.

Used sources:

Market segementation model Mosaic (Experian, 2012)

Interest survey "Residents' interest in renovation in Occupied State" by v.d. Werf (2011)

Dr. ir. S. Zijlstra (Tutor at TU Delft, Faculty Architecture, sector Housing)

Zeno Winkels (Sustainability consultant at Woonbron, 5th largest housing corporation of the Netherlands)

Delft E Design (Presentation given, and discussed, with residents of the 'Resistance Area, Delft' a typical neighborhood with 60' and 70' Dutch rowhouses.

Advantages lease concept:

- Cheaper than only perform maintenance on your home
  (maintenance + energy bill > lease concept + energy bill)
- Installations and configurations adaptable to personal whishes
- No third party necessary as provider of funds for residents (involving low interest rates)

- Create additional living space
- A complete new modern appearance of the house

- Ability to buy elements at end of contract and become owner
- Ability to improve and update dwelling at end of contract
- Ability to increase property value
- Ability to include relatively cheap maintenance and service contract
- Ability to sell lease contract to the next resident

Disadvantages

- Postive monthly net living costs still oblige longterm contract
- By reciting the contract, investment costs are lost
- At end of contract, elements may return to lease company, dwelling needs alternative facade or renovation
- Interior remain unaddressed
- Not attractive if dwelling has already energy saving upgrades

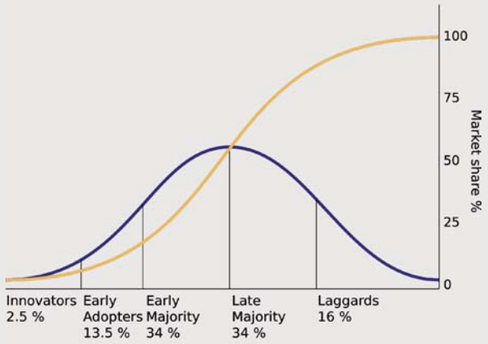
Chapter 10

Residents Interest

Interviews and discussions

Sake Zijlstra (TU Delft, sector Housing):

There is no direct answer with measurable data for the willingness to pay, but an insight in possible target groups may be obtained by the study of Rogers. The time that it takes residents are convinced about the need for renovation, and the agreement for a renovation, differs from resident to resident. Rogers (1962) made for this purpose a distribution in which five groups of people are distinguished and described in a frame. The five groups are; the Innovators, Early Adopters, Early Majority, Late Majority and the Laggerds. For large-scale renovation projects it is advised to focus on the early adoptors and the early majority. They are often benevolent and make an average of nearly 50% of the residents.
The group innovators often are too far ahead to the other residents and are therefore taken less seriously. The Late Majority and the Laggards offer often resistance to change. To convince these groups the Early Adaptors and Early Majority may convince these people, the behavior and choices of residents is largely determined by adopting from other residents. (Tiemeijer, 2009)



31) Acceptance Curve

Zeno Winkels (Woonbron, 5th largest housing corporation)

"'We do not have a customer or resident file with residents' interests nor wishes, we use renovation strategies. When residents move out we thoroughly renovate the dwelling. In the meantime we use maintenance plans to preserve the property value and a healthy living environment for the residents. Regarding the lease concept; a lease construction is not attractive for us. Because of our large portfolio we can obtain loans at a very low rent, therefore buying a renovation will be cheaper for us."

Delft E Design (Presentation given at residents meeting 'Verzetstrijdersbuurt, Delft')

A mixed attendance of 20 to 25 residents, spread over 13 dwellings.
A realistic and common shared answer given by the residents towards the prefab renovation concepts including lease construction: "An interesting concept, however we (the residents) tend for more accesible, single energy upgrades as crawl space insulation, pv panels etc. Also some of us have already energy saving measures applied ourselfs, this would be a loss in investment. A possitive effect on the cost of living - if this really would be the case - does sound good, but a longterm commitment will probably prevent us from participating"

Interim conclusion:

The willingness to pay is hard te measure. There is no literature with harsh facts. There is literature to aim at different target groups however there is no source found to directly answer the question which amount of money residents are willing to pay for certain house upgrades. A large scale survey could provide more clarity, however these results may again differ when the concept becomes truly reality.

The average person lives about 10 years is his dwelling (Ministry of National Affairs, 2013a), the 10 year operational lease contract may be the most desirable contract. The average extra costs for more comfort and a sustainable living are about €1100/year within the 10 year contract, which corresponds with 3% of the average incomes of the residents (Ministry of National Affairs, 2013b). A new resident moving in can order his new composition, upgrades or extra livingspace, according to his needs. In other way, if the resident wants to keep living in his home, he can now order new facade elements to fulfill his new interest and needs. The option to extend the current contract is after 10 year also attractive because the 'loss in investment' is already paid off and monthly costs will lower from now.

Literature study

To obtain more insight in the behavior of residents and to convince them to participate in a sustainable energy saving renovation, the next chapter will go deeper in the perception of residents.

Resistance to renovation

Resistance to a renovation is often not directly aimed at the renovation itself, but against the change. Change leads to feelings of insecurity what most residents dislike (Dijkstra, 2010). In addition, it requires a lot of time and energy of all parties. For the contractor it is his job and he gets paid, but for residents their money and free time is involved. Pros and cons should be explained clearly to avoid a feeling of imposing by the lease company. The residents should be remembered it is their choice and their interest are most important.

Chapter 10

Residents Interest

Literature Study

Besides a resistance for change per se, residents may resist to the renovation solution itself. Dijkstra (2010) identifies five points in which resident may resist to:

- The resident can doubt the seriousness of the problem,
  he does not believe that there is a need for improvement
- The resident may have difficulty accepting the necessity of the solution,
  he does see the problem but thinks it can be resolved more easily
- The resident doubt whether the chosen solution is effective,
  he may think this is not the best solution to improve the dwelling
- The resident thinks the solution is not realistic,
  he considers the costs and inconvenience too large in proportion to the benefits
- The resident is not convinced of the policy or regulation,
  he dislikes the idea of a lease contract

Convince and inspire

Majcen (2013) concludes the actual energy usage is strongly depended on the behaviour of the resident, and differs a lot from the theoretical energy usage. The energy savings will be lower due to a less worse initial energy reference, combined with a worse energy performance after renovated state. The graph below shows the large different in actual and theoretical energy usage. One explanation is when the dwelling has an theoretical weak energy performance and has energy label G assigned, home owners will only heat the living spaces they are currently in. This in contrast when energy label A is present, home owners tend to live more luxurios and neglective, resulting in leaving windows open and losing heat and energy.

To convince and to change the behavior of residents, the model of Green and Kreuter (1999) can be used. Green and Kreuter mention three main factors: motivating factors (focusing on the 'willing'), enabling factors (focusing on the 'ability') and enhancing factors (aimed at 'promoting').
Translated to the residents, residents should 1) change their behavior so they would like a renovated energy efficient home, 2) be able to participate, 3) contribute to the realization of the renovation and live sustainable. The following influencing factors are presented in 'Residents interest in Occupied State' by v.d. Werf (2011), according to the Green and Kreuter model (1999);

Motivating factors (Willing)

- Awareness and attitude: the occupant must be aware that a large energy saving renovation is desired and that maintain the dwelling in original state is no solution. Advatages and disadvantages should be explained clearly.
- Social influence: the resident will be influenced by social norms and beliefs of other people
- Capabillity: the view of the occupant on his ability to live in an energy efficient renovated home may need to improve

Enabling factors (Ability)

- Financial: the resident must be able to pay for the investment or rents. Involve subsidies when possible, mention total living costs and a decreasing energy bill
- Technical: the renovation must be technically feasible, but also offers ease of use and making energy efficient behavior easy
- Organizational: the renovation process should be arranged so that residents can continue to live in the dwelling with few nuissance

Enhancing factors (Promoting)

- Social support: support during the renovation process
- Advice: how residents themselves can contribute to energy savings (workshops, manual)
- Feedback: what has been achieved so far

When all three points are met, there still exist barriers for the homeowners (Schilleman, 2006):

Barriers Willing

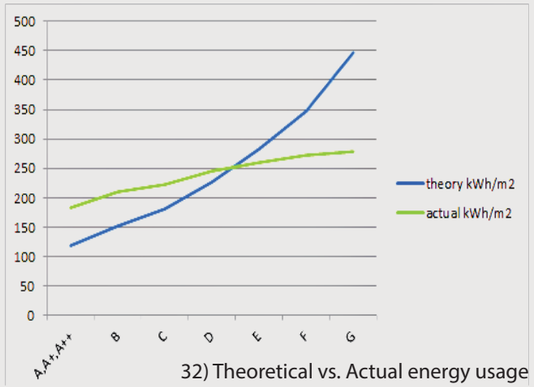
- Basic disinterest because energy price is perceived as "not high" (relative prosperity)
- Disinterest due to low attention to the environment
- Resistance due to anticipated nuisance
- Disfiguring effects (e.g. double glazing and ventilation units)
- Fear of imperfections
- Undesired effects
- Unprofitable investment or too long payback time

Barriers Ability

- Lack of knowledge about the environment
- Unfamiliarity with own energy usage
- Unfamiliarity with sustainable and energy saving solutions
- Lack of sufficient financial resources for homeowners

Barriers Promoting

- Slowness and uncertainty of providing subsidies
- Slowness and lack of clarity municipal regulations



32) Theoretical vs. Actual energy usage

Chapter 10

Residents Interest

Literature Study

The model of Green and Kreuter, however, assumes that if people have sufficient knowledge they be able to adjust their behavior accordingly. However, the vast majority of human action consists of automatic actions that occur through imitation and routine. People try to make complexity, such as deciding on a renovation solution, manageable by simplifying it, resulting in behavior with a bounded rationality (Schillemans, 2006). This usually results not in a simple cost / benefit consideration, but in habit and adopting behavior. Due to this non-rational thinking, financial aspects have often less impact than usually is expected. (Tiemeijer, 2009).

A large part of the choices people make are determined by emotions, therefore it is greatly appreciated when residents can choose between different options. However, the options must remain transparent (Tiemeijer, 2009) people want to choose, but ultimately are not necessarily happier if they have more choices. It even appears that more choices lead to greater attention, but that people are reticent to eventually pick a product. People often settle for a pass, even though this is not the best solution but it spares trouble and effort at that moment; residents tend to their old situation (Tiemeijer, 2009). Also residents may lose overview, making them insecure and again rather stay to their old and certain situation.

Finance

Finance has a much smaller influence than often is thought, due to most people are financial illiterates (Boerbooms, 2010). For a decision making as participate in a renovation process, pros and cons are not considered 100% rational, but many social environmental and behavioral aspects are involved. This also comes forward in the experiences of professionals in convincing residents. In a meeting for the social housing program approach Smart & Fast (Platform31, 2011) the following sayings are shared:

- Occupants are often not interested in energy saving renovations. They believe nothing like that in a refurbished or new "expensive" house they can live cheaper than in their current situation. With beautiful figures and tables they are not convinced. They only look at the low rent.

By providing a housing costs guarantee, the resident has a guarantee for the total amount of their housing costs. This agreement ensures that the energy savings from the renovation is provided. If it turns out this not the case, the lease company has to pay a portion of the rent back. This tool can be used to get more people to participate in a renovation process. There should be made clear agreements about various risks such as rising energy prices, falling energy savings due to weak winters, or by changes in residential behavior and compositions (Weevers, 2010).

According to v.d. Werf (2011) within a renovation process, the financial aspects are divided in:
- The impact on the energy bills
- The amount of the investment
- The length of the payback time
- The influence on the value of the home
- The impact on monthly expenses
- The current subsidies and regulations
- The possibility of financing structures

Residents interest

Van der Werf (2011) attempts to generate an overview with aspects and corresponding importance, in which residents have interest to participate in a renovation. The aspects below can be concluded as general shared interests for renovation.

- Maintain low housing costs
- Generate higher comfort
- Create a healthier indoor climate
- Reconfiguration of the dwelling
- Expansion of living space
- Increase safety
- Improving environement
- Improve porperty value
- Make home life cycle proof

Conclusion

Although a certain renovation concept may seem very attractive for residents (as well financially as gaining more comfort as a new attractive modern look of their dwelling), there are several reasons why people will not participate in a renovation.
Important barriers are the disinterest in sustainability, being afraid for change, the side effects or associated effort, but also considerations are often taken not rationally; residents are more influenced by his fellow man than by financial pros and cons. It also appears that the behavior of residents is of great influence for the energy performance of the dwelling, which leads to substantially lower energy savings than previously calculated.
If a target group should be appointed for the Prefab Renovation with Lease construction as described in this thesis, the early adopters and late majority will have to introduce the - succes of - the concept and may convince the others.

Due to the absence of specialized literature and the versatile character of the human mind, measureable results and figures for the wilingness to pay is at this moment for this study not possible. In a next phase a large scale survey could provide a more detailed answer.

Chapter 11

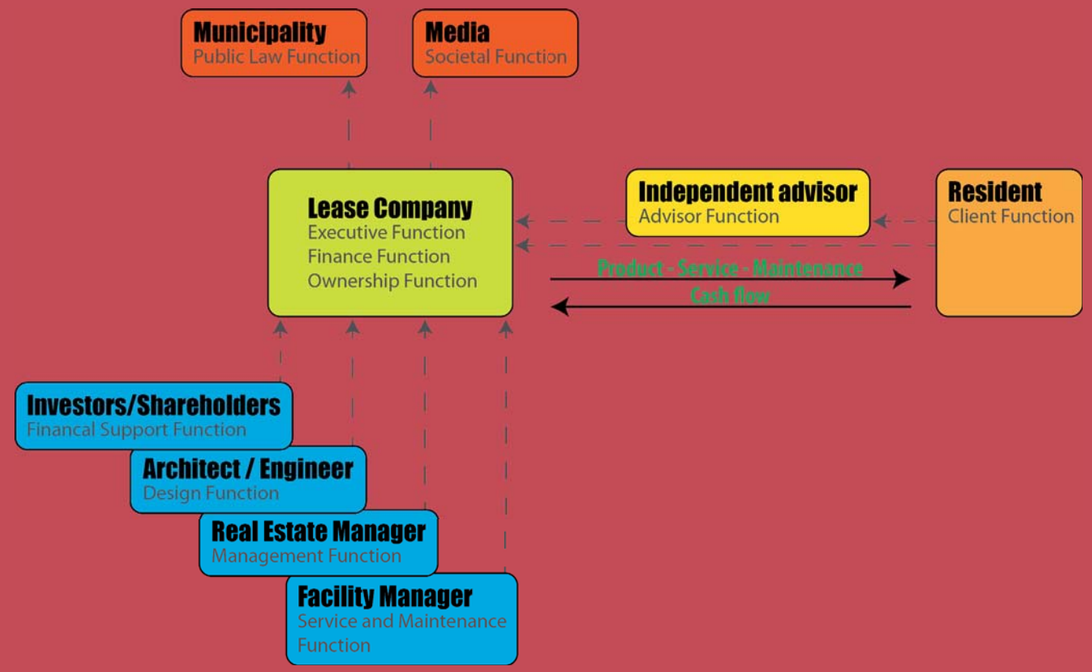
Functions and Actors

A function is a coherent set of activities such as the provision of a contract or the execution of a building. An actor or stakeholder is a party with a specific input, knowledge or skill, such as a client or contractor. In essence it is about different parties in a common process or project, to get together the best result. There is no one to one relationship between functions and operators, and actors can perform multiple functions, and functions can be tackled by multiple parties (den Heijer, 2004)

The various functions in the construction and real estate sector often are:
The user function, the function of ownership, the client function, finance function, design function, executive function, the advisory function, a public law function, a societal function, and a management function. It depends on the nature and complexity of the real estate assignment which actors are involved in which functions.

Facility Management is implemented as actor for the integration of processes within an organization, to develop and maintain agreed services. This includes among others required services for housing, maintenance, cleaning, information and communication. (NEN-EN 15221-1 Terms and Definitions, 2010)
Property management relates to different functions within a single building, or functions across a stock of buildings with multiple locations. In this case it includes the stock and exchange policy of the renovation components.

The diagram on the right shows in which manner the functions and actors may be appointed in an organization with a lease company as assigned in this thesis.



Phase:		Initiative & Design	Preparation & Pilot	Sale & Execution	Use & Maintain
Actor	Intern:	Architect Engineer	Executor Investor	Executor	Facility Manager Real Estate Manager
	Extern:		Media Municipality	Resident Advisor	Resident

By integrating multiple actors and function in the activities of the lease company, the lease company can eliminate concerns for residents, making the renovation proces less laborious and time-consuming for the residents. An external independent advisor can also help the resident making contract choices in a trusted environment.

The municipality and media can play a major role to lift the project. Due to the innovated character of the renovation and the lease construction, residents will resist easeier. The municipality however, benefits if residents do renovate their dwellings, making their homes sustainable, increase the property value and upgrade the street scene, making a safer living environment. The municipality could provide subsidies, for example paying for the rent the first year. They could create pilot projects and let people experience the benefits. The media can be utilized to promote the sustainable living and pilot projects.

Also nearby residents do suffer from nuisance (dust, dirt, noise, shut down streets). To prevent resistance and delayment they should be informed clearly what will happen; what kind of nuisance is presented, when and for how long. Thereby it should be encouraged to renovate together with your neighbors, this is not only better for the environment but also leads to a reduction in construction costs.

Chapter 11

Functions and Actors

Risks

Lease companies are increasingly implemented in the construction and real estate sector, however, up to this moment it mainly concerns climate installations as implemented by Energy Saving Companies. Construction elements will probably be leased and exchanged in the future, which can be seen in the increased demand for knowledge and studies in e.g. the circular economy. It is understandable that another study can go deeper into the effects what a lease or circular economy will mean for the different stakeholders. For now three topics concerning lease companies are shortly discussed: bankruptcy, valuation of used renovation components, and construction technology.

Bankruptcy

Lease contracts involve long term commitments, but what happens if the lease company goes bankrupt? It is no option for the occupant to hand in their facade before the end of the contract. The risk to be left with an open facade will be too large. An external entity or insurance should be integrated, however this could led to higher lease terms for the residents which makes the renovation less attractive. Residents should also preserve the right to return their elements when the elements do not reach the Performance Key Indicators as stated in the Service Level Agreement. Due to the already executed operations as demolishing of the old facade and removed roof tiles, giving back the money to the residents is no option. Residents should be provided with correct performance elements. This leads to a risk for residents for more nuisance and delayment due to imperfections or installation and construction errors.

Valuation of used renovation components

With operational lease the residual value of the elements is addressed to the lease company. However, the elements are used by the residents. Residents could treat the elements more rude or bequeathing because it is just not theirs. A new stakeholder may enter in order to determine in an independent manner the value of the elements at the end of the contract. If residents enter a contract with financial lease, it is set resident will own the elements at the end of the contract, thus residents are responsible for their own value of the property and there will be no need for this valuator.

Construction technology

The basic principles of the renovation design in this thesis, relies on the reuse of installations and several materials, however the prefab timber frame can not be re-used and needs to be recycled. When using an aluminum frame instead of a wooden frame, the construction of the prefab facade elements is easier to detach without damaging the load bearing frame. The dimensions of the frame can also be extended or shortened more easily by demountable joints, thus the frame can be reused on dwellings with different facade lengths or heights, which improves the feasibility fr the lease company. Yet the wooden frame was preferred due to the small dimensions of the facades and the cost related aspects. Concerning the removal and replacing of the elements which are integrated in the prefab frame, elements such as window frames and sills are easily detached and relocated in an other wooden frame. When using an aluminum frame, the construction technology differs due to the requirement of standardized dimensions with pre-drilled holes or (dynamic) connections, which involves other and more specific knowledge and technologies from the construction stakeholders. The architects mind should also incorporate the skills of executor and funds of lease company or client.

Chapter 12

Conclusion

Content & Structure

In this chapter the final conslusions of the research are presented.

Each element discussed is covered and contains one or more conclusions.

The treated topics are:

- Problem Statement
- Research Question
- Scope
- Design
- Construction Costs
- Energy Performances
- Payback Times
- Lease Constructions
- Results
- Sensitivities
- Residents Interest
- Functions & Actors
- Final Conclusion

Is leasing a renovation, a solution
to improve the energy demanding dwellings
in private ownership in the Netherlands?

Conclusion

20% less CO_2 emissions

+

20% less energy demand

+

20% renewable energy

2.

Problem statement

The Problem statement consists of an assembly of three elements. The first element is the European sustainability target; the 20-20-20 target which means according to 1990, in 2020 Europe will have a 20% reduction in CO_2 emission, a 20% less energy demand, and 20% of the used energy will be generated by renewable resources. The Second element is the large impact of the existing housing stock in the CO_2 emissions and energy demand of the Netherlands. The third element is the high investment costs for sustainable renovations.
The following research question has been established:

Research Question

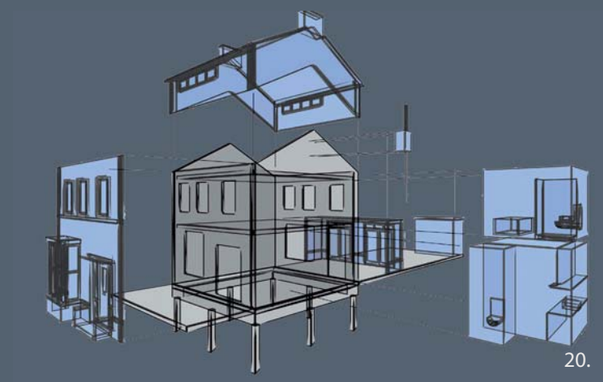
Is leasing a renovation, a solution to improve the energy demanding dwellings in private ownership in the Netherlands?

Scope

A large research has been performed in the scope of this research question. The results led to the most potential building typology and target group: the system built dwellings from the 60's and 70's, with as common occupant the "Average Modal Citizen". The results of the research in the interests of this target group led to a matching renovation concept: the prefab components renovation which fulfills the desires of the residents, including extending their living space and have different design options to chose from.

Design

The design is elaborated in different configurations: A Basic model with insulation values Rc = 3.5, 4.5, and 6.0. Next to the insulation three different installation variants have been examined: a Basic configuration, a Full Options configuration, and a Full Options including a Geothermal Heatpump variant. Again, next to these renovation models, four variants have been developed: one with dormer, one with a flat roof, one with an extension and one with an XL-extension. Besides the elaborated designs, three alternatives are presented: perform Only Maintenance, Maintenance + Energy Saving Upgrades, and a Traditional Renovation concept.



20.

Construction Costs

No Major differences are found in the additional costs for a thicker insulation package, however, the different installation configurations do let the price increase considerably. Construction costs starts at ca. €40.000 for a Basic renovation, go up to €50.000 for a Full Options variant, and rises over €70.000 if a geothermal heatpump is included. The four variants which are adding additional living space add another €5.000 to €28.000. The variants Maintenance, Maintenance + Energy Saving Upgrades, and Traditional Renovation, costs respectively €28.000, €34.000 and €43.000

Energy Performance

Due to the energy saving renovations, the energy bill decreases enormous. Reference is €2600 per year for a dwelling in original state. With a basic renovation energy bills decrease to ca. €950 a year, with a Full Option package to €680, and with a geothermal heatpump to €620. Only perform "Maintenance" retains an energy bill of €2600 per year, by including "Energy Saving Upgrades" the bill lowers to €1740, and with the "Traditional Renovation" concept the energy bill decreases to ca. €820 per year.

Payback Time

Payback times are calculated using the energy savings and accompanying construction costs. The result is a payback time of ca. 22 years for a Basic renovation, 24 years for a Full Options configuration, and 32 years for a renovation with a geothermal heatpump. Perform only maintenance has no decreasing energy bill and thus no payback time exists. By including energy saving upgrades the paybacktime is ca. 35 years. For the traditional renovation concept the payback time is set to 22 years. The payback periods are valued as too long by the occupants.

To decrease the payback time research has been performed in integrating the property value due to the renovation. The outcome is that the energy saving measures and installations have no influence on the property value, however the extended living surface – included in the renovation variants by adding dormers and extensions - , does positively affect the payback time of the renovation. Payback time reduces from 25 years to 21 by adding a dormer, and decreases from 33 to 25 years when adding an prefab extension to your dwelling.

Subsidies do not affect the payback time at this moment because no (national) subsidies are available for leased elements.

Chapter 11

Conclusion

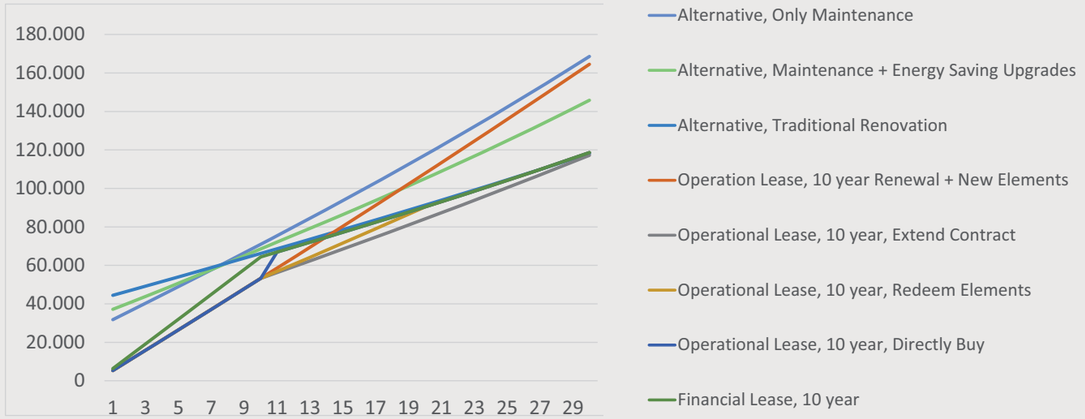
Lease

Two different lease strategies have been elaborated: Financial Lease and Operational Lease. The Financial Lease does not affect the amount of investment costs because it is comparable with a hire and buy construction, the client (resident) will always become owner of the product. Operational Lease does affect the investment costs because residual values are integrated in the investment costs. This means the client does not directly own the products at the end of the contract but has different options to buy the elements afterwards. Because the residual value is addressed to the lease company, reduced monthly fees can be offered to the residents.

Results

According to a 10 year operational lease contract in the renovation concept of a Basic Prefab Renovation with insulation value Rc = 4.5, the investment costs decrease from €40.000 to €29.000, leading to a reduced monthly payment from €330 to €240. Whenenergy savings are substracted the net living costs of this renovation model are determined on €90 / month. When entering a contract with a length of 20 years, the monthly fee (€125) becomes even less than the energy savings (€145) resulting in positive net living costs. This effect is explained due to the fact that losses in investment costs are nw spread over a larger period.

Because the high investment costs and the long-term commitment are the largest barrier for residents to participate in a sustainable renovationg process, not the positive 20 year Operational Lease Contract is elaborated, but the contract with a length of 10 years. After the period of 10 years, 4 variants are elaborated: 1) Renew contract and gain new elements, 2) Extend contract and pay according depreciation of elements, 3) Redeem elements in 10 years, 4) directly buy elements. In the results below the assumption is made that residents are able to pay for the renovation themselves, so no loan and interest rates are integrated. Further in this chapter an analysis including loan and interest rates is performed.



Conclusions

- 1) Within six years the extra costs for the "Energy Saving Upgrades" and the "Traditional Renovation", compared to "Maintenance only", have already paid back.
- 2) Operational lease has the least initial investment costs, however the "Renewal" variant becomes after 19 year the most expensive strategy, "Only Maintenance" variant excluded. Within 12 years the strategy is already more expensive than the Traditional Renovation concept.
- 3) Whether you choose to extend your contract, redeem your elements, or directly buy the elements after the 10 year operational leas contract, the financial end result after 30 years just differs about €1.000.
- 4) The Financial Lease Contract has initial larger monthly payments, however due to the integrated redeem of elements in the first 10 years, the end result after 30 year is comparable with the Operational Lease strategies.

If the largest motivating factor for residents is a financial benefit on the short-term, an Operational Lease Contract with Prefab Facade elements will be the best option, they save about €13.000 in the first 10 years. However if residents are motivated by a long-term strategy the benefits from a 10 year operational lease strategy are negligible. Entering a contract variant with a larger period, the financial benefits from the first 10 years are higher due to the larger spread of loss in investment costs, however the end result remains about the same. Entering a more expensive renovation model (Full Options variant) the financial benefits in the short-term are less large, and in the long run due to the combination of a larger investment and a relatively less saving on the energy bill, there is a slight disadvantages compared to the "Basic" operational lease model.

				10 Year Contract
				Financial
Renovation Model	Investment	Energy Bill	Payback time	Lease
Basic Rc 4.5	€ 40.000	€ 960	22	€ 330
Basic Rc 4.5 Full Options	€ 50.000	€ 680	24	€ 440
Basic Rc 4.5 Full Options + Geothermal heat pump	€ 70.000	€ 620	32	€ 590
Dormer Rc 4.5 Standard	€ 45.000	€ 950	19 (24)	€ 370
Dormer Rc 4.5 Full options	€ 58.000	€ 710	22 (26)	€ 480
Double Dormer Rc 4.5 Standard	€ 50.000	€ 990	17 (27)	€ 420
Double Dormer Rc 4.5 Full options	€ 63.000	€ 690	20 (28)	€ 530
Extension Rc 4.5 Standard	€ 63.000	€ 1.010	24 (33)	€ 530
Extension Rc 4.5 Full options	€ 76.000	€ 700	26 (33)	€ 640
Extension XL+ Rc 4.5 Standard	€ 69.000	€ 1.060	25 (36)	€ 570
Extension XL+ Rc 4.5 Full options	€ 82.000	€ 760	21 (36)	€ 680
Alternatives				
Only necessary maintenance	€ 28.000	€ 2.680	0	€ 230
Necessary maintenance + Energy upgrade	€ 34.000	€ 1.740	35	€ 280
Traditional renovation concept 113ZCT	€ 43.000	€ 820	19	€ 300

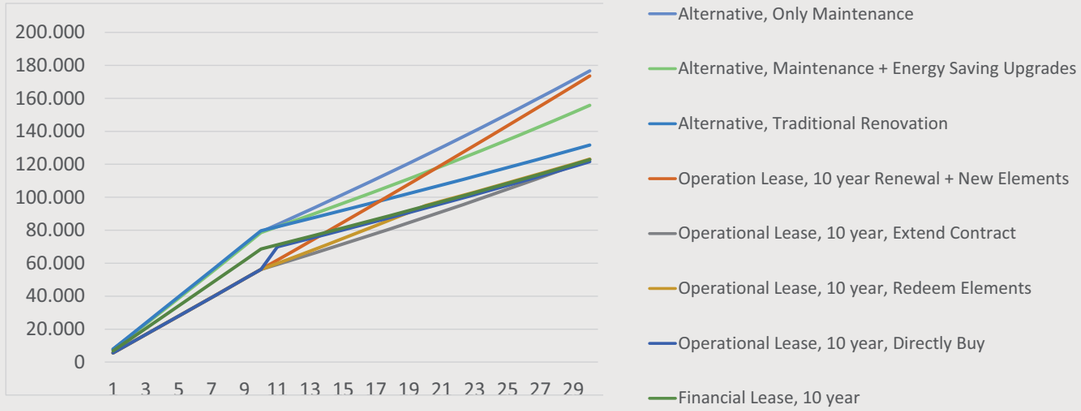
10 Year Contract					Operational Lease		
Operational Lease	Recalculated	Monthly			5 Year	15 Year	20 Year
Residual value	Investment	Payment	Energy saving	Net Costs	Net Costs	Net Costs	Net Costs
€ 11.000	€ 29.000	€ 240	€ 145	€ 95	€ 290	€ 20	-€ 20
€ 19.000	€ 31.000	€ 280	€ 165	€ 115	€ 310	€ 40	€ 0
€ 18.000	€ 52.000	€ 430	€ 170	€ 260	€ 620	€ 140	€ 75
€ 14.000	€ 31.000	€ 250	€ 145	€ 105	€ 310	€ 35	-€ 5
€ 22.000	€ 36.000	€ 300	€ 165	€ 135	€ 330	€ 55	€ 15
€ 18.000	€ 32.000	€ 270	€ 140	€ 130	€ 335	€ 50	€ 10
€ 25.000	€ 38.000	€ 310	€ 170	€ 140	€ 350	€ 70	€ 25
€ 26.000	€ 37.000	€ 310	€ 140	€ 170	€ 380	€ 85	€ 45
€ 34.000	€ 42.000	€ 350	€ 165	€ 185	€ 400	€ 105	€ 60
€ 30.000	€ 39.000	€ 330	€ 135	€ 195	€ 420	€ 110	€ 65
€ 38.000	€ 44.000	€ 370	€ 160	€ 210	€ 430	€ 130	€ 80
				€ 0			
€ 0	€ 28.000	€ 230	€ 0	€ 230	€ 460	€ 155	€ 115
€ 0	€ 34.000	€ 280	€ 80	€ 200	€ 490	€ 115	€ 65
€ 0	€ 43.000	€ 300	€ 155	€ 145	€ 440	€ 35	-€ 20

Chapter 11

Conclusion

Sensitivity

Down below the same analysis is performed as on previous page, but this time the assumption is made that residents are not able to pay for the renovation themselves. A loan with an interest rate of 5,5% (average interest rate past 10 years) is included in the "Maintenance", "Maintenance + Energy Saving Measures" and "Traditional Renovation" variants. At the same time an interest rate of 2,07% is integrated in the Operational Lease strategies, this is the interest rate the lease company could gain if it did not invest in the renovation, but put their money in the bank.



traditional renovation while in the operational lease constructions the elements still have to be redeemed. After 20 years the difference is ca. €14.000, and after 30 years €9.000. On both the short-term as well the long-term, operational lease becomes interesting for residents. The differences will reduce if residents are able to put in their own money in the traditional renovation concept, while the amount of interest for the lease company remains the same. When entering a traditional renovation with 50% loan and 50% own capital, the investment lowers with ca. €7300, making the difference with the operational lease contract considerably less. When using the same interest rate for the operational lease contracts (5,5%) as within the traditional renovation model, the extra costs are ca. €6.000 at the end of year 10, €10.000 at the end of year 20, and €12.000 after 30 years.

This shows that a fluctuation in interest rates is of great influence for the total investment costs. If the interest rate for the private loan for residents in a traditional renovation process is lower than the interest rate determined by the lease company, a large financial benefit may occur by entering a operational lease contract.

A sensitivity analysis has also been performed in the fluctuation of the net living costs. The results can be found in the table down under.

Model	Paybacktime	Nett cost			
	(year)	5 Year	10 Year	15 Year	20 Year
Standard	21,3	290	92	22	-18
plus 10% Construction costs	23,2	356	124	44	-1
min 10% Construction costs	19,4	224	58	0	-34
1% Annual Energy increase	19,4	287	84	10	-35
1% Annual Energy decrease	23,8	293	97	32	-3
1,3% missed interest savings	29	298	107	46	16
2,07% missed interest savings	40	302	115	59	31
1000E subsidy	20,8	274	82	16	-22
2500E subisdy	20,1	249	70	8	-28
90% Energy usage	24,8	313	114	45	7
75% Energy usage	32,8	347	148	81	43

Conclusions

- 1) The total costs of the "Traditional Renovation" model increases with €13.000 in the first 10 years. The model is financially less attractive than the 10 year operational and financial lease, with an exception of the lease variant "Renewal, each 10 year new elements".
- 2) At the end of year 30, the "Traditional Renovation" is about €9.000 more expensive than the lease strategies, ending in €132.000 at the end of year 30.
- 3) The lease strategies mutually differ just about €1.000 at the end of year 30, including the Financial Lease strategy. Costs at the end are about €123.000.
- 4) The costs for doing nothing but "Maintenance" will eventually rise to €176.000 in 30 years, the costs for "Maintenance" + Energy Saving Upgrades" will end in €156.000 in 30 years

If residents are not able to pay for the renovation themselves and a loan is integrated, the financial advantages for the first 10 years in an Operational Lease construction are, compared to a Traditional renovation, large (ca. €24.000). This includes the investment (loan c.q. lease amount), energy bill and maintenance costs. The difference does reduce after the first 10 years, due to the fact at this moment residents already own their

A crucial element for the net living costs is the initial energy reference. Two scenarios are elaborated in which the dwelling is not in its original state, but already had some energy saving upgrades. These energy references are fixed at 90% and 75% of the initial 100% energy demand if the dwelling is it in its original state. Due to the less energy savings, the payback period increases by 3.5 and 11.5 years respectively. This is a significant increase and the leasing concept will therefore be less attractive if the dwelling is already partly renovated. This is also reflected in the monthly net living costs which rise from € 290 / month to € 347 / month in a 5 year contract, and from - € 18 / month to + € 43 / month in a 20 year contract.

If residents were able to pay the renovation from their own pockets, they missed the interest rate for putting their money in the bank. The payback period increases from 21.3 years to 29 years at an interest rate of 1.31% (average interest rate November 2014). If calculated with an interest rate of 2.07%, - the average interest rate of the past 10 years -, the payback period even rises to over 40 years. The monthly fees also increase by € 12 / month for a 5 year contract and € 49 / month for a contract with a term of 20 years.

A 10% fluctuation in construction costs are reflected in a difference in the payback period of about 2 years, and a large difference of extra monthly expenses of around € 66 / month for a lease contract of 5 years and € 17 / month for a contract 20 years. If the annual energy price increase each year 1% more than calculated in the reference, there is an additional payback time of 2 years. The monthly costs fluctuate less as the monthly results for the miscalculation in construction costs. €1000 or €2500 subsidy affect the payback period the least (respectively 0.5 and 1.2 years).

Chapter 11

Conclusion

Residents

The willingness to pay is hard to measure. There is no literature with harsh facts available and discussions with professors and housing corporations did unfortunately not led to measurable results. There is no direct answer given to the question which amount of money residents are willing to pay for certain house upgrades as more comfort or extra living space, however the prefab renovation with lease concept is presented at a residents meeting. The common shared opinion was that residents were looking for more easy and accessible singular energy upgrades instead of an extensive renovation. A large scale survey could provide more clarity.

Because the average person lives about 10 years in his dwelling the 10 year operational lease contract may be the most desirable contract. The average extra costs for more comfort and a sustainable living are about €1100/ year within the 10 year contract, which corresponds with 3% of the average incomes of the residents. A new resident moving in can order a new contract with new elements; appearance, upgrades or extra living space are customized to his personal needs. In other way, if the current resident wants to keep living in his home he can now order new facade elements to meet his new interest to fulfill his new interests and needs. The option to extend his current contract is at this moment also attractive due to the low monthly costs because the loss in investment is already paid off and only the residual value has to be redeemed.

Important barriers for residents to participate in the renovation are the disinterest in sustainability, being afraid for change, the side effects or associated effort, but also considerations are often not taken rationally; residents are more influenced by his fellow man than by financial pros and cons. It also appears that the behavior of residents is of great influence for the energy performance of their dwelling, which may lead to substantially lower energy savings than calculated in this thesis. Extra advantages for the lease concept besides financial benefit are among others; create more comfort, a heathier indoor climate, expand living space and renovate with a new appearance for the dwelling. If a target group should be appointed, the early adopters and late majority will have to introduce the (success of) the prefab renovation with lease concept. Thay may convince the others.

Functions & Actors

Compared to a traditional renovation extra functions and actors may be necessary in the lease structure. An independent valuator can be assigned at the end of the contract, to evaluate the residual value of the elements. Also an extra insurance should be implemented in order to avoid complications if the lease company goes bankrupt. The media and municipality could fulfil a public role to provide subsidies and encourage residents for a sustainable renovation.

Final Conclusion

Is leasing a renovation, a solution to improve the energy demanding dwellings in private ownership in the Netherlands?

According to this research, by integrating the residual value in an operational lease construction, leasing a renovation has a financial benefit for the residents and thus is a solution to improve the energy demanding dwellings of the Netherlands,

However:

- The payback period of the renovation project is strongly depended on the current state of the dwelling
- Market related figures as interest rates have a major impact
- The willingness to pay is difficult to measure
- Financial considerations are often perceived as less important than social influences
- The theoretical versus actual energy usage is strongly depended on the residents' behavior

When it is recommendable for residents:

- If dwelling is in original state
- If looking for short-term results
- If stable market with financial benefit due to interest rates
- If daring to take risk in new concept and company

When it is not recommendable for residents:

- If dwelling has already energy saving upgrades
- If looking for long-term results
- If assurance is your priority (depreciation factors)
- If not able to live sustainable

When it is recommendable for the lease company:

- If large housing stock with dwellings in original state
- If large resident interest (making reusing elements able)
- If more technical knowledge is available (reduce fail and start-up costs)
- If municipality and media encourage residents (subsidies, branching)

When it is not recommendable for the lease company:

- If small housing stock with dwellings in original state
- If no large residents' support
- If unstable market (relative high interest earnings and low interest charges)
- If legal difficulties occur (bank has dwelling as collateral)

Recommendations

In the continuation of this thesis, it is recommended to do more research in the following typics:

- Willingness To Pay

  Perform a large scale survey among homeowners to reach a more accurate and measurable result regarding the amount of money people are willing to invest in aspects as more comort, extending living space and a new up to date appearance of the dwelling.

- Amount of dwellings in original state

  For the net living costs and the feasibility of the lease concept, it is important to gain insight in the amount of dwellings in original state. Due to the focus on private owned dwellings and often self implemented or not registrated energy saving upgrades, this is difficult to determine.

- Energy Performance Software

  To gain more specific energy performance results for the renovation models, more advanced software with dynamic calculations may be used.

- Juridical aspects

  Little attention has been devoted to juridical aspects as insurances, dwelling collaterals, and building permits. More knowledge is desirable.

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Images - Layout

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p.146 http://imganuncios.mitula.net/4_kamers_westeraam_oost_89b_elst_192500 euros_99886096838442794.jpg
p.147 http://cloud.funda.nl/valentina_media/040/717/797_groot.jpg
p.148 http://www.geerpark.nl/images/janssen-de-jong-morgen-ii/Exterieur-3kapper_small.jpg
p.149 http://www.delanenwonen.nl/media/item/74/1200x900/rij-en-hoekwoningen.png
p.156 http://s01.qind.nl/userfiles/46/Image/Al%20-%20Ik%20Woon%20Betaalbaar%20in%20Blaricum.jpg

Reflection

The relationship between research and design

The goal of the research is to adapt and upgrade an innovative renovation concept and to combine this with a non-traditional financial construction to make sustainable renovations available for a wider audience. The outcome is a result which contribute in reaching the European 20-20-20 target and reduces the energy bill for the residents, while giving these residents also more advantages such as more comfort and extra living space. It is therefore this research contains a variety of different subjects; engineering capabilities, energy performance, financial constructions, residents' interests, risks and opportunities, and several functions and actors.

The physical design has been established by comparing several renovation concepts and relate them to the residents' interests. By adapting the most promising design concept to the existing dwelling typology (which has been found earlier by an research into the different building systems), the prefab component renovation is elaborated in one basic renovation with three variants. These four models, each in itself have again three different installation configurations.

The construction costs are calculated using large databases as Archidat and Bouwkosten.nl. Also several tenders are requested for specific building components. For the energy performance caluculations, the software tool EPG & Costs is used. It contains parameters for geometry, thermal values and installations. This software will give a good indication in the energy demand per renovation model for now, however in next stage it is possible to use more advanced software tools for a more detailed simulation. Using the required key indicators (inflation and interest rates, energy price increases, etc.) calculations are made for the energy bills for the next 40 years, again for each renovation model.

Next to the elaborated design, the construction costs and energy performance for three other renovation models are calculated. The three variations are; 1) no renovation but only necessary maintenance, 2) maintenance + energy saving upgrades, and 3) a traditional renovation concept according to Toolkit Existing Buildings, sustainable home improvements. All renovation models are compared to the initial energy performance of the dwelling in original state, which corresponds as the best case scenario. With the results the payback periods for each renovation model is calculated. In this research Further in the research the sensitivity of the results is examined to determine the reliability and to soften the impact of the best case scenario, for now the payback time is considered too large, which corresponds to the largest barrier for residents to participate in a sustainable renovation project (too high investment and longtime commitment)

Considered is to implement the increase in property value due to the renovation, to reduce the payback time of the renovations. Funda.nl is the largest organization the presents the Dutch offer of real estate on the internet and has been used for the research. If the chosen renovation adds extra living space, the property value did increase, however there was no influence by facilities nor energy saving measures, which also corresponds with the literature

Another method to reduce the payback time was by implementing subsidies. Traverse Advisory Group is contacted for a reliable outcome, however the result was that it is not possible to implement subsidies within lease strategies at this moment

The last and most interesting method for this research is to implement a new financial construction. The Operational Lease construction gave the possibility to integrate residual values and thus to reduce payback times. The residual values are calculated using a simplified linear approach, while in reality the first few years will cause the most depreciation. The results manifest themselves among others in monthly amounts for different renovation models and for durations of the lease contract.

In order to obtain a more reliable result a sensitive analysis is performed. Ten different analysis include miscalculations for construction costs, energy performance, interest rates, initial energy demand and the integration of subsidies.

There is also set a step towards the willingness to pay and interest of residents. Different sources have been consulted including literature, mentors specialized in the housing sector, housing corporation Woonbron, and also a presentation has been given at the residents meeting of the Verzetstrijderbuurt Delft, organized by Delft E Design. Within the results, including the literature, it is harsh to give a detailed answer in this new innovative renovation strategy. In a next phase a large scale survey is recommended to obtain more insight with measurable results regarding the willingness to pay of the residents.

The relationship between the methodical line of approach of the studio and the method chosen by the student in this framework

Due to the implementation of different subjects and elements the research has been performed with guidance of mentors from two different master tracks; the Building Technology sector, and Real Estate & Housing. From both studios methods are introduced, however at the same time due to the diversity and wide range of the topics, the entirety of the research does not directly correlate with a particular methodology used in the Building Technology studio or the Real Estate & Housing sector

The relationship between the theme of the studio and the subject chosen by the student within this framework

The research on energy efficient renovation fits in the Building Technology and Sustainable Design sector. Knowledge from the Real Estate & Housing sector is gained to obtain reliable financial calculations. Due to the importance of this financial feasibility in the project, the project has more financial characteristics than the average graduation project in the Building Technology sector.

The relationship between the project and the wider social context

A large social interest and context is reached in this research due to;

- The focus on a large part of the existing housing stock in the Netherlands
- The sustainable and energy saving character and the European 20-20-20-target
- The implementation of both the technical as the financial side
- The implementation and feedback of the interest of the residents

Content

No country in the worlds has as much rowhouses as the Netherlands. If you place each house next to each other, you achieve a length of 16.000 km which can be visualized as a road between Amsterdam and Beijing, uninterrupted with Dutch rowhouses on both sides.

The first rowhouses are dated from the 15th century, with an appearance of a sequence of identical houses around a shared garden. In the 19th century housing associations established and with help of cheap government loans the rowhouse became a more common housing typology in the Netherlands. Due to a housing shortage after World War II, the need for housing became public enemy number one. New technology led to quick and cheap building systems and new districts with almost exclusively rowhouses.

Nowadays the rowhouse is still a popular building typology, with thematized Vinex-districts praised for its large living surface and private gardens. However, the old housing stock can not keep up with the modern and sustainable standards of today. Something needs to be done to change the old unsustainable houses into modern and energy efficient dwellings.