

## WHAT'S IN IT FOR YOU?

### CONSUMERS MAKING THEIR DWELLING ENERGY NEUTRAL COLLECTIVELY

Graduation thesis

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## TABLE OF CONTENTS

<b>1. Introduction .....</b>	<b>5</b>
<b>2. Research design.....</b>	<b>7</b>
2.1 Problem analysis.....	7
2.2 Research Question.....	7
2.3 Research objective and limitations .....	8
2.4 Research relevance.....	8
2.5 Research methods .....	8
2.6 Report outline.....	9
<b>3. Energy neutral dwelling.....</b>	<b>11</b>
3.1 Definition .....	11
3.2 Trias Energetica .....	12
3.3 Reduce energy demand.....	12
3.4 Use of energy from residual flows.....	15
3.5 Use of energy from renewable sources.....	16
3.6 Installation systems .....	17
3.7 User-related measures .....	18
3.8 Legislation .....	19
3.9 Finance.....	20
3.10 Conclusion .....	21
<b>4. Value creation .....</b>	<b>23</b>
4.1 Introduction .....	23
4.2 People .....	24
4.3 Planet .....	25
4.4 Profit .....	27
4.5 Conclusion .....	30
<b>5. Renovating dwellings as a collective .....</b>	<b>33</b>
5.1 Introduction .....	33
5.2 Collective energy efficiency measures .....	34
5.3 Advantages .....	35
5.4 Disadvantages.....	35
5.5 Cooperation and financing .....	36
5.6 Conclusion .....	38
<b>6. Research methodology .....</b>	<b>39</b>
6.1 Financial model.....	39
6.2 Measuring energy neutrality .....	43
<b>7. Case study .....</b>	<b>47</b>
7.1 Method .....	47
7.2 The case - Venne-Oost, Drunen.....	49

7.3	Identifying scenarios.....	50
7.4	Data.....	52
7.5	Model.....	55
7.6	Sensitivity analysis .....	56
<b>8.</b>	<b>Results.....</b>	<b>59</b>
8.1	Analysing yearly costs.....	59
8.2	Cash flows by scenario.....	61
8.3	Cash flows by scale .....	63
8.4	Investment needs .....	63
8.5	Sensitivity analysis .....	64
8.6	Conclusion case study.....	69
<b>9.</b>	<b>Conclusion.....</b>	<b>73</b>
<b>10.</b>	<b>Discussion and recommendations .....</b>	<b>77</b>
10.1	Discussion .....	77
10.2	Recommendations.....	78
10.3	Reflection.....	78
	<b>References .....</b>	<b>81</b>
	<b>Appendices .....</b>	<b>87</b>
	<b>Summary in English</b>	
	<b>Summary in Dutch</b>	

## 1. INTRODUCTION

Sustainability is a hot topic, governments, businesses and consumers are getting more and more involved. Sustainability policies and measures are made and carried out by governments and businesses. European regulation states that from 2020 only 'near zero energy buildings' are allowed to be built (Agentschap NL, 2010). Municipalities set sustainability and energy efficiency goals for the future, the municipality of Eindhoven for example wants to be energy neutral in 2035-2045. People are also becoming more conscious of the environment and energy usage. To reach the ambitious sustainability goals that are set a lot of effort is still needed.

In the Netherlands 35% of the energy usage is for the account of buildings and almost half of this amount is used by households (Agentschap NL, 2012c). Thus a lot energy can be saved by making buildings more sustainable and dwellings can play a large role in that. The government already have set an Energy Performance Coefficient (EPC) for new built dwellings as a benchmark for energy efficiency. The EPC for new built dwelling is now 0,6 and will be 0,4 in 2015, with as ultimate goal energy neutral dwellings in 2020 with an EPC of 0 (Agentschap NL, 2012b). Thus new built dwellings must comply with regulations regarding energy efficiency. They will become more energy efficient in the future and in 2020 they have to be energy neutral. That new built dwellings will be energy neutral in the future is a good start, but also for existing dwellings a lot of energy can be saved.

Housing associations and some private home owners have started by making their existing dwellings more energy efficient by renovating them. A lot of housing associations are already making their dwellings more energy efficient, but most of the private home owners are not taking this step yet, while a lot of benefits can be gained for them. This can be caused by the ignorance about energy efficiency, they are not aware of the possible benefits and only think of the involved costs. When consumers would be more aware of the benefits then maybe they would take the step to renovate their dwelling.

There is a large difference in energy efficiency between existing dwellings and new built dwellings, certainly when all future new built dwellings are energy neutral. Energy neutral dwellings will have low energy costs, which results in lower housing costs. While existing dwellings have a lot of energy costs, especially when a dwelling is not energy efficient. The forecast about the energy prices indicate that they will increase in the future, but how much they will increase is uncertain. Thus there will be a gap in housing costs between the existing dwellings and the new built energy neutral dwellings. This will also cause a difference in value, because a dwelling with low additional energy costs will have more value than the same dwelling with a lot of energy costs. By renovating a dwelling to energy neutral added value can be created, because then the dwelling is more independent from the uncertain increasing energy costs. But renovating a dwelling is also about prolonging the lifespan and improving the quality of the building, besides only making it more energy efficient. Thus there are several benefits that can be gained from making a dwelling energy neutral, these benefits can be a better quality of a dwelling, financial benefits or an increased comfort level.

When a lot of consumers are willing to renovate their dwelling to energy neutral then they could also cooperate to renovate them. If the consumers would renovate their dwellings collectively, added benefits can arise with regards to renovations costs and organizational benefits. When a lot of consumers in a neighbourhood cooperate to renovate their dwellings they can also encourage each other to take part in the renovation. This can result in redeveloping the entire district, where also other stakeholders can be involved and gain from the redevelopment. A municipality, for example, will not restructure the living environment when only a couple of dwellings are renovated, but they can possibly do it when all dwellings in the district are renovated. Businesses, including retail, can get inspired to renovate their properties to. Housing associations can also cooperate in the redevelopment by renovating their dwellings in that district. Thus the entire district can be renovated to an energy neutral district and the dwellings and living environment can also be improved. This can be extended from one energy neutral district to multiple districts and even into an energy neutral city.

## 2. RESEARCH DESIGN

This chapter describes the research design of this graduation thesis. First the research problem is analysed which follows into the research questions. In the third paragraph the research objective and limitations are described. In the next paragraph the research relevance is explained followed by the research methods. Finally a reading guide is explained.

### 2.1 PROBLEM ANALYSIS

In the future all the new dwellings will be energy efficient or energy neutral. This creates a difference with the existing dwellings that are less energy efficient regarding energy usage and energy costs. Also entire districts and regions are going to be energy neutral in the future. This means that districts with existing dwellings also need to be made energy neutral. To realize the transformation to energy neutral districts, dwellings will play a key role, because most of the buildings are dwellings. And consumers can play an important role in making the existing housing stock sustainable. But not all consumers want to make the investment to make their dwellings more sustainable, because of the costs or ignorance about the topic. A solution can be that consumers renovate their dwellings as a group, where they can have collective benefits. There are already some initiatives to renovate dwellings with a group of people from the neighbourhood. But it is not certain what the added value of renovating as a group is and what the benefits are for the consumers. When the benefits and the created value are known, then people who are hesitating can be persuaded to renovate their dwelling. The participation of consumers is needed to realize energy neutral districts.

### 2.2 RESEARCH QUESTION

This leads to the following research question:

*What are the benefits when consumers make their dwelling more sustainable into an energy neutral dwelling as a collective?*

To answer this question the following sub questions are formulated:

#### Energy neutral dwelling

- What is an energy neutral dwelling?
- What measures can be taken to make a dwelling energy neutral and what are their costs?
- What are the savings on energy usage and costs when a dwelling is made energy neutral?

#### Value creation

- What is value creation and how can this added value be measured?
- What is the added value for a dwelling that is made energy neutral?

#### Renovating dwellings as a collective

- What are the benefits of renovating dwellings as a collective?

- What is the added value when a dwelling is made energy neutral as part of a renovation as a collective?
- What financing structures are possible when renovating dwellings as a collective?

### **2.3 RESEARCH OBJECTIVE AND LIMITATIONS**

The research objective is two folded. The first research aim is show the added value and benefits that consumers can gain by making their homes energy neutral. When the benefits weigh up to the investment that needs to be made, then the research can show that everybody should renovate their dwellings. The second aim of the research is to show that renovating dwellings as a group has benefits over renovating dwellings individually. When the results prove that renovating as a collective has more benefits then it might easier to get people to join a collective renovation. These results can have great value to get people to participate and renovate their districts into energy neutral districts.

Research limitations have to be set, because the research has to be elaborated in a time frame of six months. These limitations are needed to make sure that the research can be carried out in the time frame.

- The research will be focused on one group of stakeholders, the consumers (private home owners)
- The research will focus on existing dwellings that can be made energy neutral
- The research will be limited to the dwelling and the measures that can be carried out to make the dwelling energy neutral. The building process and materials are excluded from the research.

### **2.4 RESEARCH RELEVANCE**

The relevance of the research for the TU/e is the gained knowledge about consumers renovating dwellings as a collective. There is not a lot of scientific information about de subject available at the moment. The research can deliver information about the benefits of renovating as a group over renovating individually. Also knowledge can be gained about the benefits and added value from renovating dwellings to energy neutral dwellings. The information about value creation when renovating dwellings as a group is also very useful, because there is not much information available about that subject.

The relevance of the research for ARCADIS is gaining knowledge and insight about consumers renovating dwellings as a group and in the added value and benefits of renovating a dwelling into an energy neutral dwelling. ARCADIS can use this knowledge to advice the government or other businesses to stimulate consumers to participate in renovating as a group.

### **2.5 RESEARCH METHODS**

To find the answers on the research question different methods will be used. For the theoretical part a desk research will be carried out. This will provide a part of the answers to the sub questions. It will also provide a base for a case study. The second part of the research is a case study. In the case study the added value of renovating dwellings individually and as a collective will be researched. This focuses on the benefits and added value of renovating a dwelling to energy neutral and it compares an individual renovation to



a collective renovation. A research method needs to be selected that can be used to determine the benefits of the renovation to energy neutral. Several methods will be examined of which one will be chosen that will be used. Another method is needed to determine the energy neutrality of a dwelling, so also for this method several alternatives will be examined.

## **2.6 REPORT OUTLINE**

The first part of the research is the literature study that consists of three chapters. The first will focus on the energy neutral dwelling. In this chapter the definition for an energy neutral dwelling will be set and measures to make a dwelling energy neutral will be examined. Financing regulations and legislation concerning the energy neutral dwelling are also looked into. The chapter ends with defining which measures can be used as best to make a dwelling energy neutral. The fourth chapter focuses on value creation, the added value when a dwelling is renovated to energy neutral will be examined on three parts the social, ecological and financial value. The next chapter will examine the subject renovating dwelling as a collective. Collective energy efficiency measures will be examined, the advantages and disadvantages are determined. The chapter also looks into specific cooperation forms and financing regulations for renovating dwellings as a collective.

The second part is concerns the case study and starts with a chapter that looks into the needed research methodology. This chapter examines possible models to indicate the benefits and costs of the renovation and several methods that can be used to determine energy neutrality. The seventh chapter explains the case study, the method that is used, which case was selected and how the case study was carried out. Then the next chapter analyses the results from the case study.

Then the final third part of the research concerns the conclusion, discussion and recommendations. In the chapter about the conclusion the answer is given to the research question. Then in the final chapter the conclusion is discussed and recommendations for further research will be made.



### 3. ENERGY NEUTRAL DWELLING

This chapter focuses on the energy neutral dwelling. The chapter discusses the definition, the measures to make a dwelling energy neutral and finance and legislation that concern the renovation to energy neutral. And finally a comparison between the measures will be made to identify which measures are most preferable to reach energy neutrality.

#### 3.1 DEFINITION

This paragraph explains the definition of an energy neutral dwelling. A clear definition is important to prevent confusion about the used terms in this report. There was no unambiguous definition set for energy neutrality, until the 'Platform energietransitie gebouwde omgeving' (PeGo, 2009) carried out an extensive definition study. They have compared several definitions found in literature before they set clear a definition for energy neutrality. The definition for energy neutral by PeGo (2009) is:

*'A project is energy neutral when on a yearly basis there is no net import of fossil or nuclear fuels from outside the system boundary needed to develop, use or demolish a building. This means that the energy usage from inside the project boundary is equal to the amount of sustainable energy that is generated within the project border or on basis of external measures may be contributed to the project. The energy usage which arises from the creation or demolition of a building will be settled to an annual contribution based on the expected lifespan of a building.'*

The project boundary covers all buildings and installations for energy conversion and carbon fixation that are located within the direct influence sphere of the project owner and have a geographical border (PeGo, 2009). The project boundary for an energy neutral dwelling would be the border of the property. The system boundary includes the project and the installations for energy conversion and carbon-fixation outside the direct influence sphere of the project owner, the energy or carbon neutrality is determined on the basis of energy exchange or carbon emissions in the system boundary (PeGo, 2009). The location of the system boundary is a choice of the project owner and defines the search area for renewable energy generation and/or carbon compensation, the system boundary will generally have a virtual character and does not need to be fixed geographically (PeGo, 2009). The system boundary can be, for example, the energy system where the dwellings is part of. The system boundary for an energy neutral dwelling is the border which includes relevant energy flows and emissions.

In this report the energy neutral project will be the dwelling or group of dwellings that will be renovated. As stated in chapter 1 this research focuses on the energy neutrality of the dwelling and not the building process. This means that energy neutrality during creation, renovation or demolition of a dwelling will not be taken in account. The dwelling needs to be energy neutral during the use phase. Thus the definition for an energy neutral dwelling that will be used in this report is:

*'A dwelling is energy neutral during the use phase when on a yearly basis there is no net import of fossil or nuclear fuels from outside the property needed for the exploitation building. This means that the energy usage from inside the property is equal to the amount*

*of sustainable energy that is generated within the property or on basis of external measures may be contributed to the project.'*

The energy usage is different for each dwelling or household, this depends on the type of dwelling, the behaviour and activities of the consumers. The energy usage of the property can be divided in two parts, the energy related to the use of the dwelling, such as heating and generating hot water and the energy related to the activities of consumers, such as electricity for a television or a washing machine. The energy that is needed for the activities for consumers can vary greatly and when consumers use a lot of energy it is difficult to reach energy neutrality. Therefore there is chosen in this report to use average energy usage to determine energy neutrality.

### 3.2 TRIAS ENERGETICA

The Trias Energetica is an often used strategy, that can be used as a guideline to make buildings more sustainable. The "new steps strategy" by Dobbelsteen (2008) is an updated version of that strategy. The new steps strategy is based on the three steps of the Trias Energetica, the steps are adjusted to realize energy neutral dwellings and buildings (Agentschap NL, 2012a). These steps are:

- Step 1: Reduce energy demand.
- Step 2a: Use of energy from residual flows.
- Step 2b: Use of energy from renewable sources.
- Step 3: If usage of finite (fossil) energy sources is inevitable, use them very efficiently and compensate them on a yearly basis with 100% renewable energy.

These steps should be completed in the correct sequence to deal with energy usage as efficient as possible. First the energy demand needs to be reduced and after that when the amount of energy needed is reduced, energy from residual flows and renewable sources is used. When dwellings are made energy neutral, the usage of fossil fuels should be avoided completely. In this research the dwelling needs to be energy neutral on a yearly basis and use 100% renewable energy on a yearly basis. This means that it is possible to extract energy from the net during peak hours when the renewable sources are not sufficient and it is possible to resupply the sustainable energy back to the net on other hours. The measures to make a dwelling energy neutral will be classified according to the trias energetica strategy. These measures will be described in the paragraphs 3.3 to 3.5. Besides the measures related to the building, the users can also take some actions to reduce their energy usage, the attitude towards energy usage by consumers is described in paragraph 3.6.

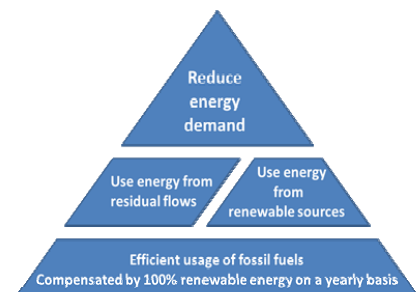


Figure 3.1: Trias Energetica model

### 3.3 REDUCE ENERGY DEMAND

An energy neutral dwelling starts with a solid shell around the dwelling to reduce the need for heating and cooling of spaces (TNO & Except, 2011). The measures to reduce the energy demand of a dwelling mainly consider measures to insulate the building envelope. The

measures that will be described are all suited for the after-insulation of an existing dwelling. There are constantly new insulation materials and methods developed, so when applying insulation measures always look for new insulation materials and methods with high insulation values.

### **3.3.1 WALL INSULATION**

There are different ways possible to insulate the façade: cavity wall insulation, interior wall insulation and exterior wall insulation.

#### **Cavity wall insulation**

When the cavity wall is after-insulated, the insulation material is inserted through openings in the cavity. Insulation materials are for example mineral wool flakes, polystyrene foam grains (PS-grains) or PUR-foam (Agentschap NL, 2011a). Owners experience almost no inconvenience when this method is applied and another advantage is that the method has relative low costs. The disadvantages of this method are that thermal bridges and moisture problems can arise, with consequences such as heat loss and a less healthy living climate. The saving potential is limited because the possible amount of insulation material depends on width of the cavity and the state of the cavity wall. This measure has the least amount of saving potential of the wall insulation measures and saving potential is probably not enough to meet future requirements.

#### **Interior wall insulation**

When insulating the wall from the inside, insulation material is placed on the inside of the walls and it is also possible to use finished thermal insulation panels. Disadvantages of this method are relative much inconvenience for the owner when the insulation is placed and the indoor floor space is reduced. Another disadvantage is that thermal bridges and moisture problems can occur (Senternovem, 2009). An advantage is that sound proofing between dwellings is possible and high insulation values can be achieved. This measure can be easily implemented, but there are major disadvantages for the owners, there is a lot of inconvenience and their living surface decreases.

#### **Exterior wall insulation**

A façade can also be insulated from the outside, then the insulation will be placed on the exterior walls, this is the most extensive wall insulation measure. It is possible to remove the existing outer wall and apply a new insulated outer wall or apply outer wall insulation on the existing exterior wall. There is also external wall insulation available with stone strips on the outside, which looks like a stone wall. Advantages when insulating the exterior wall is that there is minor inconvenience for the owner, high thermal insulation values are possible and there is less chance for thermal bridges (Agentschap NL, 2011a). Another advantage is that it is possible to improve the exterior of the dwelling. There is a high saving potential for insulating exterior walls, but costs are relatively high and it is not always allowed or possible to change the exterior of a dwelling. This measure is also relatively future proof, because high insulation values are possible.

### **3.3.2 ROOF INSULATION**

A roof can be insulated from the inside or the outside. Insulation from the inside of a pitched roof is applied underneath the roof deck. Advantage of this method is that it has a

favourable ratio between investment costs and energy savings. Disadvantages are chance for building physical problems and limited saving potential due to the possible thickness of the insulation material (Agentschap NL, 2011a).

When a roof is insulated from the outside, insulation is applied to the roof boarding underneath the roof tiles. Advantages for this method are minor inconvenience for the owners, it is easy to combine with exterior wall insulation and minor chances for building physical problems. Another advantage is that it is also an option to change the entire roof by prefabricated roof construction, this creates possibilities to incorporate solar panels, that generate sustainable energy, in the roof. Advantages are the combination with energy saving measures and airtight connections that are possible, a major disadvantage is the inconvenience for the owners.

The same options are available for insulating flat roofs, but it is more difficult. Insulating from the inside causes serious moisture problems and insulating on the outside gives problem with the roof edges.

### **3.3.3 FLOOR INSULATION**

By insulating floors energy losses are reduced and comfort increases through a higher surface temperature on the floor. A method is to insulate the soil, by putting insulation material on the ground. Advantages are that the humidity of the crawl space is decreased and disadvantages are that the insulation value is lower due to ventilation above the insulation layer. Another option is to insulate the bottom of the floor construction. Advantages are minor inconvenience for the owner and improvement of the comfort level. A disadvantage is that there should be enough height available in the crawl space.

When there is no crawl space it is difficult to insulate the floor, it is possible to put insulation on top of the floor or replace the entire floor. A disadvantage is that the floor height increases and the entire floor needs to be renewed. These options have relative high costs and inconvenience for the owner. Another option is to insulate the foundation of the dwelling from the outside. Then insulation material is placed on the outside of the foundation. This prevents heat losses from underneath the floor to the outside and then the ground under the floor becomes warmer, which causes less heat loss. The option with the highest energy saving potential is insulating the bottom of the floor, it also gives the least amount of inconvenience for the user and it has relatively low costs.

### **3.3.4 WINDOW AND DOOR INSULATION**

By insulating door- and window frames and replacing glass a lot of energy can be saved. By replacing the glazing of windows by energy efficient glass the comfort level improves, sound insulation improves and heating costs can be saved (Meer met minder, 2012). Single or double glazing can be replaced by high performance glass, HR++ or HR+++. Advantages are the energy saving potential and improved comfort levels. A minor disadvantage is chance of condensation on the outside of the windows (Agentschap NL, 2011a). When triple glazing is applied the frames should also be replaced, because the glazing does not fit in regular frames.

Another possibility is to replace the window frames and combine the replacement with high performance glass, this includes higher costs, but also has a higher saving potential. There are well insulated window frames on the market that have high insulation values. By replacing the entire window frame, draft can be decreased and heat losses can be minimized. Replacing windows or glazing brings inconvenience for the owners, but the owners can stay in their dwelling during the procedure (Agentschap NL, 2011a). Also the door frames of the front and back door can be replaced by insulated doors, which improves comfort levels and decreases heat losses.

### **3.3.5 DRAFT PROOFING**

Draft and heat losses can arise from cracks and seams in dwellings. Energy can be saved by sealing those cracks and seams. Owners can seal the cracks and seams themselves with draft strips or other materials that are available (Meer met minder, 2012). This measure has relative low costs and it is easy to save energy and reduce draft. When a dwelling is renovated, most of the cracks and seams are sealed when other measures are applied, so less draft proofing is needed.

## **3.4 USE OF ENERGY FROM RESIDUAL FLOWS**

A lot of energy is wasted through residual flows of a dwelling and by their residents. Air and water are heated, but they are simply discarded while these flows contain residual heat or in other words energy. The heat and energy of these flows can be used to heat new water or air, resulting in less energy that is needed to heat these air or water flows. Other residual flows besides water and air are waste flows, these can be used to create bio-energy.

### **3.4.1 HEAT RECOVERY**

A heat recovery system can be applied to several residual water and air flows in the dwelling. Best known is a heat recovery system for the shower. There are two methods for heat recovery of a shower through the shower pipe or the shower base. The heat is extracted through a heat exchanger from the water and the cold water to the boiler or shower is preheated (Agentschap NL, 2009). And then a boiler needs less energy to operate during a shower and has a return of 20-30% (Senternovem, 2009). A heat recovery system for water can also be applied to other residual water flows. An example is that in Finland heat recovery is applied to the sewage system (Senternovem, 2009).

Heat recovery systems are also available for air flows, they are often integrated in ventilation systems. When a new installation system is installed it is beneficial to combine it with a heat recovery system, to use residual heat that passes through these installations. Heat recovery systems can deliver the highest returns when applied to the most common and largest residual flows. These flows are main hot water residual flows such as the shower, washing machine, dishwasher and kitchen sink and main residual air flows through ventilation systems.

### **3.4.2 BIO-ENERGY/BIOMASS**

Besides residual water and air flows, there are also waste flows. It is possible to generate energy from these waste flows. Biomass boilers can be used for heating the dwelling and domestic water. Energy from biomass is generated by combustion, gasification or fermentation of organic materials (Milieucentraal, 2013). To produce bio-energy for a

dwelling most of the time extra ground is needed for the production of biomass (TNO & Except, 2011). Thus it is not realistic to realize for one dwelling, but there are possibilities for district heating. There is an on-going debate about if bio-energy is sustainable or not, the used materials are not depleting, but it is not clear what the different side-effects are of converting them in energy.

### **3.5 USE OF ENERGY FROM RENEWABLE SOURCES**

There are several methods that generate energy from renewable sources. In this paragraph the solar boiler, solar power, wind energy and thermal energy storage are discussed.

#### **3.5.1 SOLAR BOILER**

A solar boiler delivers heat for domestic water and can also be used for space heating. Through a solar collector the solar energy is captured in a fluid, that flows through the collector and is converted into heat (Agentschap NL, 2011a). A solar boiler can be used to heat domestic water, but it can also be used for space heating. It is also possible to combine both by generating energy to heat domestic water and use the remaining amount for space heating. A solar boiler requires regular maintenance, depending on the type once a year or once in the five years. For an optimum return on the solar boiler, the collector surface, storage volume and usage of hot water should fit together as close as possible (Agentschap NL, 2009). Solar boilers are becoming more advanced, such as an high vacuum solar boiler, that generates a higher amount of energy by square meter than existing solar systems.

#### **3.5.2 SOLAR POWER (PV-PANELS)**

With PV-panels solar energy can be converted in electricity. PV-panels can be installed on both pitched and flat roofs, they can be placed on top of a roof, but can also be integrated in the roof itself. By an evolving market much better PV-panels are available every year and over the past five years prices of PV-panels are reduced by half. Furthermore there are subsidies available, which makes it possible for solar energy to compete with grey electricity (Milieucentraal, 2013). For optimal performance of the panels the orientation towards the sun (between southeast and southwest) is important and they should be placed under an angle towards the sun (TNO & Except, 2011). The roof surface should be without obstacles and possible shading on the roof should be prevented, because that can decrease the revenue of the panels.

#### **3.5.3 WIND ENERGY**

It is possible to place small wind turbines in residential districts, they are much smaller than the wind turbines we see in the landscape. Wind mills can generate a lot of energy, but a certain wind speed is necessary for a small windmill to be profitable. This is an average wind speed of 5,5 m/s, but in the Netherlands only in the coastal provinces the wind is blowing hard enough (Milieucentraal 2013). Besides that other important disadvantages are that not everybody wants a small windmill in their area, several licences are required to install a wind mill and that a wind mill has high investment costs. Therefore wind mills are not option for dwellings. But it is also possible to place bigger wind mills outside of the district, that can generate energy for the entire district.



### 3.5.4 THERMAL ENERGY STORAGE

With thermal energy storage (“Warmte Koude Opslag”) a certain source is used where heat and cold can be retrieved from. In the Netherlands usually the soil is used as a source, then heat and cold are stored in the water bearing sand layer (aquifer) in the soil. The heat or cold are extracted from the groundwater, then above the ground the heat is extracted from the water by using a heat exchanger, then a heat pump upgrades the heat to a higher temperature and through a low temperature heating system the heat or cold is used to heat or cool the dwelling (Haas et. al., 2011). Usually there are two sources made in the soil, one for heat and one for cold, when heat is needed, the heat is extracted from the hot source and vice versa. In the winter the heat is extracted from the hot source and the exchanger extracts the heat from that water and then the cold is put back in the cold source, see figure 3.2 for this system. In the summer the cold from the cold source is used for cooling the dwelling.

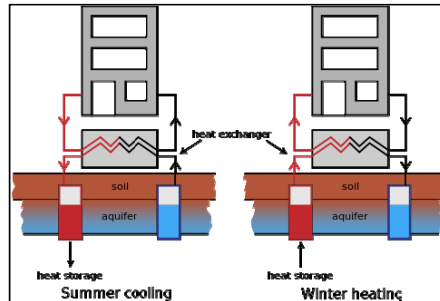


Figure 3.2: Thermal storage (Geothermal genius, 2012)

An advantage of thermal storage is that it is possible to cool the dwelling besides only heating the dwelling. The system is more energy efficient than current heating systems with a heating boiler. When the system is combined with low temperature heating, the dwelling can be heated on a constant temperature, which increases the comfort levels and it has less dust formation. A disadvantage is that the installation of the system, this is more difficult for existing dwellings, because enough space is needed above and under the ground. Another disadvantage that it is possible the sources get exhausted and it is not possible to extract heat from the soil.

## 3.6 INSTALLATION SYSTEMS

When a building is made energy neutral, it is necessary to apply certain installation technical measures. These systems consider heating, ventilation and domestic water systems. The installations should also be improved, because they are not always energy efficient.

### 3.6.1 VENTILATION

When a dwelling has a high insulation level, as in the case with an energy neutral dwelling, ventilation is very important. Otherwise moisture in the dwelling increases too much and the air is getting polluted by daily activities and the people living in the dwelling (Meer met minder, 2012). Good ventilation prevents health and mould issues. Several types of ventilation systems are natural ventilation, central balanced ventilation and decentralized ventilation.

#### Natural ventilation

Key for natural ventilation is the natural air supply from outside air. This can be combined with mechanical exhaust. A simple system can be based on natural air supply of fresh air and mechanical outlet of polluted air, a disadvantage is that owners can close ventilation grates themselves and shut down the ventilation supply (Agentschap NL, 2011a). There are also self-

regulating grates available, that keep the capacity of the system steady independently of differences in pressure. Advantages are that this system has minor inconvenience for the owner, it has minor added costs compared to a regular ventilation grate and thermal comfort improves and a disadvantage is the draft issues (Agentschap NL, 2011a).

### **Mechanical ventilation**

With a mechanical ventilation system the air supply or outlet are regulated automatically. There are different mechanical ventilation systems available. First is central balanced ventilation, where the air supply is regulated central. Another system is a decentralized ventilation system, where the indoor climate is regulated at room level. A general advantage from mechanical ventilation is that ventilation is regulated automatically. Disadvantages are the costs and some adjustments need to be made to the building to place the system. A decentralized ventilation system has as major advantage that the ventilation is regulated at room level and it only ventilates where it is needed and where the people are.

Mechanical ventilation can be equipped with a heat recovery unit, to recover heat from air that is removed and use it to heat air that is coming in. By applying heat recovery heat losses through ventilation are minimized and it has energetic benefits. It is also possible to adjust the ventilation demand to the air quality with a demand regulated ventilation system. The system regulates the demand through CO<sub>2</sub> measuring or it can be time programmed. This system ensures a healthy living climate and will increase the comfort level the most for consumers.

### **3.6.2 HEAT GENERATION AND HOT DOMESTIC WATER INSTALLATIONS**

Heat generation requires a lot of energy, but there are a lot of measures available to reduce energy demand from these systems. This often requires replacing the system with a new one. Heat generation systems that reduce energy demand are low temperature heating and high efficiency boilers. High efficiency boilers are more efficient than older heating boilers, they are already applied in a lot of dwellings and thus this is not a measure that will make the difference to reach energy neutrality. A different system that is not applied in a lot of dwellings is a low temperature heating system. In this system the water temperature is maximum 55 degrees Celsius and therefore uses less energy or gas to heat a dwelling than a standard heating system (Milieucentraal, 2013). This system can be combined with a thermal storage system, because it needs less heat to operate. A major advantage is that the low temperature heating system gives a comfortable radiation heat and therefore gives more comfort than ordinary radiators. A disadvantage is that the system takes longer to heat up and is therefore very useful for rooms that are used constantly and not for rooms that you would like to heat quickly. (Milieucentraal, 2013)

### **3.7 USER-RELATED MEASURES**

A part of the energy that is used is created by the residents themselves, by using appliances and lighting. Consumers can take several measures themselves to reduce energy, besides the building-related and technical measures. Because when energy usage of a building is optimal reduced, energy from residual flows is used and renewable sources are used for energy, the amount of energy needed depends on how much the residents use.

The consumers should change their mind-set, because when a dwelling is renovated to an energy neutral dwelling a lot of things have changed for them. Consumers tend to behave the same in the new situation as they were used to in the old situation (TNO & Except, 2011). While the indoor climate has changed and new installations have been installed, such as heating- and ventilation systems. Their dwelling is energy neutral, but they should not assume that the dwelling does all the work for them. A part of the energy usage in a dwelling is depending on the activities of the residents. So, the residents should also be more aware of the energy they use in a dwelling. Information about how they should use the dwelling and about energy usage must be provided to ensure less energy usage. Something to pay also attention to in the design is the robustness of the system, so when an actual situation differs from the standardized situation, the system continues to function properly (TNO & Except, 2011).

Energy can also be saved by using appliances efficiently using less appliances and discarding old appliances. According to Milieucentraal (2013) 450 kilowatt hour (kWh) of a total average electricity usage of 3400 kWh is used by appliances on stand-by and two-thirds of that can be saved by turning appliances off. But also household appliances such as washing machines, dish washers, kitchen appliances etcetera use a lot of energy. By buying energy efficient appliances energy can be saved. Since a couple of years energy labels are introduced for appliances and you can see for yourself how energy efficient the appliances are. Energy can also be saved by making the lighting more energy efficient. An easy way to save energy is by turning lights off in rooms that are not used. Furthermore lighting can be replaced by energy efficient lamps.

### **3.8 LEGISLATION**

There are a few points within the legislation that concern consumers that want to make their dwelling energy neutral, as an individual or as a collective. In this paragraph offsetting and specific building requirements for sustainable buildings will be discussed.

#### **3.8.3 BUILDING REQUIREMENTS**

Sustainability requirements for dwellings are defined in the building regulations. Currently these requirements are only defined for new built dwellings through the Energy Performance Coefficient. As stated in chapter 1, the EPC for new built dwellings is currently 0,6 and will be 0 in 2020. This means the new built dwellings will be near zero energy buildings.

#### **3.8.1 OFFSETTING**

Solar panels generate energy, the energy can be used in the dwelling and then less or no energy needs to be extracted from the grid. Solar panels generate more power in the summer than in the winter, so it is possible that there is a surplus in the summer and a shortage in the winter. This surplus of energy can be fed back to the grid and for the shortage in the winter the energy will be extracted from the grid.

When a consumer produces more than he uses he may 'resupply' the surplus energy back to the grid (Sunday, 2011). The energy company is obliged to deduct this electricity from the energy that is supplied to the user up to 5000 kWh per year (Sunday, 2011). For example when a household produces 2000 kWh and uses 3000 kWh, then they only have to pay for

the 1000 kWh they have used more than they produced. The energy company pays the consumer the same amount of money for the resupplied energy as they charge for the energy they supply to the consumers. So the purchased energy and the resupplied energy can be offset against each other. The electricity meter keeps track of the energy usage and runs back when energy is resupplied to the net.

When a consumer resupplies more than he uses or when he resupplies more than 5000 kWh, than the energy company should pay a reasonable fee for that part of the resupplied energy (Sunday, 2011). This reasonable fee is much lower and is about € 0,05-0,07 for a kWh (Sunday, 2011). Thus resupplying energy to the grid is beneficial up to 5000 kWh, because up to that amount the energy can be offset. There are a few energy companies that are also offsetting above 5000 kWh, but not all of them guarantee the offsetting or applying higher limits for offsetting (Wij krijgen kippen, 2012).

When electricity is generated by a collective, the electricity is often returned to the net directly, because otherwise a cable must be pulled from the installation to all the users. When it is a collective system there is no private meter keeps track of the supply and resupply of energy. Electricity supplied directly to the net has a low financial yield, because offsetting can't be applied. This is a disadvantage between collective systems and individual systems. There are a few experiments with virtual offsetting, but by legislation this is not yet permitted. When virtual offsetting is permitted then collective generation of energy would have a higher profitability (Wetering duurzaam, 2013). There is an on-going discussion about offsetting and if it is possible for groups and cooperation's that generate sustainable electricity collectively. That is also why the government is allowing experiments with virtual offsetting, to see the effects and to gain experience with it. There is the possibility that virtual offsetting will be allowed in the future.

### **3.9 FINANCE**

When consumers are making dwellings energy neutral there are several financial factors that may concern them. First of all the financing possibilities, this concern mortgages and loans. There are also several subsidies or financing regulations available for consumers when they make the dwelling energy neutral.

#### **3.9.1 LOANS AND MORTGAGES**

There are several loans available for projects that concern making a dwelling more sustainable. These loans have favourable conditions, with for example a low interest rate. The government wants to make it more attractive for consumers to make investments in sustainability. There are also several municipalities that have made a 'sustainability' loan available for consumers who own a dwelling and want to make it more sustainable.

Besides these loans, research from Nibud (2011), national institute for budget information, shows that for consumers who buy an energy neutral dwelling or renovate their dwelling to be energy neutral it should be possible to get an extra mortgage. The height of additional mortgage may add up to € 29.000 for renovations and depends on the increased energy efficiency in energy label steps. The additional mortgage when an energy neutral dwelling is bought is on average € 15.500. This is possible because consumers who live in an energy neutral dwelling do not have to pay the variable costs for gas and electricity, because the

needed energy is generated by themselves. The current financing rates are based on 'average' energy usage, while an energy neutral household has less energy costs. This creates more space in the budget and this makes it possibly more justified to engage in a higher mortgage burden.

### 3.9.2 SUBSIDY

The government provides subsidies and other financing regulations to promote sustainability and to encourage consumers to take energy efficiency measures for their dwelling. The provinces and municipalities also offer subsidies or other finance regulations to stimulate the consumer to participate in making their dwelling more sustainable. These subsidies are tied to the province or municipality where the dwelling is located and can be different for each consumer. A website is set up for the consumers, where they can see themselves what subsidies or other regulations are available for them, this is [www.energiesubsidiewijzer.nl](http://www.energiesubsidiewijzer.nl).

A regulation which is applicable in this research is a tax-reduction for insulation for existing dwellings older than two years that was set by the government. For the labour costs for making the floors, walls and roofs more energy efficient in dwellings older than two years the tax rate of 6% can be applied (Belastingdienst, 2012). This regulation is further explained in appendix 7 about the parameters.

## 3.10 CONCLUSION

In this final paragraph the different measures that were described in this chapter are analysed. The measures are given a score on certain aspects to make it able to compare the different measures with each other. The measures are divided in insulation measures, energy generation measures and ventilation systems, because for some of the measures other criteria have an important role. Two factors are taken into account for all types of measures, these are the costs and the applicability. The applicability is about how well the measure can be applied for an existing dwelling and if there is a lot of inconvenience for the consumers. For the insulation measures the possible height of insulation value and problems for draft and thermal bridges are taken into account as extra criteria. For the energy generation measures the contribution of the measures to the energy neutrality is taken in account. And finally for the ventilation systems the contribution of the systems to a healthy indoor climate is taken in account. The measures are scored for these criteria on a five point-scale from very bad to very good. These score tables are displayed in appendix 1. In this paragraph the measures that are best to use for an energy neutral dwelling are explained. In the appendix all the scores for the measures will be described more in detail.

The best wall insulation to apply is exterior wall insulation, because insulation material with high insulation values can be applied, there are less chances for thermal bridges and there is not much nuisance for the consumers. Only disadvantage is that the costs are relatively high, but the advantages outweigh the high costs. An added advantage is that it is possible to improve the exterior of the dwelling by applying wall insulation. For floor insulation it is best to apply insulation on the bottom of the floor, because a high insulation value is possible, it has relative low costs and there is not a lot of nuisance for the consumers. For roof insulation it is best to apply exterior roof insulation, because there are less chances for thermal bridges and a high insulation value can be applied. By applying exterior insulation for the entire house, the house has put on an insulation coat. By doing this the chances for

thermal bridges are minimized. Because the insulation on the exterior from the roof and the walls can be connected to each other. When the walls are already well insulated it is also good to place new window frames with a high insulation value, this prevents draft, thermal bridges and cold air draught by the windows. The measure has relative high costs, but is also well applicable and high insulation values can be realised. When in a renovation of a dwelling to energy neutral the entire outside of a dwelling is renovated it is also best to replace the door frames of the front and back door by better insulated frames, this will have minor costs and contributes to saving energy.

When the entire outside of a dwelling is renovated, new insulation material is installed on the outside and also the window and door frames are replaced, then draft proofing and sealing cracks and seams can be done during this renovation process. This can save time and money by making sure when all the other insulation measures are applied the draft proofing and sealing cracks and seams are done at the same time.

The energy generation systems that can be best applied for an energy neutral dwelling are the PV-panels and the solar boiler, because they are well applicable on existing dwellings and they have relatively low costs. But the roof must be suited for installation of PV-panels and solar boiler and the orientation of the roof should be good to ensure enough sunlight falls on the panels to generate as much energy as possible.

The ventilation system that can be best applied for an energy neutral dwelling is a decentralized CO<sub>2</sub> demand regulated ventilation system. Because this system provides the most healthy and comfortable indoor climate and it only ventilates the rooms where it is necessary. Heat recovery is applied for the ventilation system, to prevent heat losses through the air that is ventilated.

The package of measures consist of the best insulation for the entire dwelling, generating enough renewable energy and applying a ventilation system. By applying this combination a comfortable dwelling will be created, with a small energy usage and a good indoor climate can be realised. When all these measures are combined it can be possible that a dwelling is energy neutral, in the case study it will be determined if it is possible indeed.

## 4. VALUE CREATION

This chapter examines the created value when dwellings are renovated to energy neutral. The chapter begins with an introduction to value creation in sustainable development. By means of the triple P the created value for people, planet and profit are examined. Finally in the conclusion an overview is presented of the created value when dwellings are renovated to energy neutral.

### 4.1 INTRODUCTION

When projects or areas are developed, value creation has an important role. Puylaert and Werksma(2011) state that the creation of social and financial value for the long term is important in sustainable area development. What an sustainable development is, is explained in the Brundtland report 'Our common future' from the Brundtland commission in 1987. They state that: 'a sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs'(Puylaert and Werksma, 2011). This definition relates to the needs in the present and does not forget the needs in the future. Elkington(1998) based the Triple-P approach on the ideology of the Brundtland commission(Puylaert and Werksma, 2011). The triple P stands for the dimensions People, Planet and Profit. They represent the social-cultural dimension, the ecological dimension and the economical dimension(Puylaert and Werksma, 2011). In sustainable development it is important that value is created on all three of the dimensions and that these values are in balance with each other.

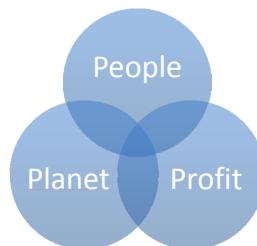


Figure 4.1: Triple P

Value creation also plays a role in investment decisions, it determines the profitability of an investment for the involved stakeholders. For consumers the created value can be a reason to make the investment and therefore it is important that the value creation is insightful. Renovating a dwelling into an energy neutral dwelling requires a large investment, so there should be added value for the consumers to make the investment profitable. The created value when the dwellings are made energy neutral will be examined for the three dimensions of the triple P. People will represent the created value that is user-related, such as increased comfort and restricting inconvenience during the renovation. Planet will represent the created value for the ecological part, such as energy savings, energy usage and energy neutrality. And finally the Profit represents the created value on economical level, such as costs savings and added value. These values will be explained in the next paragraphs, first the role of future value in a sustainable development is explained.

Future value is an added factor in sustainable development, this is also mentioned in the Brundtland definition. According to the Brundtland definition the needs in the future should also be taken in account. The future value is important, because if the investments in the renovation have a low or no future value then the added value and benefits are lower than if the investments have high future value. So the future value of the measures should also be considered when choices are made how a dwelling can be made energy neutral. Future value is thus an important part of the value creation and future value can be maximized when value is created on all three parts of the triple P. When a dwelling is made energy

neutral the renovation measures that are needed should be future-proof, long lasting and innovative to create a higher future value. Also the systems must be solid and they must be able to cope with future changes, such as changes in energy usage or when the dwelling is sold. So the long term value of the measures will play a key role in the decisions for certain measures. Renovating the dwelling is also increasing the future value of the dwelling, because the future value of a dwelling is increased when the condition and the building quality of a dwelling are increased (Otter, 2008).

## **4.2 PEOPLE**

The user-related value, people, is about what the benefits are for the residents. These are benefits that do not consider the ecological or financial part. The benefits consider an increase in the quality of living, such as an increase in comfort and a healthy living environment. The higher goal of making a dwelling energy neutral is not only saving energy, it is also about creating a comfortable, healthy, safe, practical and affordable dwelling (TNO & Except, 2011). The user-related values are more social values and are difficult to measure in exact numbers. Besides that is the perception of living quality different for everyone. That the user-related values are more softer values does not mean that they are less important, they can play an important role in a decision to make an investment. This paragraph discusses created value for the living quality and creating value during the renovation process.

### **4.2.1 QUALITY OF LIVING**

A dwelling has a key role in the living quality of people, it provides one of the basic needs, a roof over their head. A healthy and comfortable indoor climate of a dwelling has a high value for the consumers. When a dwelling is renovated it is also possible to improve the indoor climate of the dwelling which results in an increase of the quality of living. When energy saving measures are properly applied, they can provide more comfortable and healthier buildings (Agentschap NL, 2010). Especially the measures that belong to the first step of the Trias Energetica, that reduce the energy demand, can improve comfort greatly (Agentschap NL, 2010). By insulating a dwelling draft is limited and sound proofing is improved, which benefits the comfort in the dwelling. When a dwelling is insulated, the air quality must be regulated by installing ventilation systems. It is possible to improve the indoor climate by applying a ventilation system which regulates the air quality. A system that is CO<sub>2</sub> demand regulated can provide a good quality of air, by supplying enough fresh air and draining CO<sub>2</sub>. Another option is to regulate the heat flow through heating system which creates a comfortable and constant indoor temperature. Thus added value can be created by applying insulation, a ventilation system or regulating the heat flow. In particular by combining insulation and a ventilation system a comfortable and healthy indoor climate can be realized.

### **4.2.2 VALUE DURING THE RENOVATION PROCESS**

Renovating a dwelling can give a lot of inconvenience for the residents. The inconvenience of a renovation is a negative factor for the residents when they choose measures to renovate their dwelling. When this inconvenience can be limited, the comfort during the renovation rises and value on that level is created.



It is possible to renovate the dwelling when the dwelling is inhabited. This can be done in different ways, such as the traditional way and the fast way. In the traditional way the work is spread as much as possible over the renovation period, so that the least amount of work happens at the same time and the residents can live their normal life as much as possible (Werf, 2011). In the fast approach the work will be completed as soon as possible, the residents will have more inconvenience, but for a shorter period of time (Werf, 2011). Then one day can be used to execute all the major work and a few days before and after can be used to do all the preparations for the work. It is in both situations important that the dwelling is liveable during the evening and night, residents should be able to use the toilet and have to be able to sleep normally (Werf, 2011). By shortening building time there will be more discomfort for a few days, but after that normal life can continue and this creates extra value. Renovation in inhabited state is less possible when floors should be changed too, because this requires moving out all the furniture and increases inconvenience a lot. The choices for certain measures can also depend on the amount of inconvenience for the owners, when inconvenience is high for a certain option this can be a disadvantage for choosing that option. An option with minor inconvenience can be a better option even when the costs are a bit higher.

From an inquiry in the research from Werf (2011) is stated that for home-owners some inconvenience for one week is acceptable. Having no access to gas, water or electricity and no normal toilet are the least acceptable inconveniences, but this is mostly considered acceptable for only one day. The inconvenience of a fast renovation seems acceptable therefore and is a good option to apply for renovation. A lot of providers of building work or installations offer solutions that can be executed as fast as possible with a least amount of nuisance for the residents.

### **4.3 PLANET**

The ecological value, planet, considers the possible energy savings and energy usage. 35 % of the energy usage in the Netherlands is for the account of buildings and almost half of this amount is used by households (Agentschap NL, 2012c). This indicates that households use a large amount of energy and there is high energy saving potential for these households. The ecological value when a dwelling is made energy neutral can be measured by the amount saved energy and the dependency on fossil fuels. Especially when a dwelling is made energy neutral the benefits on the part of planet are high. The dwelling will have less CO<sub>2</sub> emission, saves a large amount of energy and for the remaining part of energy that is needed renewable energy is generated. In this paragraph the energy usage of a household and a forecast of energy sources will be discussed. The energy usage is also where the added ecological and economical value for a dwelling connect, because the energy usage is connected with the energy costs. In the paragraph about profit a closer look will be taken at the energy costs.

#### **4.3.1 ENERGY RESOURCES**

Most dwellings are depending on the use of fossil fuels for their energy, but this dependency should be avoided. Energy from fossil fuels will become scarcer and more expensive, the sources are depleting, while the demand is increasing globally (Agentschap NL, 2012d). In energy trends 2030 (Capros et. al, 2010) a prediction is made of the increase of the average global fossil fuel price as displayed in figure 4.2. It should be noted that these prices are

average for the world, prices in the Netherlands are relatively higher. The figure shows that the prices of fossil fuels will be rising. The exact increase in price is hard to determine because it is related to several factors, thus the increase may differ from the figure. Theories about the increase in price differ from very high increases to almost no increase at all, therefore it is important to take several growth rates in account when making calculations.

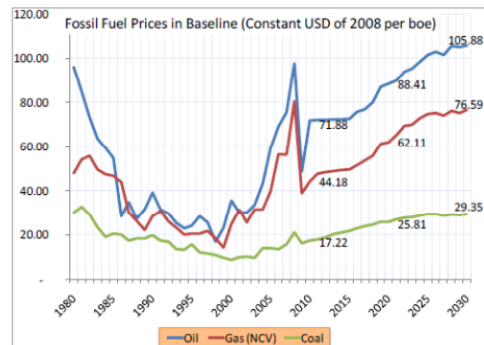


Figure 4.2: Increase in fossil fuel prices (Capros et al, 2010)

Reducing the energy usage in the built environment and using energy from renewable sources reduces the dependency for energy on fossil fuels and CO<sub>2</sub> emissions will decrease significantly (Agentschap NL, 2012d). When a dwelling uses as less energy as possible and is not depending on the use of fossil fuels, added value can be created. Because then the energy usage of an energy neutral dwelling is no longer depending on the use of fossil fuels and the dwelling can generate its own energy.

#### 4.3.2 ENERGY USAGE HOUSEHOLD

A lot of energy can be saved by renovating dwellings into energy neutral dwellings. The average energy usage by type of dwelling is displayed in table 4.3. This shows that dwelling types that have on average a larger surface also have a higher energy usage and then the energy saving potential is even higher.

	Gas (m <sup>3</sup> )	Electricity (kWh)
<b>Average for all types</b>	1850	3300
<b>Apartment</b>	1250	2250
<b>Row house</b>	1700	3350
<b>Corner house</b>	2000	3500
<b>Semi-detached dwelling</b>	2400	3950
<b>Detached dwelling</b>	3100	4550
<b>Dwelling type unknown</b>	1700	2900

Table 4.3: Average energy usage by dwelling type in the Netherlands 2010 (CBS, 2012)

By reducing the energy usage and using energy from renewable sources for the remaining amount of energy, will result in a decrease in CO<sub>2</sub> emissions. Less CO<sub>2</sub> emission will reduce the environmental impact of a dwelling. The environmental impact of an energy neutral dwelling can be near-zero during the use phase, this is better for the environment and reducing the climate change. DHV, ECN &TNO (2007) made a comparison between four dwellings, as shown in figure 4.4, the figure gives an overview of possible savings related to CO<sub>2</sub> emissions. The figure clearly shows the savings on account of space heating that can be realised with a passive dwelling.

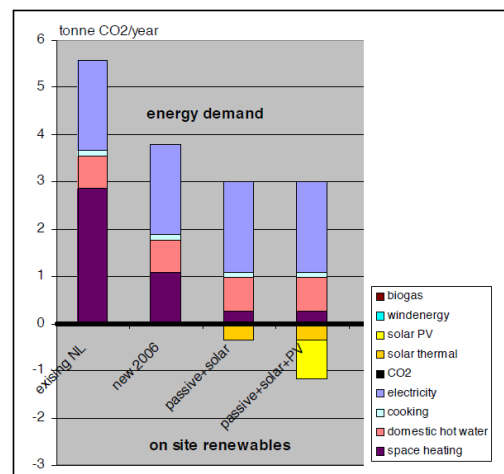


Figure 4.4 Comparison potential energy savings (DHV, ECN & TNO, 2007)

An energy neutral dwelling will even save more energy and CO<sub>2</sub> emissions, because an energy neutral dwelling extracts on a yearly basis net zero energy from the net and if energy needs to be subtracted from the net this needs to be compensated by 100% renewable energy on a yearly basis. This means that an energy neutral dwelling do not uses energy from fossil fuels and only uses renewable energy. This has consequences for the costs of energy, these will be zero when a dwelling generates its own renewable energy. The added value is that no fossil fuels are needed, the CO<sub>2</sub> emissions of a dwelling will decrease and there will be no energy costs. In the next paragraph a closer look is taken at the energy prices and the future expectations.

#### 4.4 PROFIT

The economic value, profit considers the financial part of renovating a dwelling to an energy neutral dwelling. Factors such as value of a dwelling, investment costs, mortgage payments, energy costs and savings, payback period and other costs such as maintenance all play a role in the economic value of a dwelling. These factors are connected and have an influence on each other. To create an overview of the economic value all these factors should be taken in account. These housing costs, the renovation costs and the value of a dwelling will be explained in this paragraph.

##### 4.4.1 HOUSING COSTS

Housing costs are the fixed costs of living, the costs of being a home-owner. But not all of the housing costs will be influenced by renovating a dwelling to energy neutral. The housing costs that are influenced are the energy costs and the maintenance costs. Other housing costs that are not influenced are municipal taxes and possible payments for a current mortgage, because these costs are not influenced they will not be discusses in this report.

The main housing costs that are influenced by making the dwelling energy neutral are the energy costs and they play a key role in this research. Energy costs are built up from several components, delivery costs, network costs, meter costs and taxes (E.ON Benelux, 2012). The delivery costs are the costs charged for the delivery of the consumed amount of energy, a fixed amount for administration of the supply and transport of energy. Network costs are the costs for managing the network, the cables and pipes and the connection. The network costs are determined by the government and the supplier charges them directly to the consumer. The meter costs are costs for metering services, meter rental and usage and maintenance of

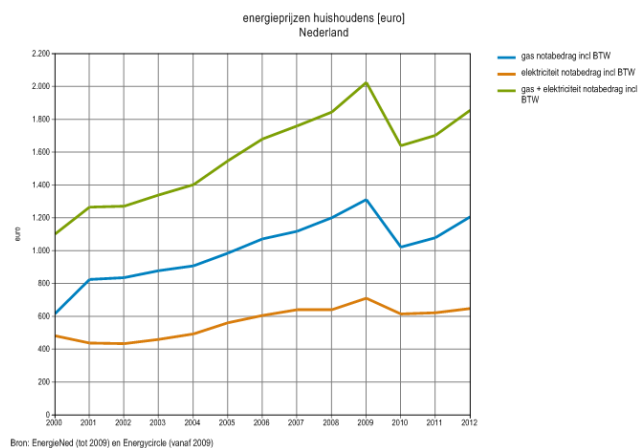


Figure 4.5: Increase in energy prices compared to the year before (Sentervovem, 2013)

the gas- and electricity meters. Besides those costs also taxes and VAT are part of the energy prices. They are determined by the government, they want to stimulate a lower energy usage through the taxes, so these are relatively high.

As mentioned in paragraph 4.3.1 the prices for fossil fuels have been increasing over the past years. The energy we consume is mostly generated from these fossil fuels, thus an increase in prices for fossil fuels also indicate an increase in energy prices. In figure 4.5 the increase of gas and electricity prices over the past years are shown. This figure indicates that prices for gas and electricity fluctuate a lot, they are subject to market changes and are influenced by energy companies. Based on the expectation for the increase in fossil fuel prices in paragraph 4.3.1 the conclusion can be made that the energy prices will also increase. Although there is a lot of uncertainty about the future of energy prices it becomes clear that the energy prices will keep increasing in the future.

When the energy costs are increasing the housing costs will also be increasing. Thus when there are no energy costs for an energy neutral dwelling this will be an added value. Because then the costs do not depend on the energy prices, and the uncertainty about the future energy prices. Consumers will have more certainty about their housing costs, because they know the cost will not increase and they have fixed housing costs.

Other costs that occur for a dwelling that are maintenance costs. Home-owners should have maintenance carried out for their dwelling regularly to keep it up-to-date. These costs do not occur every year, but once in the few years and the costs are different for each dwelling. Installations that are installed in the dwelling also need regular maintenance, so they work well.

#### **4.4.2 RENOVATION COSTS**

When a dwelling is renovated an investment needs to be made. This investment can be financed from own capital or by means of a mortgage. The housing costs are increased when a mortgage is taken out for the renovation, because monthly payments have to be made for the mortgage. Dwellings are often bought by means of a mortgage, but sometimes the dwelling is financed entirely or partly by own capital (COELO, 2012). COELO (2012) calculated average housing costs and they found that more than half of the average housing costs consist of mortgage costs. Throughout the duration of the mortgage the home-owners must make mortgage payments, consisting of repayment and interest of the mortgage. These monthly payments will be added to the total housing costs. When an investment for the renovation is made it is likely that a mortgage is needed to finance the investment, because most consumers do not have the amount of money to pay for the renovation. This also indicates that housing costs will increase with the mortgage payments. The height of the renovation costs and thus the height of the mortgage payments will depend on the kind of measures that are applied in the dwelling and how much they cost. For renovating a dwelling to energy neutral these costs will be relative high, because a lot of extensive measures need to be applied to reach energy neutrality.

#### **4.4.3 VALUE OF A DWELLING**

An energy neutral dwelling is not a standard dwelling and therefore the value of the dwelling should be approached different. Taking measures to make a dwelling energy neutral are not

only about investment costs and payback period, but also about a higher quality, independency of fossil fuels and a higher comfort level (Agentschap NL, 2010). When a dwelling has a higher quality, the higher financing costs can be accepted, when the eventual housing costs are lower and more stable by a significantly reduced energy bill (Agentschap NL, 2010). By renovating a dwelling into an energy neutral dwelling the quality rises and the lifespan will be expanded. Thus renovating a dwelling is also about value retention, because aging process of the dwelling stopped and the dwelling is updated.

The value of a dwelling is determined through valuation. Most residents do not have to deal with their dwelling value daily, mostly with buying or selling the dwelling. The most important factor of determining the value of a dwelling is the location, housing prices in the Netherlands can differ greatly per region. Other factors that have an influence on the value of a dwelling are the physical and environmental characteristics of the dwelling, such as the lay-out, the state of the dwelling and the neighbourhood. The physical and environmental characteristics of a dwelling are more important to consumers than energy efficiency when a dwelling is bought (Groenestein, 2011). Also the price and affordability have an important role in buying a dwelling, but the factor energy does not play a key role (Groenestein, 2011). But people are becoming more aware of the energy efficiency of their dwelling. This increased since energy labels were introduced for dwellings, these energy labels give an indication of how energy efficient a dwelling is. Is this increasing awareness reflected in the value of a dwelling or not? This paragraph discusses how the value of an energy neutral dwelling can be measured, the added value and the willingness to pay for an more energy efficient dwelling.

### **Measuring value**

Current methods that measure energy performance or value, such as energy labels (EPA and EPC) and valuation reports give little or no information about actual energy usage of dwelling, not to mention about future expectations for the energy usage and therefore give little guidance on valuation and decisions about renovation (Avelino, Loorback & Witkamp, 2011). This has as result that consumers do not have an overview of the effects of energy efficiency and can't create an overview of the effects of renovation decisions. It is time for change of mentality regarding the valuation process, professionals should incorporate energy efficiency in their valuation in the future. But there is no consensus about the factor sustainability in determining the value of real estate (Berkhout, G., 2010). Therefore it will take a while before energy efficiency will be fully incorporated in the value and all the stakeholders should cooperate to make the change happen. The value of a dwelling is not only based on valuations, the transaction price represents the real price of a dwelling and this is also based on what people think a dwelling is worth and what they are willing to pay for the dwelling.

### **Added value**

So although energy efficiency is not incorporated in the valuation, does the value of the dwelling reflects in the energy efficiency of a dwelling? According to research from NWBO (2008) an energy efficient dwelling has a higher selling price. The research shows that better insulated dwellings with a high energy label (A, B or C) have a higher selling price than poorly insulated dwellings. The influence of an energy label on the value of a dwelling can be that a higher energy label indicates lower energy costs and that for an older dwelling it

means that there were recent investments for improving the dwelling (NWBO, 2008). Besides that people search more for dwellings with acceptable housing costs and the rising energy prices have a big influence on these costs (NWBO, 2008).

Research from Brounen and Kok (2009) also shows that an energy performance certificate affects market value. It shows that dwelling with a green rating (i.e. A, B or C) has a higher value, of about €8.395 more, than a dwelling with a D-rating or lower. This higher value can go up to €30.000,- when the difference between the dwellings is large. They cannot determine that these effects are caused by the effects of labelling itself or by the effects of energy savings. And research from (Groenestein, 2011) shows that an energy efficient dwelling has a higher (direct and indirect) value compared to a standard dwelling according to real estate professionals. Brounen and Kok (2009) also indicate that the effects from the changing economic climate on the valuation of energy efficiency in the housing market must be awaited. Since the economic crises the housing market collapsed and prices of dwellings have dropped. The dwellings have less value than a few years ago and it is harder to sell dwellings. The recent crisis have learned us that the value of a dwelling is hard to predict on the long term. The future expectations for dwelling prices are uncertain, it is possible that dwelling prices will drop even further.

#### **Willingness to pay**

Research about the willingness to pay for an energy efficient dwelling indicates that respondents are willing to pay about €5.000,- more or 5% of the cost covered selling price (Groenestein, 2011). Luijten et. al (2010) concludes also that consumers are willing to pay extra for energy efficiency in a new built dwelling when the energy bill is indeed lower, the height of the investment can vary from € 5.000 until € 30.000. Their research shows that consumers are willing to pay between the € 5.000 and € 10.000 more for an energy neutral dwelling unconditionally. Investments above that have predetermined conditions, such as a certain payback period and a lower energy bill, then consumers are willing to pay an average € 15.000 more for energy efficiency measures (Luijten et. al, 2010). These researches have indicated that consumers are willing to pay more for more energy efficient dwelling and that consumers realize it has added benefits in it for them. Thus, consumers are willing to pay for energy efficiency measures as long as they are well informed and when a reduce of the energy bill and a certain payback period are guaranteed.

#### **4.5 CONCLUSION**

In this chapter the added value of renovating a dwelling to energy neutral are identified. In table 4.5 an overview is given of the created value. There are several studies that show that the financial benefits of an energy efficient dwelling are most important for consumers and they are followed by the factors comfort and health (Groenestein, 2011). Another important characteristic is the environmental awareness, but this is not valued financially (Groenestein, 2011). This indicates that most important value for consumers is the financial value, followed by the user-related value and then the environmental value.

The added value for profit aspect are an increased value of the dwelling, a decrease in housing costs and more stable housing costs. Evidence from literature states that an energy neutral dwelling has a higher value than a standard dwelling. This value can be between € 5.000 and € 10.000, but it can also be higher. But the remark should be made that the value

of a dwelling is hard to predict and that future prices are uncertain. The housing costs also have decreased and have become more stable, because the energy costs have decreased. When housing costs are more stable consumers know exactly what their future expenses are and they have more certainty about their financial situation.

The most important added value for people aspect is the improved indoor climate, since draft is limited and a healthy indoor climate can be regulated by a CO<sub>2</sub> demand regulated ventilation system. This improves the living quality of the consumers, because the quality of the indoor climate is increased. It is also possible to create added value during the renovation, by making sure the inconvenience for consumers will be minimized.

The added value for planet aspect is that a the dwelling is no longer depending on fossil fuels, the energy usage has decreased and for the remaining amount of energy renewable energy is generated. Consumers no longer depend on suppliers of energy and changes in the energy market, they generate their own energy and are more independent. Another added value for planet are the decreased CO<sub>2</sub> emissions.

Table 4.5: Overview of the created value	
<b>People</b>	Improvement indoor climate and a higher living quality Added value during the renovation process when there is less nuisance for the consumers
<b>Planet</b>	No more use of fossil fuels and less CO <sub>2</sub> emissions Less energy usage and using only renewable sources
<b>Profit</b>	Decrease in housing costs, by a decrease in energy costs More stable housing costs, no longer dependent on increasing energy costs Increase in dwelling value





## 5. RENOVATING DWELLINGS AS A COLLECTIVE

When home-owners are going to renovate their dwellings together extra advantages can arise. This chapter is about home-owners that want to renovate their dwellings as a collective into more energy efficient dwellings. The possible advantages and disadvantages will be discussed in this chapter. But first is explained what renovating dwellings is all about and if there are existing initiatives.

### 5.1 INTRODUCTION

Initiatives to renovate dwellings as a collective have a large potential for home-owners, because they don't need to figure out and organize the renovation themselves (Van de Werf, 2011). There are several initiatives of consumers in the Netherlands that want to make their dwellings more energy efficient. Some of them are initiated by the government or other businesses and some of them are initiated by the home-owners themselves. Some examples of initiatives will be described shortly.

#### **Wetering sustainable**

In the Wetering district in Amsterdam old and monumental buildings are made energy neutral. The initiative is set by the inhabitants and they are also the ones in charge of the project and making the choices for energy efficiency measures themselves. They have guidance from technical and financial experts and some inhabitants of the districts. One of their goals is to ensure the investments are not higher than what their energy costs are now. They also search for innovative measures to make their dwelling energy neutral without compromising the historical character of the buildings.

#### **'Lokaal alle lichten op groen'**

The project locally all lights turned green is a encouragement program from Energiesprong|SEV with as goal to improve the market conditions for energy neutral renovations. Several practical experiments are initiated where at least 120 dwelling are renovated to energy neutral to learn about the possibilities and barriers for energy neutral renovation. They work together to scale up the local demand for renovations and to realize an adequate supply to fit it, which consists of new technical, financial and organisational arrangements (Energiesprong, 2012).

#### **Sustainable Zwaag**

This is an initiative by consumers and they want to make dwellings more energy efficient in the Fruit-district of Zwaag. The initiative focuses first on measures that reduce the energy demand, because with those measures the most profit can be realised. Their goal is to save a considerable amount of energy in two years and the consumers are assisted by professionals. Besides smart building technical measures, they also look for favourable financing and collective buying options.

When consumers join these initiatives it is not always clear up front what their benefits are. They know there are benefits, but not exactly and they join partly from an ideological point of view. This results in the fact that not all the home-owners want to join the initiative, because they are sceptical about the eventual benefits for them. And when consumers cooperate scale advantages can occur, which results in benefits for them.

## 5.2 COLLECTIVE ENERGY EFFICIENCY MEASURES

When consumers are cooperating it is also possible to apply installations that generate energy collectively. Options that can be considered for an existing district are a heating district, geothermal heat, wind energy, collective solar panels and collective heat recovery.

### Heating district

A heating district is a network that distributes the heat in a district. The heating network uses a heat source from where heat is provided. This heat can be generated from different sources, options for renewable energy are a large biomass installation or geothermal heat. A disadvantage is that it is more difficult to install a heating district in an existing district, this will have added costs and inconvenience for the consumers.

### Geothermal heat

Heat from the earth is used in a geothermal heat system. The principle of geothermal heat works about the same as thermal energy storage, but now the heat is retrieved from deeper in the soil and the heat is warmer about 50 – 70 °C (Agentschap NL, 2011b). Hot water from about 2 kilometre depth is pumped up and used to heat dwellings, the cooled down water is pumped back in the soil. Geothermal heat system has large sources and a large capacity to for heating a larger amount of dwellings. Disadvantages of this method are that the installation of the source gives inconvenience for the local residents and that it has very high installation costs. Besides that a heat distribution network would be necessary to distribute the heat to the dwellings.

### Wind energy

A large wind turbine would generate enough energy for an entire district. It is a possibility to place the wind turbine outside the district. But there are several regulations that need to be taken in account before a wind turbine can be installed. Disadvantages are that people often do not want a windmill in their backyard and a wind turbine can give shadow over surroundings of the windmill. It is also necessary that the generated electricity should be distributed, this is only profitable when virtual offsetting is permitted.

### Collective solar panels

Consumers can put solar panels on their roofs, but this is only an individual measure. Another option is to place solar panels in a field, so they can form a solar panel farm. By doing this the solar panels can have an optimal orientation and generate a maximum amount of energy by panel. In Spain and Germany these large solar energy installations have been realised, they have a surface of thousands of square meters and they can generate up to one megawatt-peak of electricity (Milieucentraal, 2013). Disadvantage of these systems is that they take a large amount of space and it must be possible for virtual offsetting to let it be profitable for consumers.

### Collective heat recovery

In a dwelling there are several water waste streams that still contain an amount of heat when they leave the dwelling. Such as heat from a washing machine, a dishwasher or from the shower. This heat can be re-used when heat recovery would be applied. It is possible to collect these hot water waste streams from a group of dwellings, then at a central point the heat can be extracted and that heat can be resupplied to the dwellings. Then in a dwelling

less or no energy is needed to heat the water for a shower, washing machine or a dishwasher.

### 5.3 ADVANTAGES

There are several advantages that can be gained from cooperating as home-owners to make their dwellings more energy efficient. These can be categorized in organizational, financial and other benefits. An organizational advantage of cooperating is that consumers do not have to figure out the details of the renovation themselves, such as the several measures to make a dwelling energy neutral or which contractor they should contact. The cooperation can manage the renovation process, figure out which measures should be carried out and select which contractors will execute the renovation.

Scale advantages occur when consumers form a collective, costs will be lower and additional organizational benefits can occur. General project costs that occur for each project can be shared, such as design, management and advice. Costs will be lower because the dwellings are renovated on a larger scale. Costs for materials will be lower, because these can be purchased on a large scale. The construction work can be executed in serial by the contractor, because more of the same work needs to be executed in the same time period. The serial aspect of the work will lead to lower costs. Standard solutions can be made for each dwelling and a total renovation package can be offered, which has lower costs and can be executed fast in serial.

When consumers cooperate collective financing is possible, this has as benefit that favourable financing conditions can be realized. Banks or other companies can back up or guarantee the financing or finance a part of the renovation themselves with a certain payback time. This makes it easier for households with less money to participate in the renovation. And also less risk will be involved when other companies guarantee the investment. Paragraph 5.5 looks into possible cooperation forms and collective financing options.

There are also other benefits besides the organizational and financial benefits. When the dwellings are renovated as a group there will be social pressure to join the renovation project (Van de Werf, 2011). When more people will join the renovation, it will be possible that an entire neighbourhood can be made energy neutral. Then it is also possible to renovate other aspects of the neighbourhood next to renovating the dwelling, so the quality of the neighbourhood will improve. Then it is possible that a municipality can join the renovation and help with the renovation of the neighbourhood. Also by renovating the outside of the dwellings the exterior of the dwelling can improve and this also improves to quality of the neighbourhood. By realizing the renovation into energy neutral dwellings as a collective it is also possible to use collective energy sources, such as a heating district or wind power. This has as advantage that renewable energy can be generated on a larger scale and that the costs for the installations can be shared.

### 5.4 DISADVANTAGES

Besides the advantages from cooperating there are also some disadvantages. When construction work is executed in serial, there are less possibilities for individual exceptions, because this will cause an increase the costs and the scale benefits will disappear. The

individual consumers will have less options to choose from and standard solutions can be applied. Consumers must discuss with each other on several aspect of the renovation and possibly need to make compromises. When consumers have different opinions and cannot agree, disadvantages will occur. Also when consumers set up a cooperation there are often additional added costs involved. But these will be most of the time lower than the cost benefits, when the number of people that join the cooperation is large enough. Also when collective heating is used the heat cannot be set individually, this is a disadvantage because no consumer is exactly the same.

## **5.5 COOPERATION AND FINANCING**

As discussed before in this chapter there are several organizational and financial benefits that can be gained from cooperating. This paragraph examines possible cooperation forms and financing structures for collective renovation. And examines the possibility of financial scale benefits.

### **5.5.1 COOPERATION FORMS**

There are several cooperation forms possible when consumers want to cooperate as a collective. In this paragraph the cooperation forms are discussed that do not have a financing regulation within them. Other cooperation forms that do have a financing regulation in them are discussed in the next paragraph.

#### **Collective private commissioning**

A cooperation form is collective private commissioning, where consumers form a legal entity and cooperate together as a client. Collective private commissioning is a not yet a common form of commissioning, especially for renovation, but there are several benefits that occur from cooperating. Because of the changing market the popularity of private commissioning is rising, the focus is more and more on new construction on a smaller scale and renovation (Platform 31, 2013). For this method there are no specific financing regulations attached.

#### **Home owners association**

Home owners can also cooperate in a home owners association. This association then can act on behalf of all the participants, they can take loans out and use then for the energy efficiency measures. This home owners association can take work out of the hands of home owners and take decisions for them. This construction is already often used for apartments for standard maintenance and lighting in the common areas in the apartment building for example. This cooperating form does not have any added benefits besides organizational.

### **5.5.2 COLLECTIVE FINANCING REGULATIONS**

#### **Energy service company (ESCo)**

An energy company is an organisation that provides energy services and also invests and take risks by taking energy efficiency measures (Vethman, 2009). The company can finance the energy efficiency measures and supply energy to the home owners. The home owners can have a long term contract with the company, they then will make yearly payments for the energy costs and the energy efficiency measures. This can be done under an Energy Performance contract, which means that a certain amount of energy savings are guaranteed. Then home owners can be sure their energy costs are lower and from the difference they

can pay the ESCo a compensation fee for the investment. An ESCo often has a third party that finances the investments and the ESCo is the company that takes care of the organization and management of the financing and energy supply. A disadvantage is that there is little experience with ESCo's for private home owners. Vethman(2009) categorizes ESCo's for home owners as risky and difficult to control, because these contracts are more difficult.

#### **Finance by an energy company**

It is also possible that a financing construction can be made together with an energy company. Where the energy company can finance together with a third party financier, the energy company then can act as an intermediary who provides advice for the client, the installation and the financing of the energy efficiency measures (Vethman 2009). The payment for the energy efficiency measures is made by the energy bill, this does not decrease when the energy efficiency measures are applied, so the money that is paid too much is used to repay the loan(Vethman 2009). This is also called on-bill financing.

#### **Shares in a property**

A new kind of financing regulation is issuing shares in a property. Consumers can form a cooperation, which is responsible for the renovation to energy neutral and the financing. This cooperation then can issue shares in the cooperation, this way it is possible for a lot of investors that take a part in financing the renovation. The shareholders get every year a certain amount of money back until at the end of the financing period they earned all their money back. The consumers will make yearly payments to the cooperation to pay off their loan. For example in the United States of America the local government issues bond in renewable energy projects, then the owner pays back the loan through a tax bill for a specified term(Würtenberger et al., 2011). When the home-owners move out of their house the loan they need to pay off belongs to the house and is transferred to the new home-owner. This has as benefit that when consumers can make a large investment even though they move out of the dwelling during the term the repayments of the loan and then not all the costs of the renovation are for them, but only the costs for that period of time.

#### **Cooperation with commercial companies**

A new kind of financing cooperation is that consumers and commercial companies cooperate. In a renovation several commercial properties are involved, such as a contractor, material suppliers and installation companies. These companies can cooperate to form a cooperation which carries out the entire renovation for consumers. They then can take also the management and the financing on them. These companies can finance a part or the entire renovation for favourable conditions for the loan that consumers need to pay back. In the current economic climate companies are searching for work and this can give them a certain amount of work and benefits over a period of time, because the consumers are paying back the loan over time. This has as benefit for the consumers that the financing is more favourable and the organization is done for them. This has also a benefit for the local economy when local companies are involved, because it provides them with work in the current difficult economic climate in the construction industry.

### 5.5.3 FINANCIAL SCALE BENEFITS

When dwellings are renovated as a group, the renovation of the dwellings can be carried out using a project based approach. A project based approach means that all the dwellings will be renovated in the same way, with minor differences between the individual dwellings. For a contractor this is easier, because the work can be carried out in serial. Agentschap NL (2011c) used difference prices for measures between individual and serial based measures to calculate the total price for installing measures. These figures for the project based approach are lower than for the measures for the individual dwellings. So cooperating to realize a renovation for a group of dwellings can have financial benefits.

### 5.6 CONCLUSION

Thus there can be a lot of added benefits in cooperating, these benefits are summed up in table 5.1. These benefits weigh up to the small disadvantages of minor possibilities for individual exception, added organizational costs and difficulty with deliberating and making decisions with a large group of consumers.

The organizational benefit is that the management is outsourced and consumers do not need to worry about all those details. Several cooperation forms are possible when consumers want to cooperate. There are also some forms where other companies, such as the energy company and contractor are involved, which can add favourable financing to

**Table 5.1: Overview of benefits of cooperation**

<b>Organizational</b>	Outsource management
	Help with figuring out details
<b>Financial</b>	Lower costs renovation costs
	Favourable financing regulations
<b>Other</b>	Improving the quality of the neighbourhood
	Group pressure in participating in the renovation.
	Collective generation of energy

the cooperation benefits. There are also lower renovation costs when the scale is larger at which the renovation is carried out. Favourable financing construction can be set up when a large group of consumers take part in the renovation. This can give lower costs on a loan and consumers do not need to finance the entire renovation at once.

Other benefits when dwellings are renovated collectively are that the quality of the neighbourhood is improved. Because the exterior of the dwelling is improved and when the entire neighbourhood participates then the rest of the neighbourhood can be updated to besides only the dwellings. When a lot of people are participating in a renovation the group pressure increases for the neighbours to participate to. They can convince each other to participate in the renovation.

There are several options that can generate energy for a collective, these are large installations that can generate enough energy to supply an entire district. However they are expensive and they cannot always be installed that easily in existing situations. For every district it should be determined if the collective energy generation is a realistic option. This also depends on the amount of consumers that participate, because if costs are high a lot of consumers must take part when it would be profitable and the option should generate enough energy.

## 6. RESEARCH METHODOLOGY

This chapter will discuss the research methods that can be used for the case study in this thesis. A case study will be carried out to gain insight about the value creation for consumers when they renovate the dwelling as a collective. The goal of the case study is to create an overview of the benefits for the consumers and what the added value is when the renovation is done as a collective.

In the first paragraph several methods will be discussed that can be used to provide an overview of the benefits and costs of consumers. A method will be chosen that can be used in the case study. In the second paragraph several methods are described that can determine the energy neutrality when a dwelling is made energy neutral and also a method will be chosen that will be used in the case study.

### 6.1 FINANCIAL MODEL

There are several methods that can be used to create a financial overview of the costs and benefits involved in the renovation, some of them are more suited than others. To determine which financial method is most suited for this case study, the financial method needs to meet several requirements.

- The method should give insight in the different cash flows.
- It must be able to include different kinds of costs and benefits.
- The costs and benefits included in the method must represent the costs and benefits that are influenced by the renovation.
- It has to be possible to determine the examined period of time up front.
- It must be possible to compare different kinds of scenarios.

The methods Cost Benefits analysis, DCF and NPV, Life cycle costs, Valuation, Total Cost of Ownership, Payback Period, Real Option Analysis and Return On Investment will be described in the next paragraphs. The last subparagraph will describe which method will be applied in the case study to model the financial situation of a project.

#### 6.1.1 COST BENEFITS ANALYSIS

The Cost Benefits analysis is a method that can be used to calculate and compare the costs and benefits of a project over a longer period of time. In this method all the costs and benefits need to be expressed in monetary terms, thus a value must be assigned to the social costs and benefits that occur. The method can be used for the justification of a project or determining the feasibility of it. The costs benefit analysis can also be used for making comparisons between projects. The total expected costs can be compared with the expected benefits and then they can be compared with each other to determine which project has the most benefits or the lowest costs in the end. So the alternative with the highest social benefits combined with relative low costs can be selected. In this method it is also important to do a sensitivity analysis of the occurring events. By doing this the chance of a certain outcome can be determined and it also becomes clear if an outcome depends on certain values. An advantage of the method is that the future values will be discounted to the present, thus the time value of money will be incorporated. Another advantage is that it is possible to incorporate external factors such as the environment in the analysis if that is

needed. A disadvantage of this method is that to all the involved costs and benefits must be valued financially and for some of the social costs and benefits it is hard to determine a justified value.

### 6.1.2 DISCOUNTED CASH FLOW METHOD

With the discounted cash flow method the value and of a project can be determined. This gives insight in the feasibility of a project and can be used to determine if a project is worth investing in. This method uses the time value of money to discount all the estimated future cash flows to their present value. The following formula is used to discount all the cash flows:

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \dots + \frac{CF_n}{(1+r)^n}$$

CF = Cash flow

r = discount rate

n = number of years

With this DCF method the Net Present value(NPV) of a project can be determined, this represents the current value of a project. The NPV can be calculated by taking the sum of all the discounted future cash flows, the in- and outgoing cash flows. When the DCF method is used, assumptions need to be made about several parameters, such as the discount rate and the interest rate. A disadvantage of the method is that the quality depends on the accuracy of the assumptions for these parameters. Because the outcome depends on these parameters and the outcome can vary greatly when small changes in the parameters are made. An advantage of the method is that insight is gained about the different cash flows that are involved in the project and their value in the present. Another advantage is that the method gives a close to real value and the method is widely used in financial management and real estate development.

### 6.1.3 LIFE CYCLE COST ANALYSIS

A life cycle cost analysis examines all the costs over the entire life cycle of a product, structure or system. The life cycle and life phases play an important role in this analysis, the product will be examined from the initial phase until the disposal phase. The costs for the initial investment, operation costs, maintenance costs and disposal costs will be included in the analysis. The method offers the opportunity to compare the costs in the different phases in the life cycle of the product. Also the related effects of the costs over the entire lifespan of a product can be made insightful. It can be used to minimize the total life cycle costs, for example analyse in which life cycle phase the costs for a product are highest and where in the life cycle the possible cost savings are highest. An advantage of the method is that the costs can be made insightful for each phase in the life cycle. The second advantage is that the most profitable option can be chosen from several alternatives.

### 6.1.4 VALUATION METHODS

The value of a dwelling can be determined through valuation and the added value of making and investment in the dwelling can be calculated through these methods. There several types of valuation methods, but as mentioned in chapter 4 the sustainability of a dwelling is not yet incorporated in all of these valuation methods. This is a disadvantage for determining the added value in this research, because renovation concerns only the



sustainability measures. An advantage of these methods is that they give an estimation for the value of a dwelling. A remark should be made that in the current market conditions it is more difficult to determine the value more exact.

#### **6.1.5 TOTAL COST OF OWNERSHIP**

The Total Cost of Ownership (TCO) approach originated in the ICT and is a derivative of the life cycle analysis method. The method gives an overview of all the costs involved with the ownership of a product or service. The costs which are included in this method are the initial investment and the other occurring costs during the life of a product. These other costs are for example services, maintenance and insurances. The costs that are included besides the investment costs differs by industry where the method is applied. Besides the costs it is also possible to include the total benefits that are involved. TCO is used to support management decisions that involve costs over a longer period of time. The method can also be used to determine the total economic value of an investment or display cash flows for several scenarios. TCO can be applied to make financial comparisons between several alternatives, because the method does not only take the investment costs in account, but also the costs to maintain and support a product during the lifetime. TCO is stakeholder-based and addresses the costs from the point of view of the stakeholders.

An advantage is that it is possible to include different kind of costs and that it is possible to choose which costs need to be included. Another advantage is that the period of time which the total ownership is calculated can be determined up front and it is not necessary to include the entire lifecycle of the product. A disadvantage of the method is that it does not take in account indirect benefits, these benefits are not directly related to the involved product or service.

#### **6.1.6 PAYBACK PERIOD**

The payback period is a method that is used to determine in how many years the costs for an investment are recovered by the returns the investment generates. The following formula can be used for calculating the payback period:

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Annual cash flow}}$$

An advantage of the method is that it is easy to understand and easy to calculate. And a disadvantage of the method is that the time value of money doesn't need to be taken in account. Another disadvantage is that the method only focuses on in how many years the investment has repaid itself and does not take the cash flows in account that occur after that period of time.

#### **6.1.7 REAL OPTION ANALYSIS**

The real option analysis is a method that can be used to make business decisions about projects. A real option is the right, but not the obligation, to undertake certain business decisions that concern the size, lifetime or timing of a project. These real options are assigned different financial values and therefore the financial value of the options have changed. So these real option values can be a base for investment decisions or comparisons. An advantage is that the method takes changing circumstances during the investment in

account. For example with the method it can be determined whether it is better to invest at this moment in time or postpone the investment. An advantage of this method over other methods is that it takes the possibility in account to postpone investments. A disadvantage is that the outcome of the model is depending on the accuracy of the assumptions about parameters and the value that is given to the real options.

#### 6.1.8 RETURN ON INVESTMENT METHOD

The return on investment(ROI) method gives the relationship between the investment and the return of a product or a project. The method gives insight in the profitability of a project. The formula to calculate the ROI is:

$$\text{Return on investment} = \frac{\text{Return on investment} - \text{costs of investment}}{\text{costs of investment}}$$

The ROI is measured as a percentage, when the ROI is higher than 0 it means the project has more returns than it costs. An advantage of the method is that it is easy to understand. A disadvantage is that the method does not give insight in the risks that occur during a project and about the likelihood that the returns and costs will be the same amount as predicted.

#### 6.1.9 CONCLUSION

Some of the described methods are more suited than others. The requirements that were mentioned at the beginning of this paragraph will be used for the selection of a method. An overview of how the methods score on these requirements is displayed in table 6.1. They are scored by + for Possible and - for Not possible, because the method is either fit for the requirement or not.

	Insight in cash flows	Includes different costs and benefits	Only costs and benefits influenced by renovation	Possibility to set examined period up front	Comparison between different scenarios
<b>Cost Benefit Analysis</b>	+	+	+	+	+
<b>DCF and NPV</b>	+	+	+	+	+
<b>Life Cycle Costs</b>	-	+	-	-	+
<b>Valuation methods</b>	-	-	-	-	+
<b>Total Cost of Ownership</b>	+	+	+	+	+
<b>Payback period</b>	+	-	+	-	+
<b>Real Option analysis</b>	-	-	+	+	+
<b>Return On Investment</b>	-	+	+	+	+

Table 6.1: Overview of how the methods score on the requirements

The Life Cycle Cost analysis will not be used, because this method includes the entire life cycle of a product. And this case study focusses on a part of the life cycle of a building, the period starts with the renovation of the dwelling. The Payback Period method was not opted for because it does not take in account the financial benefits that occur from the investment after it has paid for itself. The valuation methods do not take all the involved costs in account that are influenced by the renovation, such as the investment costs and energy costs and therefore this method will not be used. The Real Option Analysis will also not be used, because this method does not give insight in the cash flows and the financial benefits

of the investment. The Return on Investment method was not used, because it does not give insight in the cash flows of the investment.

The Discounted Cash Flow method will be used to display the costs that are influenced by the renovation and to convert the cash flows into the present value. The Net Present Value will be used to give insight in the differences between the cash flows of the scenarios.

The Costs Benefits Analysis and the Total Cost of Ownership approach are quite similar, they both include costs and benefits, they examine costs over a period of time that can be set up front. They both work with cash flows and can be combined with the Discounted Cash Flow method. And with both methods it is possible to compare different kinds of scenarios with each other. Thus these methods are most fit for this research, but only one of the two will be used. There was chosen to use the Total Cost of Ownership approach and not the Costs Benefits Analysis. There was not opted for the Costs Benefits Analysis because not all the social benefits that are involved in the renovation can be translated into a financial component and this is one of the starting point of this method. The Total Cost of Ownership approach gives more freedom about which costs and benefits are included and what time period will be taken in account, provided that these choices are well substantiated. Thus the total costs of ownership will be used and this approach can give consumers an overview of all the costs and benefits that are really involved.

## **6.2 MEASURING ENERGY NEUTRALITY**

Besides a method that focusses on the financial aspects another method is needed to calculate the energy savings. The methods that will be discussed are Energy Performance Coefficient and Energy Label, BREEAM-NL in use, GreenCalc+, GPR gebouw and determining energy savings.

### **6.2.1 ENERGY PERFORMANCE COEFFICIENT AND ENERGY LABEL**

The energy performance coefficient is a method that determines energy efficiency of a building. The government also uses the EPC to establish sustainability requirements for dwellings legally. They have set a minimal EPC value for new build dwellings of 0,6. The Energy label is based on the EPC, categories of the energy labels, A++ until G, correspond with certain range of EPC numbers. An advantage of these methods is that the government also uses them. The disadvantage of the EPC is when an EPC-value is zero, the building does not have to be energy neutral. For example it is also possible to create an EPC-value of zero, by applying a lot of installations and not reduce the amount of energy that is used.

### **6.2.2 BREEAM-NL IN USE**

Breeam-NL in use is based on the Breeam-NL method, the method is adapted so it can be used for existing buildings. The method monitors the sustainability performance of existing buildings and it provides a certificate for the building (Dutch Green Building Council, 2013). An advantage is that the method reviews the building characteristics, management and use of the building separately.

### **6.2.3 GREENCALC+**

GreenCalc+ is a method that expresses the sustainability of a building in an environment index. The method assesses the sustainability based on a comprehensive life cycle analysis

which takes the material, water and energy usage in account (Stichting Sureac, 2010). An advantage of GreenCalc+ is that several building and installation technical measures can be compared and an optimum package of measures can be selected.

#### 6.2.4 GPR GEBOUW

With the method 'GPR gebouw' the sustainability performance of a building can be assessed. An overview can be created of the sustainability performance for five themes: energy, environment, health, user quality and future value (GPR gebouw, 2013). It is an advantage that the sustainability can be analysed on different themes that are important for the consumers.

#### 6.2.5 DETERMINING ENERGY SAVINGS

Another different method is to calculate the energy savings on itself and do not give a dwelling a sustainability score such as the methods before. For an existing dwelling it is possible to calculate the energy savings when energy efficiency measures are applied to the dwelling. These can be calculated on the basis of insulation values, energy generation and energy usage. When the savings are calculated these can be deducted from the energy usage before the renovation, which will result in the remaining energy usage if there is any. An advantage of this method is that it gives a clear insight in the total energy usage and savings and it does not give a certain score.

#### 6.2.6 CONCLUSION

Requirements that are important for the selection of the method are that the method should be able to determine if a dwelling is energy neutral, be understandable for consumers and the energy savings should be able to compare with other dwellings. For the research aspect it is preferable that the energy savings are presented in a universal way that can easily be compared. These requirements are scores with + = Possible and - = Not possible.

	Determine energy neutrality	Understandable for consumers	Ability to compare energy savings	Energy savings presented in universal unit
<b>EPC and Energy label</b>	+/-	+	+	+
<b>BREEAM-NL in use</b>	+/-	-	-	-
<b>GreenCalc+</b>	+/-	-	-	-
<b>GPR gebouw</b>	+/-	-	-	-
<b>Determining energy savings</b>	+	+	+	+

Table 6.2: Overview of how the methods score on the requirements

The outcome of all the methods cannot be compared with each other, except for the EPC value and the Energylabel. The main disadvantage of the EPC method is when an EPC-value is zero, the building does not have to be energy neutral. For example it is also possible to create an EPC-value of zero, by applying a lot of installations and not reduce the amount of energy that is used. This does not correspond with the Trias Energetica concept that is used in this research and with EPC it is not clear when a dwelling is actually energy neutral. The methods BREEAM-NL, Greencalc and GPR gebouw all give a building a score on sustainability. Research from Neimann (2012) concludes that these scores can't be compared with each other, because they all have a different perception of the term sustainability. Besides that

there is a certain expertise with the calculation methods needed to use them and understand the scores, so these methods are not very accessible for consumers. There is not opted for one of these methods, because they are no universal methods, not everyone uses the same program and it is a major disadvantage that it is not easy to compare and use these methods. The method to determine energy savings results in a universal unit for energy savings and usage, that is easy to understand and compare with other dwellings. And when the energy usage in kWh is zero on a yearly basis a dwelling can be labelled as energy neutral. This method has as an added advantage that the energy savings can be easily translated in a financial factor and therefore can be used in the financial model of the case study. Therefore the choice is made to convert the amount of energy saved by each measures to make the dwelling energy neutral in kWh.



## 7. CASE STUDY

The case study will mainly focus on the benefits that can be translated in a financial factor. When all the benefits have the same unit it is easy to sum them up and create an overview. Besides that the financial aspects of making a dwelling energy neutral are the most important for the consumers, they want to know how much it costs and how much the return is on the investment. The benefits that concern the People-aspect of the Triple P, such as health and comfort, are difficult to express in financially. Consumers appreciate the added value on these areas, but this is difficult to translate in a financial component in calculations. The added value that concerns the Planet-aspect of the Triple P can be translated in a financial component, because the energy savings are connected to energy prices. And the third aspect of the Triple P is Profit and this is already a financial component. Thus the case study will focus on the financial benefits and the energy savings. This does not mean that the benefits of the component people are not important for the consumers. These benefits are important and play a role in the decision to renovate.

In this chapter the design of the case study will be described. First the method and the steps that need to be taken to execute the case study will be described. Then the scenarios that will be used and the district used for the case are explained. Then the used data will be described. And finally the model and the sensitivity analysis will be explained. In the next chapter the results from the case study will be displayed and discussed.

### 7.1 METHOD

As explained in the previous chapter the methods Total Cost of Ownership, Discounted Cash Flow and Net Present Value will be used. These methods will be combined for this case study and the TCO needs to be adjusted to fit the scope of the case study. The TCO approach is originated in the ICT and is often used by companies to analyse total cost of ownership from a product or a machine they want to buy. The TCO needs to be adjusted to fit the analysis of a renovation of the dwelling. The TCO approach is very useful when it concerns making a building more sustainable, because it includes all the costs for a period of time, for example all the costs that are concerned with making a dwelling more sustainable, thus not only the investment costs, but it also includes all the exploitation costs such as energy costs and maintenance costs.

An example of the application of a TCO approach in the building industry is that the municipality of Vianen has recently tendered and awarded the development, construction and maintenance of a sports centre based on a Total Cost of Ownership approach (Duurzaam gebouwd, 2012). In this case all the costs were taken in account at the beginning of the building process, this way a lifecycle proof design was made and the costs can be controlled over the entire lifecycle. In this example the costs of the construction as well of the exploitation were included and a Design, Build and Maintain contract was made for a period of twenty years.

There is no exact guideline for the Total Cost of Ownership model, it is more an approach that can be used to identify all the costs in a certain life period of a building. The approach will be used to identify and quantify all the involved costs and benefits in the analysis. To make the Total Cost of Ownership approach suitable for this research first the scope of the

Total Costs of Ownership analysis needs to be determined up front, this concerns goal of the analysis, the included and excluded costs and the examined period. The goal of this case study is to determine the added value of making a dwelling energy neutral. The case study mainly focusses on the benefits that can be translated in financial component. It needs to be possible to compare several scenarios to find the added value and the added value of executing the renovation on a larger scale. These scenarios will be explained in paragraph 7.3.

The costs that will be included in the research will be the costs that are influenced by the renovation, thus not all the yearly costs for a dwelling of a household will be incorporated. Costs that are influenced by the renovation are the investment costs for the renovation itself, the energy costs and the maintenance costs for the added installations. These costs can be translated into yearly costs and cash flows will be determined based on these costs. The Discounted Cash Flow method will be incorporated in the Total Cost of Ownership approach to determine the different cash flows. And the Net Present Value will be used to represent the total value of these cash flows. Other costs such as costs for water, costs for internet and television etc. are left out, because they are not relevant for the investment that is made and these costs will not be influenced by the renovation.

The value of the dwelling was left out of the equation. The value of a dwelling is uncertain in this period which is characterized by a financial crisis and a crisis in the dwelling market. There are not yet valuation models used by the market that incorporate the sustainability in the value of a dwelling, thus it is hard to determine the exact value of the sustainability measures. It is possible to calculate a theoretical value, but if this value is realistic in the current uncertain market conditions is the question. The value of a dwelling depends on the market conditions, the type of dwelling, the condition of the dwelling and the location of the dwelling. Thus the value of a dwelling is not taken into account, because it is an uncertain factor at this moment and for the research it is better to provide an outcome that is more certain. As mentioned in paragraph 4.4.1, the value of a dwelling can increase presumably between the €5.000 and €30.000 when it is made more sustainable, this also depends on the type of dwelling and how much more sustainable it is made. In addition, the renovation is also about improving the condition of the dwelling. Thus an added benefit is that the value of the dwelling can be maintained and the value of the dwelling probably can be increased when the consumer wants to sell the dwelling.

Before the cash flows can be determined the examined period in the analysis must be set first. When a renovation requires a high investment the examined period should not be too short, because then the period of time maybe too short to earn the benefits from the investment. The period of time should also not be too long, because then it is possible that the lifespan of the measures might be shorter than the examined period. So the key factors to select a period to examine are that it must be able to earn the benefits of the investment and the lifespan of the measures. Insulation measures have a longer lifespan than the installations, therefore the lifespan of the major installations will be used. The average lifespan of a PV-panel is 25-30 years (Stichting monitoring zonnestroom, 2013). The average lifespan of a solar boiler is also 25 years (Milieucentraal, 2013). The remark should be made that the lifespan of these installations is the guaranteed lifespan, the lifespan can be longer. When the installations last longer than the guaranteed lifespan of 25 years, this period can



be seen as added benefits from that installation. The period of 25 years is also long enough for consumers to cash in the benefits of their investment.

To execute this research a roadmap is made, these steps are a global outline of the steps that need to be taken to carry out the Total Cost of Ownership analysis. The first step is to identify the different scenarios that will be compared with each other in the research. The next step is identifying costs and benefits for all the scenarios, these are all the costs and benefits that are affected by the measures in the scenarios. The third step is obtaining the required data for in the model, these are data about costs, energy usage and the parameters. The fourth step is assembling the model. A model will be made in Microsoft Excel and the model will be used to calculate the cash flows. In Excel several formula's and all the data will be inserted, the DCF method and NPV will also be applied in this stage of the research. The global outline of the model assembly will be discussed and some choices in formulas will be highlighted. The next step is carrying out a sensitivity analysis, this analysis is needed to determine if the outcome depends on the accuracy of certain variables. And the last step is analysing the results and after that the research questions can be answered. The first five steps will be described in this chapter and the last step is described in the next chapter.

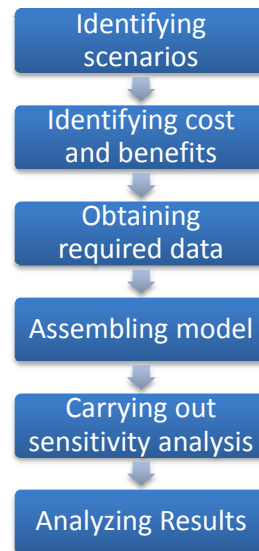


Figure 7.1: Research roadmap

## 7.2 THE CASE - VENNE-OOST, DRUNEN

For this case study it is necessary to select a district to examine. The district can provide information about the type of dwellings, the district itself and average energy usage. The district that is selected in the case study is Venne-Oost in Drunen. Drunen belongs to the municipality Heusden. This district was selected, because the district is built before 1990 and the dwellings have therefore a small amount of insulation or no insulation, so they can benefit from the renovation. A large amount of dwellings is owned by private home-owners and because renovations have already been carried out by the housing association, there is information available about these dwellings.

Type of dwelling	Percentage
Row houses	53%
Semi-detached houses	28%
Detached houses	13%
Apartments	4%
Other	5%

Table 7.2 types of dwellings in Venne-Oost. (Oostveen, 2011)

In the district Venne-Oost are 2502 dwellings, most of these dwellings are built between 1968 and 1982(Oostveen, 2011). Most of the dwellings in the district are row houses and the others are mostly semi-detached dwellings and detached dwellings, see table 7.2. 35% of the dwellings are let by housing association Woonveste, 6% is let by landlords and 59% of the dwellings are owned by individual home-owners(Oostveen, 2011). The municipality of Heusden recognizes the importance of sustainability in the built environment. They have set the goal to improve the energetic quality of the existing housing stock every year with an average of 2%, expressed in Energy-label (Gemeente Heusden, 2013). They are also developing the sustainable district Geerpark in the city of Vlijmen. In this district the

dwellings will be built according the passive dwelling principle and a total of 700-800 dwellings will be realized.

Housing association Woonveste has executed several renovations of existing dwellings in the municipality Heusden. They have carried out renovations of the building envelope together with the company 'de Bonth van Hulten', based on their 'green-update concept'(Renda special, 2011). They have also renovated several dwellings into passive dwellings together. They have realized large energy savings for these dwellings, but they have not been renovated into energy neutral dwellings. So in the municipality Heusden the housing association is renovating several dwellings, but there are no large scale initiatives by consumers to renovate their dwelling.

### **7.3 IDENTIFYING SCENARIOS**

To answer the research question it is necessary to develop several scenarios that can be compared and analysed. The research in this case study needs to find the added benefits of making a dwelling energy neutral and if there are added benefits when consumers cooperate as a collective. Thus key points that need to be analysed are based on a difference in scale and a difference in intensity of the renovation. These two points will be explained in the next two subparagraphs and the third paragraph will explain the different scenarios this will result in.

#### **7.3.1 INTENSITY OF THE RENOVATION**

To identify what the added benefits are for consumers when they make their dwelling energy neutral, it is necessary to make a comparison based on the intensity of the renovation. The intensity of the renovation refers to how sustainable a dwelling is made during the renovation. The goal in this research is set to determine the added benefits when dwellings are renovated to energy neutral dwellings, so one of the options will be renovating a dwelling to energy neutral. To make a comparison between the option to energy neutral and the current situation a reference option needs to be added, where no renovation is carried out. Thus in this research a dwelling that will be renovated into an energy neutral dwelling will be compared with a dwelling that is not renovated.

The measures to make a dwelling energy neutral can be divided in three parts, insulating the building envelope, generating sustainable energy and the remaining measures. The first two represent the main parts of the renovation. When people are now making their dwelling more sustainable they often choose one of the two, thus insulation or generating sustainable energy. The reason for this is that not every household has the financial possibilities to realize the option to renovate to an energy neutral dwelling and the costs of these options are considerably lower. Both of these options will be added as a scenario, because it are options consumers can take in consideration when they choose to make a dwelling more sustainable. Goal of adding these options is exploring if it is more profitable to make a dwelling energy neutral or do less than energy neutral by applying insulation or generating sustainable energy. The insulation option will be implementing relative good insulation, but not to energy neutral, because it is relative expensive. The generating sustainable energy option will be a solar boiler and PV-panels on one side of the roof. The remark should be made that an assumption is made that the roofs of the dwellings are

suited for solar energy. That their orientation is good and that their construction is good enough to hold the solar panels.

Table 6.3 gives an overview of what measures the three renovation concepts consist of. They are more detailed described in appendix 2. The information needed about these measures for this research are the costs, insulation values for insulation measures, the generated heat or electricity for installations, the amount of electricity installations use, the lifespan of the installations and the maintenance costs of installations. These data will be explained in paragraph 7.4.

Insulation	Sustainable energy	Energy neutral
Cavity wall insulation	Solar boiler	Exterior wall insulation
Floor insulation	PV-panels	Floor insulation
Roof insulation inside		Roof insulation outside
Closing seems and cracks		Replacing window and door frames
Replace glass by insulated glass		CO2 demand regulated ventilation with heat recovery
CO2 demand regulated ventilation with heat recovery		Solar boiler
		PV-panels

Table 7.3: Overview energy efficiency measures

### 7.3.2 SCALE OF THE RENOVATION

The scale of the renovation is also an important part of the research, because it focusses on the added benefits when dwellings are renovated as a collective. A larger scale of renovation can have added benefits, for example when the renovation is carried out in serial costs can be lower, because a more standardized process can be applied. These following scales will be taken in account in this case study: individually(1 dwelling), one row of dwellings(8 dwellings) and an large scale(100 dwellings). These represent an individual renovation, a small scale collective renovation and a large scale collective renovation.

### 7.3.3 THE SCENARIOS

The requirements that should be reflected in the scenario are the intensity of the renovation and the scale of the renovation. There are four options for the intensity of the renovation and three options for the scale of the renovation. Another variant will be added to the scenarios and that is making the investment by means of a mortgage or making the investment at once. Because not every household has the amount of money to finance the renovation, so often a loan or mortgage is needed. Therefore the option that the renovation is financed by means of a mortgage is taken in account, besides the option to make the entire investment at once.

<b>Base scenario</b>	No renovation
<b>Scenario 1</b>	Insulation
<b>Scenario 2</b>	Generating sustainable energy
<b>Scenario 3</b>	Energy neutral

Table 7.4: Overview scenarios

When these options are combined a lot of different scenario will arise, a total of 20 scenarios would be needed. This will be ineffective for making comparisons with cash flows and smaller differences between the intensity of the renovation will be harder to detect, because the amount of money involved for the different scale scenarios varies greatly. Therefore

there is chosen to use the intensity of the renovation as a base to make the scenarios and thus to calculate the cash flows. These four scenarios for the intensity of the renovation will be varied for the scale of the renovation. This gives four scenarios to compare for each scale level and then the different scales can be compared for each scenario. Thus a total of four renovation scenarios are needed.

The first scenario needs to be a base scenario which can serve as a reference dwelling, this is a dwelling that is not renovated. The three renovation scenarios will represent the different options for the intensity of the renovation. In table 7.4 is an overview of the four scenarios and their names, the scenarios 1, 2 and 3 will be described more in detail in appendix 2. These four scenarios will all be calculated with making the investment with or without a mortgage and will be varied for the different scale levels.

## **7.4 DATA**

There are several data needed for the case study. This paragraph describes which data are needed and where it will be retrieved from.

### **7.4.1 INVESTMENT COSTS**

To make an overview of the Total Cost of Ownership the investment costs of implementing the measures to make the dwelling energy neutral should be taken into account. For determining the total investment costs standardized cost figures will be used for each measure. These standardized costs give a good indication how much a measure costs and they are often published by recognized agencies.

Every year Agentschap NL(2011d) publishes an update of the EPA customized advice for existing dwellings. This advice contains cost indicators for sustainability measures for existing dwellings. The cost indicators are indicative prices and have as goal to provide a financial support for the involved costs when energy efficiency measures are applied and their effect on the living costs (Agentschap NL, 2011d). These indicators are also specified for the scale of the project, costs are specified for measures that are applied individually or in serial for multiple dwellings. The costs consist of the direct costs, such as hourly wages, prices for material and labour, and indirect costs, such as general operating costs and profit and risk(Agentschap NL, 2011d). The VAT is excluded from the costs and should be added in the calculations. Agentschap NL (2011c) also published cost figures in the document 'Voorbeeldwoningen 2011, bestaande bouw'. For the sample dwellings in this brochure the costs and energy savings are calculated when they are made more energy efficient. This is done by means of two different energy savings packages and the building- and installation technical aspects are described for each dwelling. The example dwellings in the document can be used to support policy studies into energy use and possible energy savings for existing dwellings(Agentschap NL, 2011c).

The EPA customized advice will be used in this report to provide the base for the investment costs for each measure and measures can be selected individually to combine them to an energy saving package. Because these costs are very detailed and they are specified for each measure. The costs from the example dwellings from Agentschap NL(2011c) will not be used, because they are not specified for each measure and the energy efficiency packages that are applied in the brochure do not reach energy neutrality. The costs indicators in the EPA

customized advice are indexed at the price level of march 2011 and they are re-indexed in this case study to current price levels using the BDB-projectindex. Not all measures to make a dwelling energy neutral are standard measures that available in the EPA customized advice (Agentschap NL, 2011d). For example the insulation measures that need to be applied have higher insulation values and therefore the material is more expensive. If the measure is not available in the EPA customized advice then information will be retrieved from another source. In appendix 3 the costs will be described in detail and where they were retrieved from.

#### 7.4.2 ENERGY SAVINGS

The energy savings that occur when a dwelling is renovated into an energy neutral dwelling need to be determined. Several data are needed to calculate the energy savings and these are also different for the several types of measures. For insulation related measures the Rc-value or U-value is needed to calculate the amount of saved

	Measure	Rc-value	U-value
<b>Scenario 1 Insulation</b>	Cavity wall insulation	3,07	-
	Floor insulation	2,5	-
	Roof insulation inside	2,5	-
	Replacement by insulated glass	-	1,3
<b>Scenario 3 Energy neutral</b>	Exterior wall insulation	5,7	-
	Floor insulation	5,7	-
	Roof insulation outside	5,7	-
	Replacement by insulated windows	-	0,73

Table 7.5: Overview insulation values

energy. For installation measures the amount of energy they generate is often given for the installation measures. These energy savings need to be transformed to kWh, which will be the universal unit for energy savings in this research, as explained before, the kWh will also be used to determine the energy neutrality of this dwelling. The insulation values are displayed in appendix 3 about the investment costs and an overview is given in table 7.5. The solar boiler that is used in scenario 2 and 3 generates 16,4 GJ energy. The PV-panels used in both scenarios have an output of 333 WP for each panel and a total of 13 panels will be used. Therefore the total output of the installation will be 4.329 WP.

#### 7.4.3 ENERGY USAGE INSTALLATIONS

The installations that will be applied in the energy savings package will need energy to operate. This amount of energy needs to be taken into account in the total energy usage of the dwelling, to

Energy usage installations		
<b>Ventilation system</b>	57	kWh
<b>Solar boiler</b>	200	kWh
<b>CV boiler disappears</b>	-270	kWh

Table 7.6: Overview energy usage installation

determine if the dwelling is energy neutral. The installations of which the energy usage needs to be determined are the ventilation system, solar boiler, PV-panels and the cv-boiler. The related energy usage is displayed in table 7.6 and explained more in detail in appendix 4. The usage of the cv-boiler disappears in scenario 3, because the cv-boiler is no longer needed to generate heat. Furthermore the assumption is made that the amount of electricity a PV-panel generate, is also enough for the use of the PV-panel itself.

#### 7.4.4 MAINTENANCE COSTS INSTALLATIONS

It is necessary to perform maintenance on the installations that are applied in a dwelling. Regular maintenance makes sure the

Yearly maintenance costs for each scenario		
<b>Scenario 1</b>	€ 60,00	<i>Ventilation system</i>
<b>Scenario 2</b>	€ 90,00	<i>Solar boiler + pv-panels</i>
<b>Scenario 3</b>	€ 150,00	<i>Solar boiler + pv-panels + ventilation system</i>

Table 7.7: Overview maintenance costs by scenario

installations work properly and last a longer period of time. The relevant installations are the solar boiler, PV-panels and the ventilation system. All these installations do not need a lot of maintenance, therefore costs are relatively low. In table 6.7 an overview is displayed for the total maintenance costs for each scenario. How these costs were determined is explained in appendix 5.

#### 7.4.5 DATA ABOUT THE DWELLINGS

There are a few data needed from the dwelling. The data needed are for the existing insulation values of the dwelling and the surface area of the walls, roof, floor and windows. These data are available for an example dwelling from that time-period, they can be retrieved from 'Voorbeeldwoningen 2011, bestaande woningbouw'. The exact data are not available for the dwellings from the case study, but the mentioned data for the example dwelling can be used in the calculations, because the data is made universal for every type of dwelling for that time-period. By using universal data the more applicable the results will be for that type of dwelling from that time period. Data will be used for a row-house from the period 1965-1974. The data are shown in appendix 6.

#### 7.4.6 ELECTRICITY AND GAS USAGE HOUSEHOLDS

Data for electricity and gas usage for households are needed to calculate when the dwelling is energy neutral and how much energy is saved with the measures. The national average electricity usage is 3400 kWh a year and gas usage is 1800 m<sup>3</sup> gas a year (CBS, 2012). This national average is based on every type of dwelling and is an average for the entire country. It is preferable that these data are more specific for the type of dwelling and the district that is relevant for this case study. In table 6.8 the average gas and electricity usage of the households for each type of dwelling in the district Venne-Oost in Drunen are shown. The average electricity usage for row-houses in the district is 3350 kWh a year and the gas usage is 1950 m<sup>3</sup> a year. The assumption is made that the ratio between the electricity and gas usage will remain the same for the future. In the past decades this ratio has changed, appliances and heating boilers have become more energy efficient, but also the amount appliances in dwellings have increased. In the future appliances, installations etcetera will become even more energy efficient, but there will also be more appliances in a dwelling. Thus the assumption can be made that the ratio and energy usage will stay the same in the future.

#### 7.4.7 PARAMETERS

Several standard parameters are needed in the calculations. The used parameters are displayed in table 7.9 and how they were estimated is explained in appendix 7.

	Gas in m <sup>3</sup>	Electricity in kWh
<b>Apartment</b>	1200	2250
<b>Row-house</b>	1950	3350
<b>Corner-house</b>	2200	3500
<b>Semi-detached house</b>	2600	3950
<b>Detached house</b>	3550	4550
<b>Total</b>	1850	3300

Table 7.8: Energy usage in the district Venne-Oost, Drunen. (CBS, 2012, (data:2010))

Parameter	
<b>Interest rate</b>	4,8 %
<b>Inflation rate</b>	2,0 %
<b>Increase electricity prices</b>	2,8 %
<b>Increase gas prices</b>	6,4 %
<b>Discount rate</b>	4,8 %
<b>Percentage scale benefits</b>	2,5 %
<b>Indexation building costs</b>	2 %
<b>VAT</b>	21%
<b>Electricity price</b>	€ 0,22
<b>Gas price</b>	€ 0,65
<b>Resupply electricity</b>	€ 0,07
<b>Average outdoor temp.</b>	6,55 °C
<b>Average indoor temp.</b>	20 °C
<b>Average number heating days</b>	212
<b>Average number heating hours</b>	12
<b>Performance ratio PV-panels</b>	80 %
<b>Part space heating gas usage</b>	75 %

Table 7.9: Overview parameters

## 7.5 MODEL

A model will be developed in Microsoft Excel to calculate the added value of renovating a dwelling into an energy neutral dwelling individually and collectively. Figure 7.10 represents which sheets need to be made before the Discounted Cash Flow can be made, each sheet represents a part of all the calculations. The first sheet represents the costs figures that form a base for the investment costs. The second sheet is the input sheet which represent all the input values that need to be filled in for the case study. This information is specific for the case the calculations are for. This is done so the excel model can be used also for other projects, so only the input sheet needs to be changed. The relevant calculations of the other sheets will be explained in this paragraph.

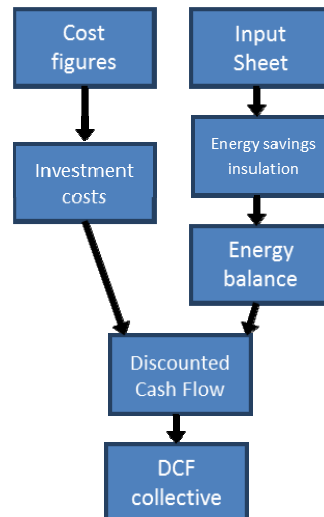


Figure 7.10: Model for excel sheets

### Determining payment investment

To realize the renovation an investment needs to be made. Not every household has the amount of money to finance the renovation, so often a loan or mortgage is needed. Therefore the option that the renovation is financed by means of a mortgage is taken in account, besides the option to make the entire investment at once. At first the total investment costs will be determined for each scenario by means of the cost references and the information about the dwelling. When the total investment costs are known the yearly repayments for the loan can be determined. The period for the loan needs to be set, this period will be as long as the period examined in this research, 25 years. Then the total amount of interest needs to be determined, this can be done by means of a formula that is incorporated in excel. Another formula calculates the yearly payments by using as input the total amount of interest, the interest rate, number of payment periods and if the payment is made at the beginning or end of the period. The payments for the mortgage will be made at the end of the period.

### Energy savings from insulation

To determine the savings from the added insulation a formula is set up. The difference between indoor and outdoor temperature needs to be multiplied with the difference between the new and old insulation values and multiplied with the insulation surface. This will lead to the savings from improving insulation in Watt, this needs to be multiplied with 0,001 to get the savings in kWh. This following formula will be used in the calculations:

$$\begin{aligned} \text{Savings from insulation} \\ &= (\text{Indoor temp.} - \text{Outdoor temp.}) * (U_{\text{old}} - U_{\text{new}}) * \text{insulation surface} \\ &* 0,001 \end{aligned}$$

### Energy balance

To determine if a dwelling is energy neutral or how much energy in a dwelling is used or how much energy is generated for a dwelling an energy balance will be made. In the energy balance the used amount of energy and the amount of generated energy will be deducted from one another. To make the energy balance it is needed to convert all the different

energy units to one energy unit, namely kilowatt-hour (kWh). The following units of energy need to be converted; current gas usage in m<sup>3</sup> gas, GJ generated energy from a solar boiler and generated WP of solar panels. The conversion factors are shown in table 7.11. Thus the amount used energy and generated energy need to be converted and then they can be deducted to calculate the total energy consumption. When this total is positive, then there still needs to be energy subtracted from the grid and when this total is negative then energy is resupplied to the grid. An important remark should be made for this sheet, because there is a maximum of energy that can be saved from insulation. About 75% of the gas usage in a dwelling is used for heating a dwelling and not the total amount of m<sup>3</sup> gas. This means that not the total amount of gas can be saved by insulating, thus the maximum of saved energy by insulation is 75% of the gas usage.

Current unit	
1 m <sup>3</sup> gas	8,77 kWh
1 GJ	277,78 kWh
1 WP	0,85 kWh
Table 7.11: Conversion factors (Agentschap NL, 2013)	

### Discounted cash flows

When all the costs and financial benefits are determined, the cash flows can be made. The cash flow for each type of costs the cash flow will be calculated for a period of 25 years. The yearly costs will be influenced by the inflation rate, except for the mortgage costs, because these are fixed yearly payments. The energy costs will also increase with the percentage increase in energy costs. Then the cash flows are made for every year and then these cash flows are discounted, the following formula will be used for that:

CF = Cash flow  
r = discount rate  
n = number of years

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \dots + \frac{CF_n}{(1+r)^n}$$

When the cash flows are made then the Net Present Value will be calculated and this represents the total present value of the costs over 25 years.

## 7.6 SENSITIVITY ANALYSIS

In this research future cash flows are determined and predictions about the future are inherent to some degree of uncertainty. These future cash flows are determined by using estimated parameters and values. The assumptions about the parameters and values are made as accurate as possible, but there is always some uncertainty. How accurate the cash flows are depends on how accurate the assumptions are about the parameters and values. A sensitivity analysis is needed to determine how much the outcome of the analysis depends on certain parameters or values. This will lead to more certainty about how dependent the benefits and profitability of the renovation are on the set parameters and other values and how certain it is that these benefits occur after the renovation. The dependency of the outcome on the accuracy of parameters is related to risk. The more the outcome is depending on the variables the riskier the investment is, because the predicted benefits and profitability of the investment are more uncertain. The less the outcome is depending on parameters the less risky the investment is.

The parameters that are chosen to be analysed in the sensitivity analysis are parameters that have some degree of uncertainty in them or that it is known that these parameters change over the years or between dwellings or households. For this research the variables that need



to be taken in account at least are the increase of energy prices, the energy usage and the time of the investment. Other parameters that need to be included in the sensitivity analysis are the interest rate, the inflation rate, the discount rate, index building costs and the percentage scale benefits. The total Net Present Value will be used to display the influence of the parameters. Because this gives a better overview for the analysis.

The starting point at which the sensitivity analysis is carried out is the individual renovation of a dwelling. The sensitivity of each of the scenarios will be determined, these are the base scenario, the only insulation scenario, the energy generation scenario and the energy neutral scenario. The sensitivity analysis will be done for both the variant with a mortgage and the variant without a mortgage. The sensitivity analysis will only be done for the scale of a single dwelling, because the parameters do not influence the scale benefits. Except for the percentage scale benefits which has only an influence on a scale larger than 50 dwellings. The parameters and other costs are set at the values mentioned in this chapter, these form the base starting point of the sensitivity analysis. In this paragraph the choices for performing the sensitivity analysis for these variables are explained, the results of the analysis are discussed in the next chapter.

#### **7.6.1 INCREASE OF ENERGY PRICES**

An important parameter for the sensitivity analysis is the increase of the energy prices, because there is a lot of uncertainty about how much the energy prices will increase. The height of the savings in energy costs depends on the increase of the energy prices in the future, because the higher the increase in energy prices in the future, the higher the financial benefits will be for a consumer when a dwelling is made energy neutral. The past ten years the energy prices have been fluctuating, but the average increase in energy prices lies between 0 % and 10%. The increase in price for electricity and for gas are different. The separate influence of these both increases in energy prices need to be examined. Since the increase in gas price and the increase in electricity price are both taken in account as separate parameters, the influence of an increase of both parameters together needs to be examined to.

To determine the sensitivity of the increase of gas price, the increase of electricity price is constant and the increase in gas price is varied between 0% and 10%. To determine the sensitivity of the increase in electricity price, the gas price is constant and the increase of electricity price is varied between 0% and 10%. To determine the influence of both increases in price together, the electricity and gas price are varied at the same rate from 0% to 10%.

#### **7.6.2 ENERGY USAGE**

Another important parameter for the sensitivity analysis is the total energy usage that is taken into account for the dwelling. The energy usage can vary by type of dwelling or by household size, but it also depends on the life style of the residents. Because the amount of energy usage is different for each consumer, it is important to take in account how much the outcome depends on the amount of energy that is used in the dwelling. The average energy and gas usage for row-houses in the districts Venne-Oost in Drunen is 3350 kWh and 1950 m3 gas. These electricity and gas usage will be varied from -50% until +50% for the average usage with steps of 10%.

### **7.6.3 MOMENT OF THE INVESTMENT**

The time of the investment can play a role in determining the optimal moment to make the investment. This can give insight in when it is best to execute the renovation: as soon as possible or to postpone the renovation and execute it in a few years. The options for the moment of investment will be varied for are now, in five years, in ten years or in fifteen years. With the sensitivity analysis for this parameter the assumption is made that the market conditions will be the same over time. In reality it is possible the market circumstances can be different.

### **7.6.4 INFLATION RATE**

The inflation rate represents the average increase or decrease of the average price level. The inflation rate varies over the years, but the variation is relatively small. Therefore the inflation is varied from 0% until 10%.

### **7.6.5 INTEREST AND DISCOUNT RATE**

Since the discount rate is based on the interest rate as explained in appendix 7, these will be varied together at the same rate. The interest rate determines how much interest is needed to pay over the loan. The interest costs can be a considerable part of the total investment costs. Therefore it is important to vary the interest rate and determine how much the outcome depends on the interest rate. And the discount rate represents the time value of money. Both the percentages will be varied from 0% until 10%

### **7.6.6 INVESTMENT COSTS**

The investment costs are based on cost references and are re-indexed at the price level of 2013. It is possible that the investment costs are a bit different in reality. Therefore it is important to include the investment costs in the sensitivity analysis. The total investment costs will be varied with steps of 5% from -25% until +25%.

### **7.6.7 PERCENTAGE SCALE BENEFITS**

The percentage scale benefits for more than 50 dwellings is estimated at 2,5%. If this percentage would be higher or lower than this has consequences for the total investment costs and the added benefits of renovating as part of a collective. Therefore the percentage scale benefits will be varied from 0% until 10%.

## 8. RESULTS

This chapter discusses the results from the case study. First the overview of the yearly costs will be discussed. Then the discounted cash flows will be analysed by scenario and between the different scales. Thirdly the investment needs will be examined. Fourthly the sensitivity analysis will be carried out for the parameters described in paragraph 7.6. Finally the overall conclusion about the results of the case study is discussed.

### 8.1 ANALYSING YEARLY COSTS

Before the discounted cash flows can be constructed the yearly costs for each type of costs were determined. The types of costs that are included in the calculations are the investment costs, the maintenance costs and the energy costs.

#### 8.1.1 INVESTMENT COSTS

The total investment costs for each scenario are based on costs figures, which are multiplied by the quantity that is needed. The detailed summation of these costs for each scenario are displayed in appendix 8 for a single dwelling, the total investment costs are displayed in table 8.1. As explained before the payment for these costs will be made by making the investment at once or by means of a loan, because most consumers do not have the amount of money available to pay directly for the costs. Therefore the total interest costs were calculated and the yearly payments to repay the loan in 25 years, these costs are displayed in table 8.1. The repayments for the loan will be used as a base for the discounted cash flows.

Scale	Type of costs	Only insulation	Energy generation	Energy neutral
<b>1 dwelling</b>	Total investment costs	€ 23.101,39	€ 19.696,45	€ 63.692,80
	Amount of interest	€ 19.116,85	€ 16.299,19	€ 52.707,01
	Yearly payments	€ 1.688,73	€ 1.439,83	€ 4.655,99
<b>2-50 dwellings</b>	Total investment costs	€ 18.899,30	€ 18.415,43	€ 59.339,30
	Amount of interest	€ 15.639,53	€ 15.239,12	€ 49.104,41
	Yearly payments	€ 1.381,55	€ 1.346,18	€ 4.337,75
<b>&gt;50 dwellings</b>	Total investment costs	€ 18.426,82	€ 17.995,04	€ 58.456,93
	Amount of interest	€ 15.248,54	€ 14.858,14	€ 48.374,24
	Yearly payments	€ 1.347,01	€ 1.312,53	€ 4.273,25

Table 8.1: Costs by dwelling

The investment costs for the third scenario to energy neutral are the highest, this is makes sense, because this scenario has the highest amount of measures and the measures are the most extensive. The first scenario with only insulation has the second highest costs followed by the last scenario generation of sustainable energy. This indicates that the costs for applying installations that generate energy are lower than the costs to apply only insulation.

Another thing that stands out is that the amount of interest that is needed to pay over a total of 25 years is relatively high for each scenario. Thus if the payment can only be made by means of a loan it has as consequence that a high amount of interest also needs to be paid. When it is possible that the entire or a part of the investment would be paid from money consumers own, they have more benefits, because then the amount of interest that needs to be paid will be lower.

These investment costs are also determined for each scenario for the larger scales. The measures have lower costs when they are carried out in serial and when more than 50 dwellings are renovated at once there are added scale benefits. Table 8.1 shows that costs are lower when the renovation is carried out collectively. The decrease in costs depends partly on what type of measures it concerns, because for the scenario insulation the costs for a scale of 2 to 50 dwellings have decreased relatively more than for the scenario energy generation. When the renovation is carried out on a scale larger than 50 dwellings the costs decrease even more. Thus renovating together with a group has financial benefits, because the costs are lower and when the scale is larger than 50 dwellings there are even more benefits.

Finally the larger the investment costs the more they will have an influence on the profitability. To make a large investment profitable the benefits should be high enough to compensate the costs. The profitability will increase when the renovation is carried out on a larger scale and the benefits remain at the same level of an individual dwelling.

### 8.1.2 MAINTENANCE COSTS

The yearly maintenance costs are not the major costs in the analysis, compared to the other costs they are relative low costs. The costs for each scenario are displayed in table 8.2. The costs are higher when the number of installations increases, which is logical, because there are more installations to maintain. It seems these costs will not make a difference on a yearly basis, but when these costs are added up for the examined period, the costs will count.

Costs for each scenario		
<b>Only insulation</b>	€ 60,00	<i>Ventilation system</i>
<b>Energy generation</b>	€ 90,00	<i>Solar boiler + pv-panels</i>
<b>Energy neutral</b>	€ 150,00	<i>Solar boiler + pv-panels + ventilation system</i>

Table 8.2: Overview of yearly maintenance costs

### 8.1.3 ENERGY COSTS

Before the energy costs were calculated an energy balance was made with all the used energy, saved energy and generated energy. In table 8.3 an overview is given of the energy balance by scenario. The energy balance is build up from the amount of energy an household used before the renovation, the amount of energy saved by insulation, the amount of sustainable energy generated, the energy used by the installations and then the estimated amount of energy that will be used after the renovation. For the energy balance all the amounts of energy usage were converted to kWh, this is used as an universal unit to add up the different energy amounts.

From these calculations it becomes evident that it is possible to make a dwelling energy neutral with this set of measures. The scenario to energy neutral even generates

	Only insulation	Energy generation	Energy neutral
<b>Energy usage before renovation</b>	20.445	20.445	20.445
<b>Energy saved by insulation</b>	11.218	0	12.821
<b>Energy generated</b>	0	7737	7737
<b>Energy usage installations</b>	57	200	-13
<b>Energy usage after renovation</b>	<b>9184</b>	<b>12908</b>	<b>-126</b>

Table 8.3 Overview energy balance in kWh

energy, even though it is a small amount. The amount of saved energy for scenario only insulation and energy generation differ about 3800 kWh. When a closer look is taken at the

energy usage after the renovation by separating the energy usage in electricity usage and gas usage, the results are different, see table 8.4. The scenario only insulation only saves gas and the scenario energy generation saves a part of the gas usage and a lot of the energy usage. But the total energy costs differ only about €200,-, this indicates that the costs for energy for both scenarios are about the same. When electricity or gas prices evolve different in the future one of the two can have more benefits. For the scenario to energy neutral it becomes clear there will be no gas usage after the renovation, thus the gas connection is no longer necessary. And by resupplying energy the scenario to energy neutral will even earn money. When the three scenarios are compared to the base scenario it becomes clear that the energy costs have dropped after the renovations.

Energy usage after the renovation in 2014				
	Base scenario	Only insulation	Energy generation	Energy neutral
Electricity usage in kWh	3350	3407	86,8	-126,2
Gas usage in m3	1950	658,9	1462,5	0
Total energy costs	€- 2.004,50	€-1.177,85	€-969,72	€8,83

Table 8.4: Overview energy usage and costs

## 8.2 CASH FLOWS BY SCENARIO

Now the input for the cash flows is analysed, the cash flows can be analysed. In this paragraph the cash flows will be analysed by scenario for an individual dwelling. In the next paragraph the analysis will be made for the different scales. As explained in the previous chapter the cash flows were constructed by means of the Discounted Cash Flow method. Since in this research the cash flows are about expenses of consumers, the cash flows are presented as negative cash flows. In these scenarios the inflation rate, the increase in energy prices, discount rate and other parameters are taken in account as set in the previous chapter. The Net Present Value represents the total value of these cash flows in the present time, an overview of the NPV's for each scenario are given in table 8.5. Figure 8.6 and 8.7 display the cash flows with or without a mortgage.

The total net present values have a negative amount, because they are based on expenses, therefore the lowest negative NPV is the best scenario. Looking at the NPV's scenario energy generation is the best option closely followed by scenario only insulation. The third scenario to energy neutral is the worst option, this option has the highest costs. This can be caused by the fact that the investment costs of the third scenario are much higher and therefore there are more benefits needed in return. The scenarios only insulation and energy generation are more beneficial than doing nothing and this indicates that the benefits outweigh the investments costs over a period of 25 years.

	NPV mortgage	NPV without
Base scenario	€ -60.100,71	€ -60.100,71
Only insulation	€ -55.638,05	€ -54.475,30
Energy generation	€ -54.295,39	€ -53.304,02
Energy neutral	€ -65.989,48	€ -62.783,67

Table 8.5: NPV by scenario

Another thing that stands out is that there is a difference if a mortgage is used to finance the renovation or when the total amount for the investment is paid at the beginning. The difference between the scenarios only insulation and energy generation is relative small, this is about € 1.000,-. But the difference is larger for the third scenario to energy neutral, this difference is over € 3.000,-. This indicates that the larger the investment costs the more the mortgage costs can make a difference and the more the mortgage costs have an influence on the total NPV and the profitability.

Figure 8.6 displays the actual cash flows when a mortgage is used to pay for the renovation. The discounted cash flows are displayed in appendix 9, because the actual cash flows give more insight in the actual yearly payments. The cash flow of the base scenario in figure 8.6 shows that the costs will double in a period of ten years to yearly energy costs of over

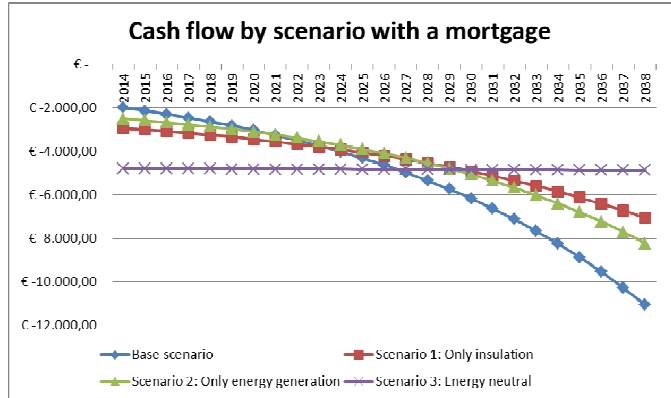


Figure 8.6: Cash flow by scenario with a mortgage

€ 4.000,- in 2024, the costs for this scenario only consist of the energy costs. Thus the energy costs will double in a period of ten years. The cash flow of the third scenario to energy neutral stands out, because the cash flow is nearly constant. The yearly costs are almost constant, because the mortgage payments are the same every year and the energy costs are also constant. The energy costs are actually no costs, because they are positive because energy is supplied back to the net. The cash flows of scenario only insulation and energy generation indicate that the yearly costs are increasing, but not as much as for the base scenario. Also the costs for the scenario only insulation are increasing less than for the scenario energy generation, these causes by a difference in energy and gas usage and different increase rates for the energy and gas usage. This indicates that it is better to have less gas usage than less electricity usage, because the gas prices are increasing more than the electricity prices.

Figure 8.7 displays the cash flows when the total investment is made in 2014. The figure shows that in 2014 the costs are very high, because of the investment that is made in that year. The figure shows that the cash flows for the scenario to energy neutral are almost constant and they are very low, thus the yearly costs for that scenario are the lowest. The

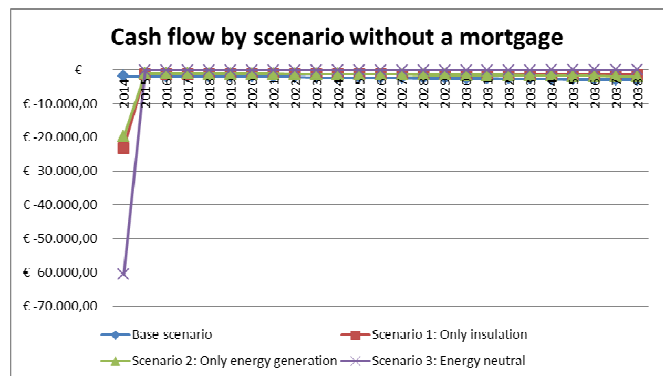


Figure 8.7: Cash flow by scenario without a mortgage

highest yearly costs are from the base scenario. Scenario energy generation has lower costs in the beginning than scenario only insulation and in the end of the period they are higher. This is the same as for the scenarios with a mortgage. In 2023 the yearly cash flows are lower for scenario only insulation than scenario energy generation. Thus scenario energy neutral is the least profitable renovation option, due to the high investments costs and that the

benefits are not high enough over 25 years to compensate them. The scenario only insulation is most profitable followed by scenario generating energy. For these scenarios the benefits over 25 years are high enough to compensate the investment costs for those years.

### 8.3 CASH FLOWS BY SCALE

In the previous paragraph the cash flows for a single dwelling were analysed and in this paragraph the cash flows for the larger scales will be analysed. In table 8.8 the NPV's by scenario and by scale are displayed. The NPV's show that when the scale becomes larger the total of the NPV's decrease. This indicates that the larger scales are influencing the NPV's and that there are scale benefits. The scale benefits are the largest for the energy neutral scenario followed by the only insulation scenario and the scale benefits are the smallest for the energy generation scenario. This indicates that the benefits are higher for insulation measures and that when the costs are higher the higher the benefits are. The cash flows for the larger scales are quite similar to the cash flows for one dwelling, therefore they are displayed in appendix 10. They show quite the same trends as for a single dwelling, but with less costs.

	Scale	NPV with mortgage	NPV without mortgage
<b>Base scenario</b>	All scales	€ -60.100,71	€ -60.100,71
<b>Scenario 1: Only insulation</b>	1 dwelling	€ -55.638,05	€ -54.475,30
	2-50 dwellings	€ -51.435,96	€ -50.484,71
	> 50 dwellings	€ -50.963,48	€ -50.036,01
<b>Scenario 2: Energy generation</b>	1 dwelling	€ -54.295,39	€ -53.304,02
	2-50 dwellings	€ -53.014,37	€ -52.087,47
	> 50 dwellings	€ -52.533,98	€ -51.650,26
<b>Scenario 3: Energy neutral</b>	1 dwelling	€ -65.989,48	€ -62.783,67
	2-50 dwellings	€ -61.635,99	€ -58.649,30
	> 50 dwellings	€ -60.753,62	€ -57.811,34

Table 8.8: NPV by scale for a single dwelling

### 8.4 INVESTMENT NEEDS

The cash flows and NPV's have given a lot of information about the scenarios. They do not exactly explain when the investment of the consumers have paid back itself. To find this moment the investment needs need to be analysed. In figure 8.9 the investment need by scenario with a mortgage are displayed. These graphs are constructed by taking the difference in yearly costs between a renovation scenario

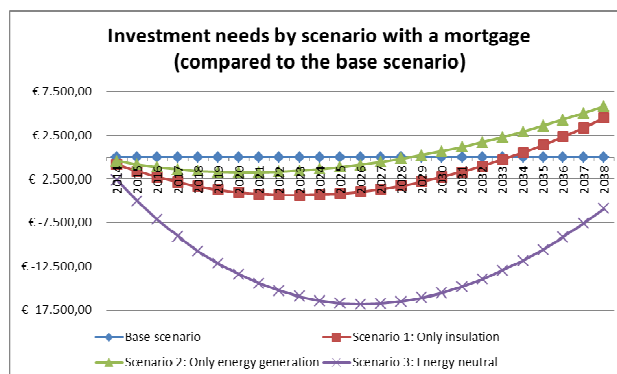


Figure 8.9: Investment needs by scenario with a mortgage

and the base scenario and adding them up every year, for each of the renovation scenarios. So all the positive and negative differences in between those cash flows are added up to determine when the investment has paid itself back in benefits compared to the base scenario. For scenario 2 energy generation with a mortgage this is in 2029, this investment of this scenario pays itself the fastest back. For scenario 1 only insulation this is in 2034, but at the end of the period of 25 years in 2038 scenario 1 is almost better than scenario 2 energy generation. Thus these benefits are increasing more when the investment is paid back than for scenario 2 energy generation. Scenario 3 energy neutral does not pay itself

back in 25 years, there is still a negative amount left of € -5.888,78. It is possible to earn this investment back after the period of 25 years in the 26<sup>th</sup> year and the added benefits for an energy neutral dwelling are higher than a dwelling that is not renovated.

In figure 8.10 the investment needs are displayed by scenario without a mortgage. Because the investment is made entirely in 2014, these investment needs graph looks different. This shows that the investment of scenario 2 only energy generation pays itself the fastest back, in 2033, but

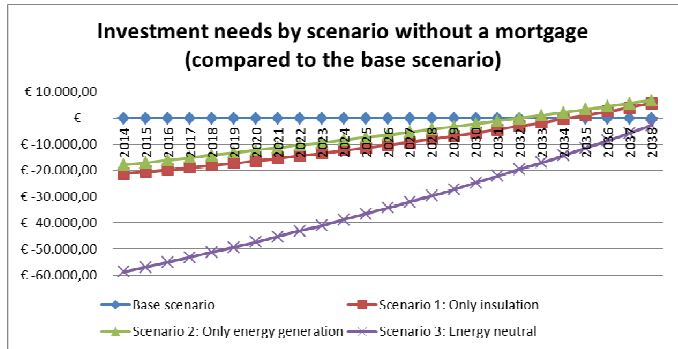


Figure 8.10: Investment needs by scenario with a mortgage

this is closely followed by scenario 1 only insulation in 2035. After a period of 25 years they are at about the same level, but it can be seen that the benefits of scenario 1 only insulation are higher after the investment has paid itself. Scenario 3 energy neutral does not pay back itself in 25 years, but the amount of money that is left is lower than with a mortgage, this is € -2.682,97. The investment needs for the larger scales are displayed in appendix 11.

To compare the scales table 8.11 is made of the payback period for all the scenarios and scales, it shows the year when the investment is paid back and when the investment is not paid back it shows the amount of money left. This table shows that when the scales increase the payback period decreases. For the energy neutral scenario without a mortgage the investment is paid back in 2038, this is exactly in 25 years. And for the energy neutral scenario with a mortgage the amount of money that is left after 25 years decreases a lot when the scale becomes larger. When the scale larger than 50 dwelling a very small amount of money is left. These results indicate that a larger scale is more beneficial for the consumers. The energy neutral scenario also becomes more beneficial then and it starts to pay itself back at the end of 25 years.

	With a mortgage			Without a mortgage		
	Only insulation	Energy generation	Energy neutral	Only insulation	Energy generation	Energy neutral
1 dwelling	2034	2029	€ -5.888,78	2035	2033	€ -2.682,97
2-50 dwellings	2029	2027	€ -1.535,28	2032	2031	2038
> 50 dwellings	2028	2026	€ -652,91	2031	2031	2038

Table 8.11: Payback periods scenarios compared to base scenario

## 8.5 SENSITIVITY ANALYSIS

This paragraph examines the results of the sensitivity analysis. The sensitivity analysis is carried out for the following variables: the increase in energy prices, the moment of the investment, the energy usage, the inflation rate, the interest and discount rate, the total investment costs and the percentage scale benefits. Why these variables are taken in account and how they are varied in the analysis is explained in the previous chapter. To



examine how sensitive the results are for these variables, the NPV's of each scenario are analysed.

#### 8.4.1 INCREASE IN ENERGY PRICE

The increase in energy prices have been volatile over the past years, for both the gas price and the electricity price. The future of how these prices will evolve is uncertain. Therefore it is important to look into the increase in electricity and gas price. First the sensitivity of the electricity price is examined, see figure 8.12. This figure shows that the base scenario and the scenarios with only insulation are most sensitive for an increase in electricity price. In these scenarios the electricity usage is also the highest. The scenarios for energy generation and energy neutral are almost not affected by an increase in electricity price, in these scenarios there is also no electricity supply needed from the net. Thus when in a scenario electricity is needed to subtract from the net then the NPV's of these scenarios are very sensitive for the increase in electricity price. Thus when the increase in electricity price is lower than 2% the scenario for insulation is the best option and when it is higher the scenario for energy generation is the best option. When the increase in electricity price is higher than 6% the energy neutral scenario is also better than only insulation.

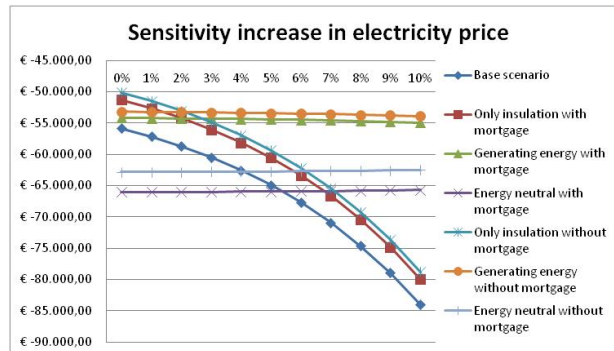


Figure 8.12: Sensitivity of NPV's for the increase in electricity price

The sensitivity for the increase in gas price is shown in figure 8.13. This figure shows that when the gas price is increased the scenarios for energy neutral are not affected, because in these scenarios gas is no longer used. The base scenario is most influenced by an increase in gas price, this is also the scenario where the highest amount of gas is used.

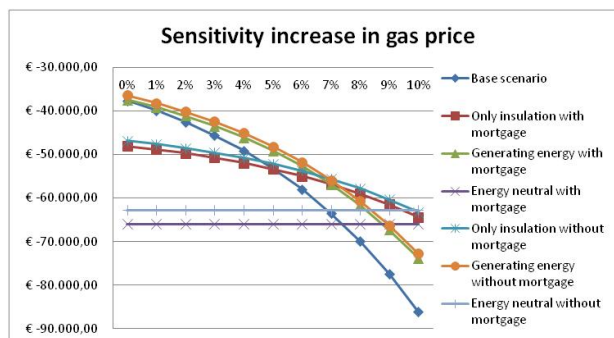


Figure 8.13: Sensitivity of NPV's for the increase in electricity price

This is followed by the scenarios for energy generation, where less gas is used. The scenarios for only insulation are a bit influenced by the gas price, these scenarios also use a small amount of gas. And the scenarios for energy neutral is not influenced, because in these scenarios gas usage is no longer needed. Thus when more gas is used in a scenarios the more sensitive the NPV's of these scenarios are for the increase in gas price. When the increase in gas price is lower than 7%, the scenario for energy generation is the best option, when the increase in gas price is higher this is the scenario with only insulation. When the increase in gas price is higher than 9% the scenario for energy neutral is better than the scenario energy generation.

The sensitivity of the NPV's when both the electricity and gas price are increased at the same rate is displayed in figure 8.14. This figure shows that the scenarios for energy neutral is not affected by an increase in both prices, because this scenario does not use gas or electricity that needs to be subtracted from the net. The base scenario is most influenced by an increase in both prices, when the increase is 0% this option is the best, but when the prices increase more than 6% it is the worst option. The increase in both prices has about the same influence on the scenarios energy generation and only insulation. The option for only energy generation is the best when the increase in both prices is between the 2% and the 8%. When the increase in both prices is higher than 8% the energy neutral scenario is the best. Thus the higher the electricity and gas usage the more the scenario is influenced by an increase in both prices.

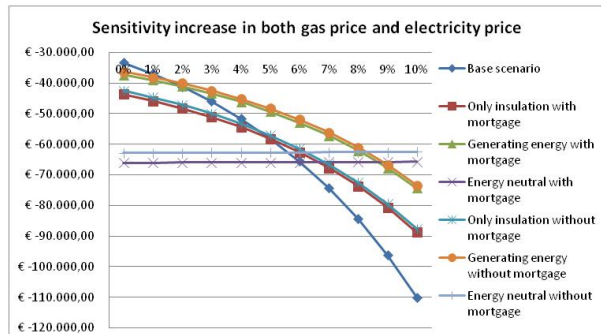


Figure 8.14: Sensitivity of NPV's for the increase in both the electricity and gas price

#### 8.4.2 MOMENT OF INVESTMENT

To determine if it is best to do the renovation now or wait with the investment, the investment moment was added to the sensitivity analysis. To determine the NPV values in the future the increase of costs was taken in account. And for the waiting scenarios the energy costs for the years that no investment was made were also taken in account, because the consumers make these costs when they wait to invest. The results are displayed in figures 8.15 and 8.16. These figures show that for all the scenarios the costs are the lowest when the investment is made now. The figures also show that the NPV's for the scenario energy neutral are almost constant when there is waited with the investment. The NPV's of the other scenarios increase when there is waited with making the investment. This indicates that costs involved with the third scenario are relatively

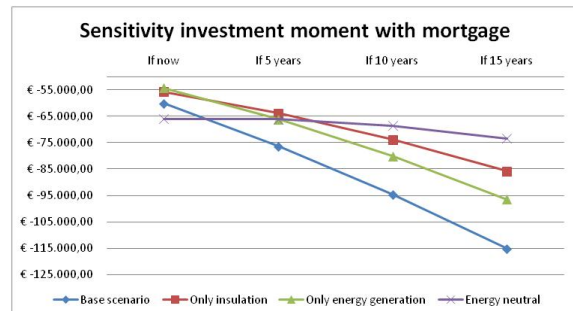


Figure 8.15: Sensitivity of scenarios with mortgage for the investment moment

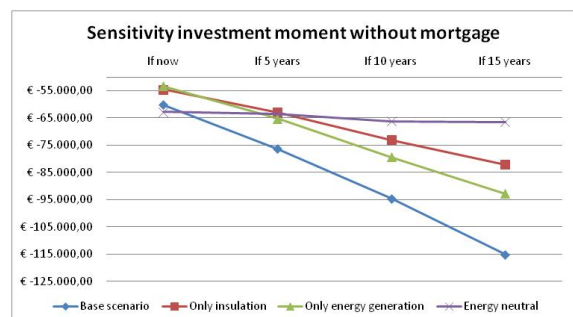


Figure 8.16: Sensitivity of scenarios without mortgage for the investment moment

constant over the years, which means that over time the option for the energy neutral scenario becomes better. The costs for the base scenario doing nothing are increasing the most, this indicates that doing nothing is the worst option over time. The scenarios energy generation and only insulation start at about the same price with the investment now, but the NPV of the scenario only insulation increases less over time, thus this is the better option of the two over time.

#### 8.4.3 ENERGY USAGE

In this sensitivity analysis the energy usages were varied from -50% to +50% with steps of 10%. In table 8.17 the electricity usage in kWh and the gas usage in m3 are displayed for each of these percentages. The variation for electricity and gas usage all have the same percentages, because ratio between the electricity and gas usage when they are higher or lower often are approximately the same.

Increase or decrease	Electricity usage	Gas usage
-50%	1675	975
-40%	2010	1170
-30%	2345	1365
-20%	2680	1560
-10%	3015	1755
0%	3350	1950
10%	3685	2145
20%	4020	2340
30%	4355	2535
40%	4690	2730
50%	5025	2925

Table 8.17: Overview increase in electricity and gas usage

Figure 8.18 displays the sensitivity by NPV. The figure shows that all the scenarios are all sensitive for a change in energy usage. The less energy is used the lower the NPV is and the higher the energy usage the higher the NPV. The NPV's of the energy neutral scenario with or without mortgage show that when the energy usage is at the same amount or lower, then the NPV's decrease less, because then the scenario is energy neutral and the investment costs remain high. When the energy usage increases the scenario for energy neutral is no longer energy neutral, because the installations cannot generate enough energy to make the dwelling energy neutral. The NPV's for the scenarios only insulation and only energy generation also decrease less when the energy usage is decreased. This can be caused by the fact that then for less energy extracted from the net needs to be paid and there is still a constant amount of money that needs to be paid for the investment. The NPV's of all the scenarios increase equally when the energy usage increases, because for all the scenarios for an equal added amount energy that will be extracted from the net needs to be paid.

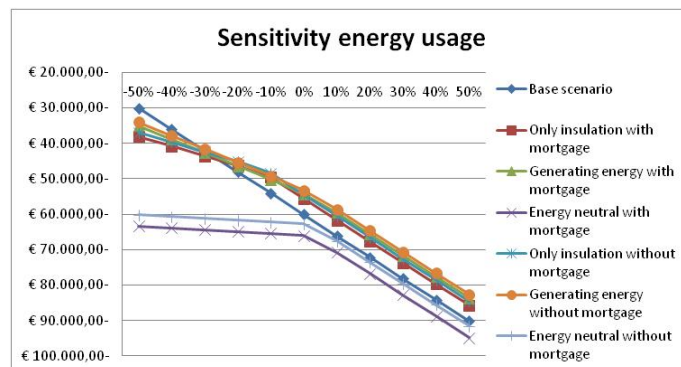


Figure 8.18: Sensitivity of the NPV's for energy usage

#### 8.4.4 INTEREST AND DISCOUNT RATE

The interest rate and discount rate for investments made by consumers are set at the same rate, therefore these will be varied together for the same amount. The base scenario is most sensitive for a change in interest and discount rate. The interest rate does not have an influence on the costs of the base scenario, because no investment is made. Thus this indicates that the energy costs are very sensitive for the discount rate. This is confirmed by

the fact that the NPV's of the energy neutral scenarios are not very sensitive for the change in interest and discount rate. For the energy neutral scenario there are almost no energy costs and the change in interest and discount rate have a minor influence on the total NPV. The influence of the interest and discount rate

for the scenarios only insulation and energy generation lies between the other scenarios, these scenarios have less energy costs than the base scenario. Thus this confirms the fact that energy costs are most influenced by a change in interest and discount rate and the investment costs are less influenced.

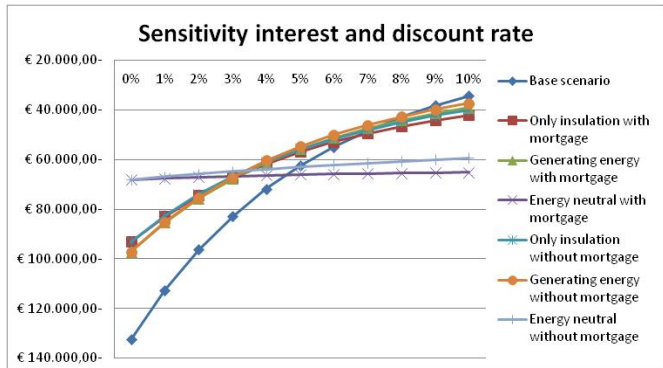


Figure 8.19: Sensitivity of the NPV's for the interest and discount rate

#### 8.4.5 INFLATION RATE

In figure 8.20 the sensitivity is shown for the inflation rate. The NPV's for the energy neutral scenario with and without a mortgage stand out, these NPV's are almost not influenced by the change in inflation rate. Because the investment costs are almost not influenced by the inflation rate and the other costs are low for the energy neutral scenario, so the influence of the inflation rate does not play a large role. The influence of the inflation on the base scenario is large, the higher the inflation the worse the base scenario gets. When the inflation is 3% or higher, then the base scenario is the worst. The only insulation and energy generation scenario are also influenced

by the inflation, when the inflation is higher scenario energy generation is a worse option than scenario only insulation. When the inflation is 5% or higher, then the energy neutral scenario is the best.

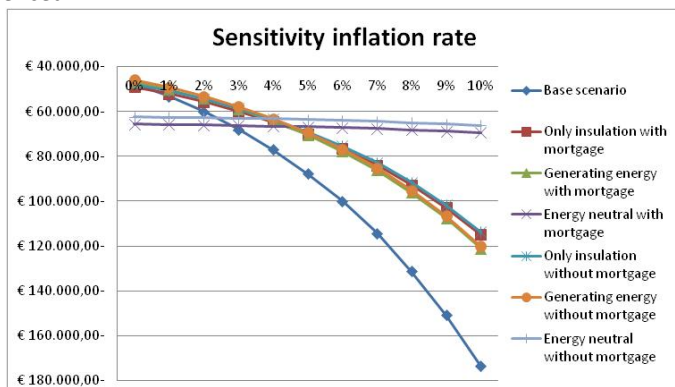


Figure 8.20: Sensitivity of the NPV's for the inflation rate

#### 8.4.7 INVESTMENT COSTS

A decrease in investment costs doesn't influence the costs for the base scenario, because there

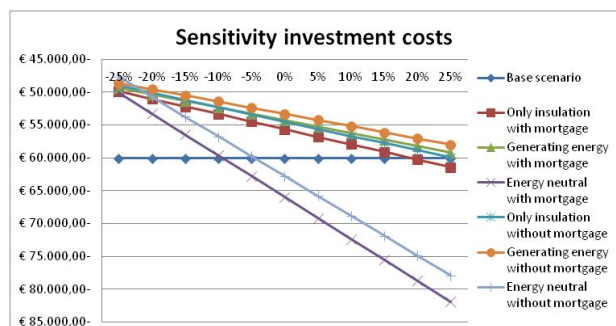


Figure 8.21: Sensitivity of the NPV's for investment costs

was no investment made. The scenarios to energy neutral are most influenced by an increase or decrease in costs. These scenarios also have the highest costs, thus therefore an increase or decrease have more influence than for smaller costs. The costs for the scenarios only insulation and energy generation are in the same range, but the costs for the scenario only insulation are more influenced by an decrease or increase in costs, because these investment costs are a bit higher. When the costs are increasing the option for only insulation becomes a bit worse.

#### 8.4.8 PERCENTAGE SCALE BENEFITS

The percentage scale benefits was only measured for the scale of more than 50 dwellings, because then these added scale benefits start playing a role. The percentage scale benefits has no influence on the base scenario, because no investment was made in that scenario. For all the renovation scenarios the higher the percentage scale benefits the lower the total NPV. The

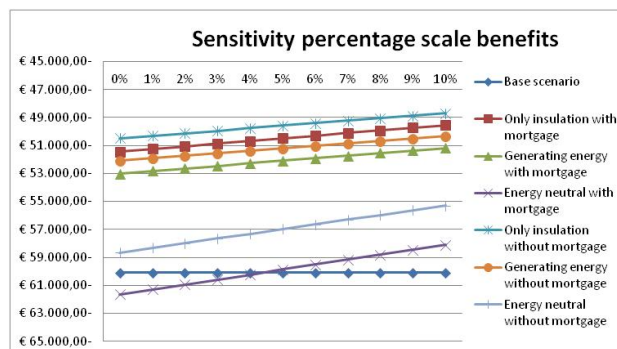


Figure 8.22: Sensitivity of the NPV's for percentage scale benefits

increase or decrease of the percentage scale benefits has the most influence on the scenarios to energy neutral, this can be caused by the fact that these scenarios also have the highest costs. The scenarios only insulation and energy generation are all in the same way influenced by the change in scale benefits. Thus the higher the percentage scale benefits the better the scenarios to energy neutral become.

#### 8.6 CONCLUSION CASE STUDY

The energy neutral scenario has the highest costs of all the renovation scenarios. This is caused by the high investment costs, because this scenario does not extract energy from the net and thus has no energy costs. The base scenario showed that the yearly energy costs are increasing a lot and will be doubled in a period of ten years to over € 4.000,- a year. Both the scenarios generating energy and only insulation have lower investment costs than the scenario energy neutral, because they both have less measures that need to be installed and both scenarios still have energy costs. The energy costs for the energy generation scenario are only costs for gas, because in that scenario no electricity will be extracted from the net. The energy costs for the only insulation scenario are mostly costs for electricity and a small part costs for gas. These energy costs for the scenario energy generation are € 969,72 a year and for the scenario only insulation € 1.177,85 a year in 2014.

The most profitable option is the scenario generating sustainable energy, followed by the scenario only insulation which NPV is € 1.000,- higher. These scenarios are also both better than the base scenario of doing nothing, both the scenarios have lower NPV of about € 5.000,- than the base scenario. The energy neutral scenario is the least profitable option for one dwelling, this scenario has a higher NPV of about € 9.000,- to € 10.000,- than the scenario energy generation. The benefits for the energy neutral scenario over 25 years are

not high enough to compensate the high investment costs, thus this scenario is not profitable over 25 years. When a period of 25 years is examined there is still a negative amount left, this is almost € 6.000,- with a mortgage and almost € 3.000 without a mortgage. The investment costs for the scenarios energy generation and only insulation are lower and the benefits are high enough to make the investment of these two scenarios profitable over 25 years. The scenario energy generation will pay itself back in financial benefits in 2029 and the scenario only insulation in 2034.

There are also some differences for the profitability when a mortgage is used or when the investment is paid at once. The mortgage costs for the renovation scenarios are very high, so they have a major influence on the profitability when a mortgage is used to finance the renovation. It is more profitable to make the investment for the renovation at once if that is possible for the consumers. The NPV's for the scenarios only insulation and energy generation without a mortgage are about € 1.000,- lower and the NPV for energy neutral without a mortgage is about € 3.000,- lower.

When dwellings are renovated at a larger scale there are added financial benefits. There are the benefits in costs when measures are carried out in serial. These are the highest for the insulation measures and therefore have the most influence on the profitability of scenario only insulation and energy generation. The NPV's for the scenarios only insulation and energy neutral at a scale of 2-50 dwellings are about € 4.000,- lower than for the scale of one dwelling and the NPV of the scenario energy generation is a bit more than € 1.000,- lower. And the added scale benefits increase even more with 2-3% when the scale is larger than 50 dwellings, these benefits are the same for all renovation scenarios. This results in the fact that when the scale is larger the scenario only insulation becomes the best option, this option is then more profitable than the scenario generation energy. Also the energy neutral scenario without a mortgage becomes more profitable than doing nothing when the scale increases.

The sensitivity analysis showed that the profitability of the scenarios is influenced by parameters, some of them more than others. The change in the percentage scale benefits has a minor influence on the scenarios and influences them all in the same way. The scenario energy neutral with a mortgage is also more beneficial than base when the scale benefits are higher than 5%. The influence of a change investments costs becomes larger when costs are higher, but this is a minor influence. The energy neutral scenario will also be better than base when the investment costs are lowered more than 5%.

The inflation rate does not influence the energy neutral scenario. But the influence on the other scenarios is high, when the inflation rate is higher the worse the other scenarios get. When the inflation is higher than 5% the energy neutral scenario becomes the best. The change in interest and discount rate also do not influence the energy neutral scenario, but the other scenarios are highly influenced. The higher the interest and discount rate are, the more profitable the other scenarios become, when the rate is lower than 3% the energy neutral scenario is the best. The increase in electricity and gas price is also not from influence for the scenario energy neutral, but it is from high influence on the NPV's of the other scenarios. The base scenario is most influenced by an increase in electricity price, gas price or both prices. The generating energy scenario is almost not influenced by an increase

is electricity price, but is influenced by an increase in gas price. The only insulation scenario is greatly influenced by the increase in electricity price and a bit influenced by the increase in gas price. The energy neutral option becomes best when the electricity price increases more than 7% and the energy neutral option is also best when both the electricity and gas price increase more than 9%.

A change in energy usage is of influence on all the scenarios. When the energy usage increases the influence on all the scenarios is the same, because for all the scenarios the added usage is the same amount. When the energy usage decreases, the influence is less for the renovation scenarios, because all of them save energy and there are still fixed investment costs. The sensitivity of the investment moment has showed that the costs for all the scenarios are increasing in the future. The scenario energy neutral is almost constant, while the NVP's of the other scenarios are increasing when the investment is delayed. The sensitivity for the investment moment shows that now is the best moment to make the investment, but when longer is waited with the investment the better option the energy neutral scenario becomes.

The sensitivity analysis showed overall that mainly the energy costs are sensitive to change in the parameters and the investment costs are less sensitive. Thus the scenarios that still have energy costs are more influenced by a change in parameters than the scenario energy neutral. The renovation to energy neutral gives more certainty about the costs and benefits towards the future, because it is less sensitive in changes in parameters. The benefits and costs of the other two renovation scenarios energy generation and only insulations are more uncertain towards the future, because they are more sensitive towards the changes in parameters.





## 9. CONCLUSION

In the previous chapters through the literature research and the case study all the benefits of renovating a dwelling to energy neutral individually and collectively have been researched. Through this research all the sub questions have been answered, the answers to these sub questions will lead to an answer on the main research question:

*What are the benefits when consumers make their dwelling more sustainable into an energy neutral dwelling as a group?*

For the answer on the research question first the added benefits for consumers who make their dwelling energy neutral are discussed and then the added value when this is done as part of a collective. The conclusion will also take a look at the profitability of an energy neutral dwelling and compares the three renovation scenarios from the case study.

### Energy neutral dwelling

The definition for an energy neutral dwelling in this research is: an energy neutral dwelling is a dwelling that has no net import of fossil or nuclear fuel from outside the property needed for the exploitation of the building on a yearly basis during the use phase. Measures to make a dwelling energy neutral were determined and the case study showed that it is possible to make a dwelling energy neutral with those measures. There are several added benefits for the consumers when their dwelling is made energy neutral, these can be categorized in financial, social, ecological and future value.

The social value is considered most important after the financial value, this value concerns comfort and health. When a dwelling is made energy neutral the added social benefits are that the indoor climate is improved, the comfort levels have improved and indoor climate is more healthy. This leads to a higher living quality for the consumers in their dwelling. An added value during the renovation process for the consumers is minimizing inconvenience. The ecological value when a dwelling is made energy neutral is mostly not valued financially by the consumers and is considered as least important. The added ecological value is that an energy neutral dwelling uses less energy and renewable energy is used for the energy usage that is left. This leads to an energy neutral dwelling that no longer uses fossil fuels and that the dwelling will have less CO2 emissions.

Consumers rate the financial value as most important when they consider renovating their dwelling. The financial value results in a large decrease in housing costs, which is mainly caused by a large decrease in energy costs. In an energy neutral dwelling there are no longer energy costs that need to be paid to the energy supplier, the dwelling even supplies energy back to the net. Thus besides that the housing costs have become lower they are also more stable, now there are no uncertain increasing energy costs part of the housing costs. Another added benefit is that the value of a dwelling can increase. A better insulated dwelling with energy label A,B or C will have a higher value of € 8.395,- on average than a bad insulated dwelling. The dwelling value is higher because a higher energy label indicates that there are less energy costs. This higher value can go up to € 30.000,- more than for a poorly insulated dwelling. So consumers are willing to pay between the € 5.000 and € 30.000 extra for an energy efficient dwelling. They are willing to pay € 5.000 until € 10.000 without

pre-set conditions and they are willing to pay an average of €15.000,- more when they now there is a certain payback time and that the energy bill have decreased.

But the downside for the financial benefits are the high investments costs that are needed to realize the renovation. The case study has showed that these high costs are not earned back in a period of 25 years. This is due to the high investment costs for the renovation, the benefits through the lowered energy costs are large. If a longer period of time would be examined these costs can be earned back. The investment can be earned back if only one year longer would be examined. When the investment is paid back or when the mortgage has ended, there are no more energy costs for the consumer. This is an added benefit, because then the only monthly housing costs that are left are the maintenance costs for the installations. Thus when the investment has paid back itself or when the mortgage has ended there are no longer energy costs and only the benefits for the consumers remain.

Future value is also considered as an important part of value creation. When a renovation is carried out now, the measures should still have the value in the future. Future value will be increased when a dwelling is renovated to energy neutral, because when a dwelling is renovated to energy neutral the condition and the building quality of the dwelling increase. When the quality of the dwelling is improved during the renovation, the lifespan of a dwelling is also increased. So the dwelling can last longer and this results in a higher future value for the dwelling. Future value is also created when an energy neutral dwelling no longer needs to subtract energy from the net. This leads to low and stable housing costs, because they are independent from the uncertain increasing energy costs. This leads to more certainty about the expenses of consumers and because of that it is even possible for consumers to get a higher or an additional loan.

### **Renovating dwellings as a collective**

Benefits that arise when consumers renovate their dwelling as part of a collective can be categorized in organizational, financial and other benefits. There are major organizational benefits for consumers when they renovate as part of a collective. Because it is possible to outsource management, so they don't have to figure out the details of the renovation themselves. They can also cooperate with a business that takes care of the entire renovation for them. The financial benefits concern lower renovation costs, because the measures can be carried out in serial and if the scale is larger than 50 dwellings there are even more financial scale benefits. The benefits for the renovation to energy neutral on a scale for 2 to 50 dwellings are about € 5.000,- and for a scale larger than 50 dwellings there are another € 1.000,- more benefits. When consumers are part of a collective they can be part of favourable financing regulations, which can have added financial benefits.

Other benefits that occur when dwellings are renovated as a collective besides the organizational and financial benefits are that it is possible to improve the quality of the neighbourhood. The exterior of the dwellings will be improved by the renovation and when all consumers work together they can improve their entire neighbourhood. Another benefit is that there will be group pressure in a neighbourhood to renovate the dwellings, so more consumers will take part of the renovation. The final benefit is the possibility for collective energy generation, but this is expensive and not always applicable for existing dwellings. Therefore the collective energy generation was not taken in account in the case study.

### Profitability

The research has shown that renovating a dwelling to energy neutral is not profitable in a period of 25 years, there will be a negative amount of almost € 6.000,- left with a mortgage and almost € 3.000,- without a mortgage. When the scale becomes larger the renovation for energy neutral will be more profitable in a period of 25 years, because of the scale benefits. Thus the scale benefits have a positive influence on the profitability of a dwelling. Also when there are scale benefits the renovation to energy neutral without a mortgage pays itself back within the period of 25 years and then the scenario will be profitable. And when a mortgage is used for a scale of 2 to 50 dwellings there is a negative amount of € 1.535,28 left and when the scale is larger than 50 dwellings there is a negative amount of € 652,91 left. The examined period was set at 25 years because the guaranteed lifespan of the installations is 25 years. But when the actual lifespan of these installations is longer, then after the examined 25 years the consumers can keep earning the benefits from their investment.

But as mentioned before the added benefits such as increased comfort levels and a healthier indoor climate are also valued financially by consumers. Thus do these benefits weigh up to the high investment costs? This depends partly on the perception of the consumers if they think it is worth it. But the literature have showed that consumers are willing to pay between the €5.000,- and €10.000,- more for energy efficiency measures when they buy a dwelling. So the increases living quality is worth a certain amount of money. Literature also indicated that an energy efficient dwelling will have an higher added value, this is on average € 8.395,- and the added value can go up to € 30.000,- when there is a large difference before and after the renovation. When this average added value for an energy efficient dwelling would be added to the financial equation the renovation would be profitable in 25 years. So, the added value of a dwelling would make the renovation profitable and make the financial benefits higher. The exact value of a dwelling is hard to determine, because of the current market circumstances. The added value of the dwelling can be seen as an added benefit for the consumer when they want to sell their dwelling. Thus by adding all benefits up it can be concluded that renovation to energy neutral is a good option and that besides the costs there are a lot of benefits that can be gained for the consumers.

The profitability of a scenario can also be influenced by a change in the parameters. The sensitivity analysis showed that changes in parameters do have an influence on the profitability of the energy neutral scenario compared to other scenarios. Thus if a couple of parameters would change the profitability can increase or even decrease. This is still an uncertain factor in the model, because it is hard to predict the future exactly.

### Comparison to other scenarios

In the case study were, besides the renovation to energy neutral, two other renovation scenarios examined. These scenarios concerned applying only insulation or only generating energy. The case study have showed that both these scenarios are more profitable, under the set parameters, than the scenario for energy neutral. Even though the yearly benefits are smaller, because both these scenarios still have energy costs after the renovation. The difference in profitability was mainly caused by the fact that these two scenarios have much lower investment costs than energy neutral and the benefits of these scenarios weigh up to the costs. But the total added value for a dwelling will be lower for these two scenarios, because the renovation is not as extensively done as for the energy neutral dwelling.

The other benefits besides these financial benefits are also be smaller. Because the dwelling is renovated not as extensively as with the energy neutral scenario. For the energy generation scenario the building quality and comfort levels have not increased, because the dwelling was not insulated. The energy usage was not reduced in this scenario and it is still needed to subtract energy for heating the dwelling from the net. The only added benefit for this scenario is that it subtracts less energy from the net and that renewable energy is generated for all the electricity usage. But it is still needed to subtract gas from the net and thus still fossil fuels are needed for the energy usage in the dwelling for the energy generation scenario. Thus the added benefits for the energy generation scenario are a lot less than for the energy neutral scenario. For the only insulation scenario the building quality is improved, which increases the life span of the dwelling and by insulating a more comfortable and healthy indoor climate will be created. But the building quality and comfort levels have improved less than for energy neutral, because the renovation was less extensive. The only insulation scenario is still needs to subtract gas and electricity from the net and thus still fossil fuels are needed for the energy usage of the dwelling.

When the mentioned benefits for the only insulation scenario are compared to the benefits of the energy generation scenario there are more benefits for the only insulation scenario. The added benefits from the only insulation scenario over the energy generation scenario are that the building quality have improved and the comfort levels have improved, which indicates that then the dwelling value would also increase. Between these scenarios the difference in NPV for renovating a single dwelling is € 1.000,-, negatively for the only insulation scenario, but when the scale is larger the only insulation option has a better NPV than for energy generation. When the scale is 2 to 50 dwellings the NPV for the scenario only insulation is almost € 3.000,- lower than the scenario energy generation and when the scale is larger than 50 dwellings the NPV is about € 1.500,- lower. Thus the only insulation scenario is a better option, because there are more added benefits and it has a better NPV when the scale is larger.

Thus the scenarios only insulation and energy generation can be more profitable than the scenario energy neutral, but their other benefits are a lot less than the energy neutral scenario. Does this difference in Net Present Value of about € 10.000,- weigh up to the more benefits an energy neutral dwelling has? This depends partly on what the consumers think the added benefits of the renovation to energy neutral are worth. Both the scenarios only insulation and energy generation will still have costs for energy at the end of the examined 25 years and the energy neutral scenario does not. Thus after the 25 years the benefits are only increasing more for the energy neutral scenario and for the other two scenarios the costs are increasing. Also the increased value for an energy neutral dwelling will be more than for the scenarios only insulation and generating energy, because the dwelling has been renovated more extensively and it is more energy efficient. Thus the energy neutral scenario will have more benefits and added value than the other two scenarios, but it will also have more costs. Thus looking at all the benefits, the future value and the fact that the investment have almost earned itself back after 25 years the renovation to an energy neutral dwelling is an option that can compete with the other renovation scenarios only insulation and energy generation.

## 10. DISCUSSION AND RECOMMENDATIONS

This chapter provides a discussion about the conclusion and the recommendations for further research. The final paragraph contains a personal reflection of the results.

### 10.1 DISCUSSION

This paragraph about the discussion contains some remarks on the research and the results.

- The sensitivity analysis has showed us that the accuracy of the parameters have an influence on the outcome. Because the model is very sensitive for a change in certain parameters. This results in the fact that the results have a degree of uncertainty in them and that the outcome can differ from the reality.
- A comment can be made about the applicability of the model in the practice, because the calculations have been made on a theoretical basis and none of them are tested in reality. The model is made as realistically as possible, but it is not reality. To test the energy neutrality of a dwelling the renovation should be carried out in reality.
- The value of a dwelling was not taken in account in the financial model. While the literature indicates that a more sustainable dwelling has more value than an unsustainable dwelling. Taking not in account this value has an influence on the profitability of the research scenarios, because a higher added value of a dwelling results in higher total benefits. This could cause a skewed picture of the profitability of energy neutrality compared to the other scenarios. Because in the other scenarios in this research the dwelling is not made as sustainable as an energy neutral dwelling, thus the added value for a dwelling would also be lower. Thus taking in account the added value could increase the profitability of the energy neutral option. But it would also increase the uncertainty of the outcome of the model. Because the value of a dwelling is hard to predict in theory at this moment, due to the large uncertainties in the current housing market. Especially the added value of a dwelling that is made energy neutral is hard to determine, because added value for sustainability is not yet fully taken up by the market or in valuation models. Therefore to provide an outcome with more certainty it was indeed best to let the value of the dwelling out of the equation.
- The collective energy generation measures were not taken in account in the energy neutral scenario, because the installations are expensive and it is difficult to apply them in an existing district. But now it is not known if these collective energy generation is a more beneficial option than individual energy generation, because this option was not examined that thoroughly. To determine if the collective energy generation is an option this needs to be researched specifically for every district and every energy generation option. This would take a lot of time and money to research this, therefore it is acceptable that this option is not researched further.
- Added benefits for certain cooperating forms and finance regulations were not taken in account in the financial model even though these can have added financial benefits for the consumers. How the benefits of these cooperating forms and finance regulations turn out will differ by situation, this is different for the type of district, involved businesses and what the consumers choose how to cooperate. Thus these benefits could not be incorporated with certainty and should be examined more extensively.
- When a dwelling uses more energy than the average amount, the dwelling will not be energy neutral after the renovation with this set of measures. It is not possible to keep

on saving energy or generating energy when consumers are still using a lot of energy. Part of making a dwelling more sustainable is also using less energy. Thus consumers should also reduce the amount of energy they use if they want their dwelling to be energy neutral.

- The current market for energy efficiency measures are evolving, more new and innovative measures will be available in the future. For example the market for PV-panels have evolved over the past years, PV-panels are much more efficient and their costs have decreased by half. Thus in the future the energy efficiency measures will probably have less costs, are more efficient and generate or save more energy than the current measures. This indicates that in the future these measures will be more profitable and it is also possible that a renovation to energy neutral will be more profitable too.

## 10.2 RECOMMENDATIONS

As a result of the research and the conclusions several recommendations can be made for further research or application in the reality.

- An addition to the financial model would be incorporating several future scenarios, that have different sets of parameters. Because the sensitivity analysis have shown that the outcome and thus the profitability depends on the accuracy of the parameters. The future scenarios can represent different ways the future might develop, with each a different set of parameters that represent these future developments. By adding this to the model the outcome can be predicted with more certainty and depends less on one set of parameters.
- The model can be expanded by adding several options to the model. A recommendation is to alter the model to make it fit for different types of dwellings, because the model is now set for a row-house. Another addition would be adding more measures to the model, so more different types of renovation scenarios can be worked out.
- In the research one set of measures was made to make a dwelling energy neutral. For further research it would be good to look into other sets of measures to make a dwelling energy neutral.
- Another recommendation is to examine the options for collective energy generation further. Look further in to if it possible that these option can be profitable and applied for existing dwellings.
- In the research several options for cooperation forms and financing regulations were shortly examined. This resulted in several interesting options that can be applied for a collective renovation, which can have added benefits for the consumers. Therefore it is recommended to examine possible business models and earning models further for consumers renovating their dwellings.
- To determine if the energy neutral renovation of a dwelling from this research also becomes energy neutral it would be best to test the energy neutral renovation in practice. Because only by applying the measures in reality certainty can be given about the energy neutrality of the dwelling.

## 10.3 REFLECTION

This final paragraph contains a personal reflection of the results of the research and the acknowledgements. During the research I have gained a lot of knowledge and experience in

relation to the subject. Therefore I want to use this paragraph for a personal reflection on the research results.

I think that investing in energy efficiency measures for the dwelling is worth it. There are a lot of benefits that can be gained besides the financial benefits, mainly the increased comfort levels and healthier indoor climate can have a great influence on the lives of people. The financial benefits can be large when a dwelling is made energy efficient and no energy bill will mean less housing costs and not depending on uncertain energy prices. I think it is best to renovate the dwelling as extensive as possible, because then the most benefits can be gained and the most energy and money can be saved on the long term. Thus the energy neutral renovation scenario can compete with the scenarios only insulation and energy generation in my opinion and it is definitely on the long term the best option.

When it is possible for consumers to be part of a collective renovation it is best to join it, because then the consumers can gain even more benefits. New financing and cooperation regulations can have even more benefits and can provide favourable financing options. Developing these financing regulations and cooperation forms is also important, because it give consumers more possibilities to make the investment for the renovation and it can help convincing people to join the renovation.

Making the built environment more sustainable can also be a boost for the construction sector and the economy. Currently not a lot of new built buildings are developed, because of the crisis and therefore improving the existing dwellings can be an opportunity. There are a lot of chances to make the existing buildings energy efficient and investments in this sector can have benefits for the ones who make the investment and the ones who carry out the renovation.

Making existing dwellings energy neutral is a step towards energy neutral districts and cities. I believe that realizing energy neutral districts and cities is possible, but it is necessary to overcome some barriers. These are political, technical, financial and social barriers that should be overcome. It requires cooperation, commitment and an innovative and positive attitude of all the stakeholders to make the change towards energy neutrality happen.

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## APPENDICES

Appendix 1: Score tables energy efficiency measures.....	88
Appendix 2: Scenarios .....	91
Appendix 3: Investment costs .....	93
Appendix 4: Energy usage installations.....	96
Appendix 5: Maintenance costs installations .....	97
Appendix 6: Data about the dwelling.....	98
Appendix 7: Parameters .....	99
Appendix 8: Overview investment costs by scenario .....	102
Appendix 9: Discounted cash flows by scenario .....	104
Appendix 10: Cash flows for larger scales.....	105
Appendix 11: Investment needs by scenario for the larger scales .....	107

## APPENDIX 1: SCORE TABLES ENERGY EFFICIENCY MEASURES

As explained in paragraph 3.10, the energy efficiency measures will be scored on several factors to determine which measure will be best to apply to renovate a dwelling to energy neutral. In this appendix these score tables will be analysed. The measures are scored for these criteria with the following scores:

- ++ = Very good
- + = Good
- 0 = Neutral
- - = Bad
- -- = Very bad

Insulation measures	Possible insulation value	Costs	Applicability	Problems with draft or thermal bridges
Cavity wall	-	+	++	0
Interior wall	+	-	-	0
Exterior wall	++	--	+	++
Exterior roof	++	-	+	++
Interior roof	+	+		0
Floor bottom	++	+	+	0
Floor on top	++	-	-	0
Soil insulation	+	+	+	-
Replace glass by HR++	+	+	+	+
Replace window frames	++	--	0	+
Replace door frames	++	0	+	+
Draft proofing	0	++	++	0

Table A1.1: Score table for insulation measures

In table A1.1 the insulation measures are scored for the possible height of the insulation value, the costs, the applicability and the possibility for problems with draft or thermal bridges. In this appendix the choices for the measures to make a dwelling energy neutral are described more and detail. It also describes why certain measures were not chosen.

### Wall insulation

The best option for wall insulation to apply when a dwelling is renovated to energy neutral is exterior wall insulation, because insulation with high insulation values can be applied, minor inconvenience for consumers and there are no problems with draft or thermal bridges. Interior wall insulation is not a good option, because this gives a lot of inconvenience for the consumers, when insulation is placed on the inside of the wall the indoor space will be decreased. Another disadvantage is that there are also chances for problems with thermal bridges. Cavity wall insulation has as a major disadvantage that the insulation values are limited, because of the limited space in the cavity.

### Floor insulation

For the floor insulation the best option is to insulate the floor from the bottom. This has as advantage that there is minor inconvenience for the owner and high insulation values can be realized, a requirement is that there is enough space underneath the floor. There is not



chosen to insulate the floor on top, this has major inconvenience for the owners, because the floor needs to be removed and the new one will be centimetres higher. A disadvantage for soil insulation are problems with draft and thermal bridges.

### Roof insulation

For the roof insulation is chosen for insulating the roof from the outside. This measure has as advantage that high insulation values can be realized and thermal bridges will be avoided. An added advantage is that the entire roof can be renovated and brought up to date. Another advantage is that by applying exterior insulation for the wall and the roof these can be connected, which prevents thermal bridges between the roof and walls. Renovating the entire roofs also extends the lifetime of a dwelling. There is not chosen for insulating the roof from the inside, because thermal bridges can't be avoided that way and space will be decreased by insulating from the inside.

### Glazing, window and door frames

For an energy neutral dwelling it is best to replace the window frames. Because when the walls are already that well insulated it is also best to place new window frames with a high insulation value. This prevents draft, thermal bridges and cold air draught by the windows. The measure has relative high costs, but is also well applicable and high insulation values can be realised. Besides that, the triple glazing with the highest insulation value won't fit in standard window frames and the new frames will have better insulation values. By replacing glass by HR++ also saves energy and decreases cold air draught, draft and thermal bridges near the windows. So, replacing glass by HR++ also saves energy, but not as much as by replacing the window frames. When in a renovation of a dwelling to energy neutral the entire outside of a dwelling is renovated it is also best to replace the door frames of the front and back door by better insulated frames, this will have minor costs and contributes to saving energy.

### Draft proofing and sealing cracks and seems

Draft proofing and sealing cracks and seems is a relative cheap measure to make a the dwelling a bit more energy efficient. During the renovation to energy neutral the draft proofing and sealing seems and cracks will be executed at the same time when the other measures are applied. This is possible because the entire outside of the dwelling is renovated by applying insulation measures on the outside and replacing window and door frames. This can save time and money by making sure when all the other insulation measures are applied the draft proofing and sealing cracks and seems are done at the same time.

Installations	Contribution to energy neutrality	Costs	Applicability
Heat recovery	0	+	+
Biomass	+	-	--
Solar boiler	++	0	++
PV-panels	++	0	++
Wind energy	+	-	--
Thermal storage	+	--	-

Table: A1.2 Score table for installations that generate energy

### Energy generation

The energy generation systems that can be best applied for an energy neutral dwelling are the PV-panels and the solar boiler, because they are good applicable on existing dwellings and they have relative low costs. But the roof must be suited for installation of PV-panels and solar boiler and the orientation of the roof should be good to ensure enough sunlight falls on the panels to generate as much energy as possible. Biomass is not an option because this is not profitable for a single dwelling and it still uses organic material to generate energy. Small wind mills are not an option, because on most locations there is not enough wind speed to generate enough energy and it can give nuisance for the neighbourhood. There was also not opted for thermal storage, because it has as disadvantage that installing it for existing dwellings is not easy, it has high costs and it is possible the source becomes exhausted after the lifespan(30 years) of the installation. Heat recovery is a cheaper option that can be applied in dwellings, thus if needed this is a good option to apply in a dwelling were it is possible. But this will have a minor contribution the energy neutrality.

Ventilation	Costs	Applicability	Improvement indoor climate/comfort
Natural ventilation	++	++	-
Central balanced ventilation	0	+	0/+
Decentralized ventilation	-	+	+
CO2 demand ventilation with heat recovery	--	+	++

Table A1.3: Score table for ventilation systems.

### Ventilation systems

When a dwelling is insulated very well it is best to apply mechanical ventilation to make sure enough fresh air is supplied. Therefore natural ventilation is the worst option. The central balanced ventilation system is not the best option for a dwelling that is renovated to energy neutral, because the supply is regulated at a central point and it does not ventilate on demand. Thus it does not give the best indoor climate of the ventilation systems. The decentralized ventilation system is better, because there air supply and outlet can be regulated for each room individually where it is necessary. The best ventilation system for a dwelling that is renovated to energy neutral is an CO2 demand regulated ventilation system. This system created the best indoor climate, because ventilation regulated based on the demand for CO2 and all the rooms are ventilated individually. This is an major advantage, because CO2 rates increase during the night in the bedroom when there is no ventilation and with this ventilation this will be prevented. Heat recovery is applied for the ventilation system, to prevent heat losses through the air that is ventilated.

## APPENDIX 2: SCENARIOS

In this appendix the scenarios are described. There are three scenarios, for each of these scenarios the measures of which they consist are described and why there was chosen for these measures. In the table an overview of the measures is presented.

Scenario 1: Insulation	Scenario 2: Sustainable energy	Scenario 3: Energy neutral
Cavity wall insulation	Solar boiler	Exterior wall insulation
Floor insulation	PV-panels	Floor insulation
Roof insulation inside		Roof insulation outside
Closing seems and cracks		Replacing window and door frames
Replace glass by insulated glass		CO <sub>2</sub> demand regulated ventilation with heat recovery
CO <sub>2</sub> demand regulated ventilation with heat recovery		Solar boiler
		PV-panels

Table A2.1: Overview energy efficiency measures by scenario

### Scenario 1 – Only insulation

This first scenario concerns the option when only insulation is applied for the renovation of the dwelling. This option will be more affordable than renovating to energy neutral. There is chosen to take other insulation measures than for energy neutral, because for energy neutral the most extensive measures are used to insulate the building envelope and these measures are relative expensive. The selected options for this scenario are more common for consumers to execute on their home, they are less expensive and still save an considerable amount of energy. The options for insulation that are chosen are cavity wall insulation, insulating the roof from the inside and insulating the floor from underneath. There was chosen for these measures, because they have relative low costs and applying these insulation measures gives the least amount of nuisance for the consumers. There was is also chosen to replacing the glass in the windows by HR++ glass, because in this type of dwelling the windows often have standard double glazing or even single glazing and HR++ glazing gives much better insulation. It is necessary to seal the seams and cracks in the dwelling to prevent draft. In older dwellings there are draft problems and when there is an investment made to improve the insulation, there will be more benefits when also the seams and cracks in a dwelling are closed. When in a dwelling the insulation is improved, also a ventilation system must be applied so ensure a healthy and comfortable indoor climate. The option that is selected is standard demand regulated ventilation, because this option gives a healthy indoor climate for relative low costs compared to other ventilation systems.

### Scenario 2 – Generating sustainable energy

The second scenario is about consumers generating their own sustainable energy. Common options for consumers to generate their own sustainable energy is by using solar power, consumers are making the choice to put PV-panels or a solar boiler on their roof. Therefore for this scenario there is chosen to combine PV-panels with a solar boiler to generate sustainable energy. To compare this measure to renovating to energy neutral the option to

install on the entire surface of half the roof will be examined. For most of the dwelling one side of the roof is more fit for solar energy than the other. There is chosen to use the entire surface of one side of the roof, because then the installation will be large enough so it can be compared realistically with the energy neutral option. A small installation will generate some sustainable energy, but this is not enough to make a big difference and will also have much lower benefits than a larger system.

### Scenario 3 – Energy neutral

The third scenario is the option that will be renovated to energy neutral. This is a total package of measures that are needed to reach energy neutrality. The measures consist of insulation measures, generating sustainable energy and applying a ventilation system. The measures that are needed are extensive measures and will be relative expensive, but this is needed to reach energy neutrality. It is necessary to insulate the entire building envelope, this is done by insulating from the outside, because this gives the highest insulation values. The measures that will be applied to realize this are exterior wall insulation, exterior roof insulation and insulating the floor from underneath. Because the entire building envelope will be insulated from the outside and window and doorframes will be replaced, the sealing of cracks and seems can be done at the same time and will bring no additional costs along. When a dwelling is insulated very well it is also necessary to install a ventilation system to make sure the indoor climate is healthy and comfortable. The best option is a decentralized CO2 demand regulated ventilation system with heat recovery, this is a system that has mechanical ventilation that reacts to the levels of CO2 in the rooms and all the rooms in the dwelling will be ventilated separately. To complete the renovation to energy neutral sustainable energy should be generated for the dwelling. There is chosen for solar boiler and PV-panels, because these are options that generate a lot of energy, are relative easy to realize and generating heat and electricity can be combined. There is chosen for this option because it is less extensive than thermal energy storage and it is easy to replace when the lifespan of the installation has ended.

### APPENDIX 3: INVESTMENT COSTS

In this appendix the investment costs of the measures will be described and where the cost figures were retrieved from. The costs will be described by type of measure, insulation measures, sealing cracks and seams, replacing window and door frames, ventilation systems and generating sustainable energy.

#### Insulation measures

The cost figures are needed for the following insulation measures: Exterior wall insulation, cavity wall insulation, roof insulation from the outside, roof insulation from the inside, floor insulation from underneath, replacing HR++ glass. All these measures can be found in the EPA customized advice (Agentschap NL, 2011d). The insulation in the EPA customized advice has lower insulation values than that are needed to renovate to energy neutral. Because only the used material is different for these measures, only the costs of the material will be changed in the cost figures retrieved from the EPA customized advice. This can be easily done, because the cost figures are built up very detailed and the material costs can be replaced with other material costs. This is only done for measures that will be used to renovate to energy neutral, because it is needed for the measures and in the only insulation scenario more common and standard insulation will be applied.

The material that will be used for the measures: floor insulation, roof insulation and exterior wall insulation is from Kingspan insulation. This company provides insulation with high insulation values for a certain thickness, this insulation is one of the best that is on the market right now. The costs were retrieved from a price list publishes on the website (Kingspan insulation, 2012).

For cavity wall insulation different references were used, a cavity wall insulation was found with a Rc-value of 3,07, this was the highest that was found now on the market and the price per square meter was € 19,-. This was different from the costs from the EPA customized advice, but it has higher insulation values and that is important. The following table gives the costs that were used, if other material costs were used and where the costs were retrieved from.

		Single total	Serial total	Insulation value	Different Material costs	Source
<b>Scenario 1 Insulation</b>	Cavity wall insulation	€ 19,00	€ 18,00	3,07	-	Isotechniek Nederland BV, 2013
	Floor insulation	€ 56,00	€ 50,00	2,5	-	Agentschap NL, 2011d and Kingspan insulation, 2012
	Roof insulation inside	€ 59,00	€ 55,00	2,5	-	Agentschap NL, 2011d and Kingspan insulation, 2012
<b>Scenario 3 Energy neutral</b>	Exterior wall insulation	€ 141,78	€ 123,42	5,7	€ 38,00	Agentschap NL, 2011d and Kingspan insulation, 2012
	Floor insulation	€ 62,93	€ 56,81	5,7	€ 31,60	Agentschap NL, 2011d and Kingspan insulation, 2012
	Roof insulation outside	€ 143,82	€ 135,66	5,7	€ 38,00	Agentschap NL, 2011d and Kingspan insulation, 2012

Table A3.1: Overview costs insulation measures

### Replacing glass, door and window frames

The costs for replacing glass in a window, replacing the door frames and replacing the entire window frames are displayed in the following table. For the first scenario the glazing is replaced by better insulated HR++ glazing, these costs are available in the EPA customized advice and they will be used. For the third scenario it is needed to replace the existing window and door frames by well insulated frames to reach energy neutrality. Costs to replace the doorframes by insulated doors and frames can be found in the EPA customized advice and these costs will be used.

Costs to replace window frames cannot be found in the advice and therefore it was needed to retrieve the costs from other cost figure databases. The website [www.bouwkosten.nl](http://www.bouwkosten.nl) (SDU uitgevers, 2013) publishes specific data for building related measures and they have cost figures about installing windows. There are no cost figures available for well insulated window frames, therefore cost figures for similar window frames with the same material are used. The assumption is made that these costs are approximately the same. Window frames in a dwelling are different and there is no price by square meter available. Cost figures for two sizes of windows are used, they can represent the different window sizes approximately. For the large windows an average size of 2,4 meter by 1,8 meter is assumed, such as the windows in the living room. And for the other small windows an average size of 2 m by 1,2 meter is assumed. For the large windows downstairs it is assumed that there are 2 windows and for the small windows it is assumed there are 4 windows.

	Measure	Costs single	Costs serial	Unit	Source
<b>Scenario 1</b>	Replace glass by insulated glass	€ 170,34	€ 145,86	m2	Agentschap NL, 2011d
<b>Scenario 3</b>	Insulated door	€ 500,82	€ 431,46	Door	Agentschap NL, 2011d
	Replacing window fr. Large	€ 1.540,00	€ 1.540,00	Window	SDU uitgevers, 2013
	Replacing window fr. Small	€ 1.330,00	€ 1.330,00	Window	SDU uitgevers, 2013

Table A3.2: Overview costs replacing glass, window and door frames

### Closing seems and cracks

Costs for closing cracks and seems are available in the EPA customized advice. These costs are needed for scenario 1 and will be applied for the entire dwelling. Thus the total costs for closing cracks and seems for an entire dwelling also need to be determined. The EPA customized advice also published for how many meters this is needed for an average dwelling, thus these data will be used for the calculation.

	Measure	Costs single	Costs serial	Unit	Amount needed	Source
<b>Scenario 1</b>	Windows and doors	€ 16,32	€ 12,24	m2	26 m2	Agentschap NL, 2011d
	Frame - closed facade	€ 38,76	€ 37,74	m.	26 m2	Agentschap NL, 2011d
	roof- facade	€ 253,98	€ 229,50	Dwelling	1	Agentschap NL, 2011d
	Seems roofplates	€ 12,24	€ 12,24	m.	75 m2	Agentschap NL, 2011d
	Top of the roof(nok)	€ 329,46	€ 304,98	Dwelling	1	Agentschap NL, 2011d
	<b>Total</b>	<b>€ 2.933,52</b>	<b>€ 2.751,96</b>	<b>dwelling</b>		

Table A3.3: Overview costs closing seems and cracks

### Ventilation system

For scenario 1 a standard demand regulated ventilation system will be applied, the costs can be retrieved from the EPA customized advice (Agentschap NL, 2011d). The assumption is

made that the CO<sub>2</sub> demand regulated ventilation can be fit with heat recovery for the same price, because a system from the EPA customized advice with heat recovery has less costs and mainly the part of CO<sub>2</sub> demand regulated increases the amount of costs.

Measure	Costs single	Costs serial
<b>Standard demand regulated ventilation</b>	€ 2.613,24	€ 2.607,12
<b>CO<sub>2</sub> demand regulated ventilation</b>	€ 4.733,82	€ 4.652,22

Table A3.4: Overview costs ventilation systems

### Generating sustainable energy

The systems that are used that generate sustainable energy are a solar boiler and PV-panels and they will be applied in scenario energy generation and energy neutral. In the EPA customized advice cost figures for these measures are included, but a different solar boiler and PV-panel will be used in the case study. Therefore the cost figures cannot be copied exactly. For the solar boiler the material costs for the boiler installation will be replaced with other costs that belong to the system that is used in this case study and the costs for the installation from the EPA customized advice can remain. The system that is used in the case study is from Clearline, it is 9 m<sup>2</sup> and generates 16,4 GJ of energy. There is not chosen to use entirely different cost figures because installation costs are not available separately.

The costs for PV-panels the EPA customized advice are not be used because the prices were for smaller systems than used in the research and there are more efficient panels on the market now. Every year an

Size	System price	Installation	Total
<b>600 WP</b>	2,14 €/WP	0,60 €/WP	2,74 €/WP
<b>2.500 WP</b>	1,67 €/WP	0,40 €/WP	2,07 €/WP
<b>5.000 WP</b>	1,40 €/WP	0,30 €/WP	1,70 €/WP
<b>50.000 WP</b>	1,40 €/WP	0,20 €/WP	1,60 €/WP

Table A3.5: Overview average costs per size for a PV-panel. (Sark et. al, 2012)

inventory is made from the PV-market and they also publish current prices for PV -panels per WP(Sark et. al, 2012). Those numbers will be used to determine the price for PV -panels, these prices are including installation costs. The most efficient solar panels on the market are PV -panels from Sunpower with a power of 333 WP per panel. A total of 13 panels is needed to generate enough energy to get to energy neutrality, this gives a total of 4329 WP. In table 3.5 the average prices are shown for several standards sizes, the larger a system the lower the WP price. The system used in the case study is between 2.500 WP and 5.000 WP, the WP price for the system will be determined proportionally to the total amount WP. This gives a WP price for the system of € 1,47/WP and installation price of € 0,33/WP, this results in a total price of € 1,80/WP. To determine the price by Watt peak when they are purchased as part of a collective, the average discount from actions that were organized for consumers were they could benefit from collective purchasing solar panels. The most successful actions realized a discount of 20-30% (Zonnestroom NL, 2012). In this case study prices for collective purchasing are needed and therefore an assumption will be needed to make about the possible discount for the collective. It is assumed that a discount of 10% can be achieved, this is much lower than the best discount actions, but it is a conservative assumption so costs will not be underestimated.

Measure	Costs single	Costs serial	Different material costs	Source
<b>Solar boiler</b>	€ 8.485,86	€ 8.206,38	€ 4.894,00	Unit
<b>PV-panels</b>	€ 599,40	€ 539,46		Pv-panel

Table A3.6: Overview costs energy generation measures

## APPENDIX 4: ENERGY USAGE INSTALLATIONS

Installations that will be installed in the dwellings also use a certain amount of energy to operate. The installations were the energy usage needs to be determined for are the ventilation system solar boiler, PV-panels and the CV-boiler.

There are new ventilation systems on the market that use a less energy than older ventilation systems. A ventilation system of IthoDaalderop (2013) uses 57 kWh a year, systems similar to those of IthoDaalderop are also used in the case study. Milieucentraal(2013) has determined energy usage of several installations and appliances. The average energy usage of a solar boiler is 200 kWh a year and the energy usage of the cv boiler is 270 kWh a year. For PV-panels the energy usage was not available, therefore the assumption was made that PV-panels generate the energy they use themselves.

**Table A4.1 Energy usage installations**

<b>Ventilation system</b>	57 kWh
<b>Solar boiler</b>	200 kWh
<b>CV boiler disappears</b>	-270 kWh



## APPENDIX 5: MAINTENANCE COSTS INSTALLATIONS

Maintenance should be applied for the installation in the dwelling, the relevant installations are the solar boiler, PV-panels and the ventilation system. The costs for maintenance of a solar boiler are € 30,- a year, Milieucentraal (2013) determined this amount as an average for yearly maintenance for pressure filled installations as part of a maintenance contract. The maintenance costs of PV-panels are an average of € 60,- a year, these costs are based on an average of € 1500,- for a lifespan of 25 years for maintenance and replacing the converter and this results in € 60,- a year. There are several maintenance contracts available for ventilation systems, they offer yearly cleaning of the system, checking the technical parts and if needed replacing parts. Based on four different maintenance suppliers the average costs a year are € 60,-. For each of the scenarios the total maintenance costs for each year are determined displayed in the table below.

Maintenance costs installations	Costs per year	
<b>Solar boiler</b>	€ 30,00	Milieucentraal (2013)
<b>PV-panels</b>	€ 60,00	Infonu (2013)
<b>Ventilation system</b>	€ 60,00	Nuon (2013)
Table A5.1: Overview maintenance costs by installation		

Costs for each scenario		
<b>Maintenance costs scenario 1</b>	€ 60,00	<i>Ventilation system</i>
<b>Maintenance costs scenario 2</b>	€ 90,00	<i>Solar boiler + pv-panels</i>
<b>Maintenance costs scenario 3</b>	€ 150,00	<i>Solar boiler + pv-panels + ventilation system</i>
Table A5.2: Overview maintenance costs by scenario		

## APPENDIX 6: DATA ABOUT THE DWELLING

In this appendix an overview is given of the used data about the dwelling. These data represent a reference dwelling, which is a row-house from the period 1965-1974. The data about the dwelling that are required for this research are surface areas of the dwelling and existing insulation values of the dwelling. The data is retrieved from 'Voorbeeldwoningen 2011, bestaande woningbouw' (Agentschap NL, 2011c), as explained in paragraph 7.4.4.

Building parts	Surface (m <sup>2</sup> )	Rc-value (m <sup>2</sup> K/W)	U-value (W/m <sup>2</sup> K)
<b>Ground floor</b>	52,0	0,17	2,33
<b>Flat roof</b>	-	-	-
<b>Pitched roof</b>	65,0	0,86	0,89
<b>Front- and rear façade</b>			
- Closed	40,5	0,43	1,45
- Single glazing	4,3	-	5,20
- Double glazing	21,3	-	2,90
<b>Side façade</b>			
- Closed	58,3	0,43	1,45
- Single glazing	-	-	-
- Double glazing	1,8	-	2,90

Table A6.1: Overview data about the reference dwelling  
(Agentschap NL, 2011c)

## APPENDIX 7: PARAMETERS

This appendix describes how the parameters are estimated that are needed in the case study.

### Interest rate

The interest rate is incorporated as a parameter, because most households need a loan or a mortgage to finance the renovation. To estimate an average interest rate, the average interest rate over the past ten years will be used. This long term average is over the past ten years 5,3%(Fidelis Financiële Diensten, 2013). This average based is on the average interest over the past ten years for an annuity mortgage with a fixed interest rate for ten years from the ABN Amro bank.

### Inflation rate

Inflation is the increase of the value of money, which leads in general to the increase of prices. In this research future cash flows are estimated and to incorporate the changing value of money the inflation rate needs to be determined. The central bureau for statistics keeps track of the inflation rate of the past years, but we need a forecast for the future inflation rate. The ROZ/IPD real estate index publishes every year the inflation scenario generated by Consensus forecast. Their forecast of the inflation rate is used and the average forecast of inflation between 2013-2027 is 2,0%(Consensus forecast, 2012).

### Increase energy prices

The average yearly increase of energy prices since 2000 was an average of 5%, the increase for only the gas prices was 6,4% and for the electricity prices 2,8%(Senternovem, 2013). Gas and energy prices have fluctuated a lot, so there are several years with peaks in the increase. For instance in 2010 energy prices dropped on average of 19% that year. When this year is not taken in account in the average increase of energy prices, the average is 7%. This shows how much that one year makes a difference in the average increase in energy prices. The forecast of the increase in energy prices all indicate that the prices will increase the next years with about the same amount of the past years, more exact figures are not available in the references. In the case study the averages for the increase of the electricity and gas prices of the past years will be used, but the increase in prices will also be examined in the sensitivity analysis.

### Discount rate

The discount rate is needed in a discounted cash flow analysis to discount the future values to present values. The discount rate reflects the time value of money or in other words the degree risk that is taken by making the investment. An investor would rather have his money right now than waiting for the return of the investment which is an uncertainty due to the possible risk of changing market circumstances. The discount rate represents the minimum return on the investment to make it profitable. The discount rate is built up from a part risk free interest and a premium for the risk.

In this research the investment is made by the consumers, thus the discount rate is different than for investors. They don't need to have a certain yield on their investment, they want to earn their investment back. Therefore it is not needed to incorporate a premium for the risk.

Consumers can take a loan or a mortgage with a certain interest rate, this rate is higher than the risk free interest. Therefore not the risk free interest is taken for the discount rate, but interest rate at which consumers can take a loan or mortgage is taken in account. This results in a total discount rate of 5,3%, this is the same percentage as the interest rate that is taken in account in this research.

#### **Percentage scale benefits costs**

Renovating dwellings in serial has lower costs due to the scale benefits. These financial benefits of a large scale, more than 50 dwellings are set on 2-3% of the total investment costs (Agentschap NL, 2011d).

#### **Indexation building costs**

The costs that were retrieved from the EPA customized advice were indexed at a price level of 2011. These prices should be re-indexed to 2013. The total increase in of the price is 2%, this is determined by using the BDB-projectindex, retrieved from [www.bouwkosten.nl](http://www.bouwkosten.nl) (SDU uitgevers, 2013)

#### **VAT**

The costs figures are exclusive VAT, since consumers need to pay the VAT this also needs to be taken in account in determining the investment costs. The VAT in the Netherlands is since October 1, 2012 set on 21%.

A regulation set by the government is a lowered VAT rate for insulation measures for existing dwellings older than two years. For the labour costs for making the floors, walls and roofs more energy efficient in existing dwellings a VAT rate of 6% can be applied (Belastingdienst, 2013). This VAT rate can be applied when the current thermal resistance rates for dwellings are met with the insulation measures, this is a Rc-value of 1,3 (Belastingdienst, 2013). When the costs for the used insulation material are less than 50% of the total costs for the insulation activities then the tax rate of 6% can also be applied for the used materials (Belastingdienst, 2013). When the value of the used materials is more than 50% of the totals then the tax rate of 21% needs to be applied for the materials (Belastingdienst, 2013). In this case study the total costs for material are less than 50% of the insulation costs for each measure, thus a VAT rate of 6% can be applied for all the insulation measures.

#### **Gas and energy prices**

To determine energy costs the gas and electricity prices need to be set. These prices differ for each provider of electricity or gas, but Milieucentraal(2013) publishes the average prices on their website. These are € 0,22 per kWh electricity and € 0,65 per m3 gas for 2012-2013. The price for resupplying energy to the net is € 0,07 kWh until 5000 kWh.

#### **Parameters to determine energy savings**

To determine energy savings from improving the insulation several parameters are needed. These are the average indoor temperature, the average outdoor temperature, number of days in a year that indoor heating is needed and number of hours of heating on those days. During a year it is not always needed to heat the dwelling, therefore a number of heating days is incorporated in the formula. The heating season from 1 October until 1 April, in this

period of time there are 212 days (Business issues kennisbanken, 2013). Often the dwelling is only heated for a part of the day, the number of heating hours a day is estimated at 12 hours a day on average. These numbers can differ some in reality, but they form together an estimation of the total number of heating hours a year.

The average outdoor temperature in the Netherlands is 10,1 °C (Compendium voor de leefomgeving, 2013). But during the heating season the average outdoor temperature is different. And because the energy savings are calculated by using the number of days in the heating season, the average temperature during this heating season should be used to calculate the savings. The average outdoor temperature over the past ten years for the heating season is 6,55 °C (KNMI, 2013).

The average indoor temperature has increased over the past decades. In 1957 the average temperature was 17,4 °C and in 1992 this was already 19,5 °C (Milieucentraal, 2013). In 2004 this average lies on 19,9 °C (Milieucentraal, 2013). More recent numbers are not available, therefore an assumption needs to be made about the indoor temperature. The average indoor temperature is estimated at 20 °C, this is based on an increasing trend for the indoor temperature.

#### **Performance ratio PV-panels**

The power of PV-panels is determined under testing circumstances, these circumstances are different from the daily circumstances in the Netherlands. Therefore a performance ratio in the Netherlands needs to be taken in account, this ratio converts the WP to yield in kWh a year. The average performance ratio for PV-panels lies between the 80% and 85%. The performance for PV-panels in this research is set at 80%. This is a conservative assumption, because then it is more certain this amount of electricity is actually generated and if the ratio is actually a bit higher than this is considered as added benefits for the consumers.

#### **Part space heating in gas usage**

The gas usage of a household can be attributed to mainly space heating and heating water, a small part is used for cooking. The ratio between the space heating and heating water needs to be determined, because this is needed for the calculations how much energy is saved. The part space heating in gas usage is estimated on an average of 75%. In 2010 73% of the gas usage can be attributed to space heating and 22% can be attributed to heating water, the other part is for cooking (Menkveld et. al, 2010). The percentage gas usage for cooking is a small part of the gas usage and more and more household cook on electricity instead of cooking on gas, so a part of the households does not even use gas for cooking. Thus the percentage gas usage for cooking will not be taken in account for in the calculations, because this research uses average gas and electricity usage of households and on average not all the households use gas for cooking. For the households that do cook on gas the amount of gas usage for cooking will not be affected by the measures and will stay the same amount. The average part space heating in gas usage is estimated at 75%.

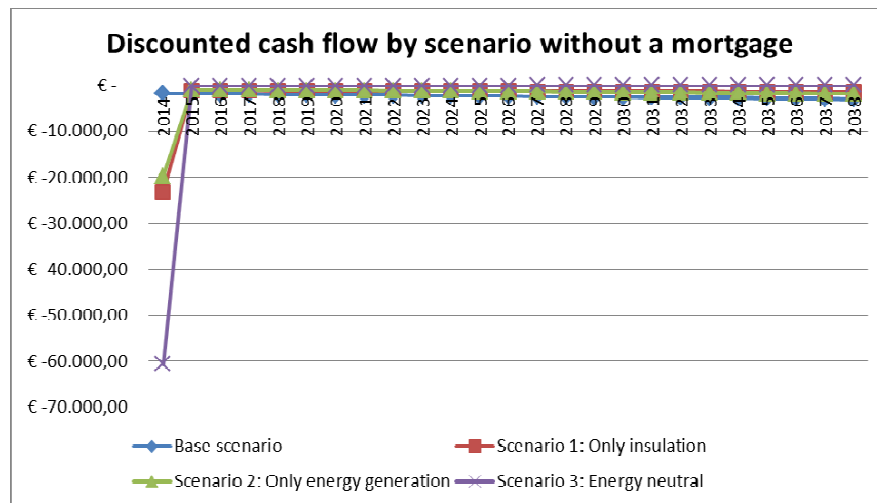
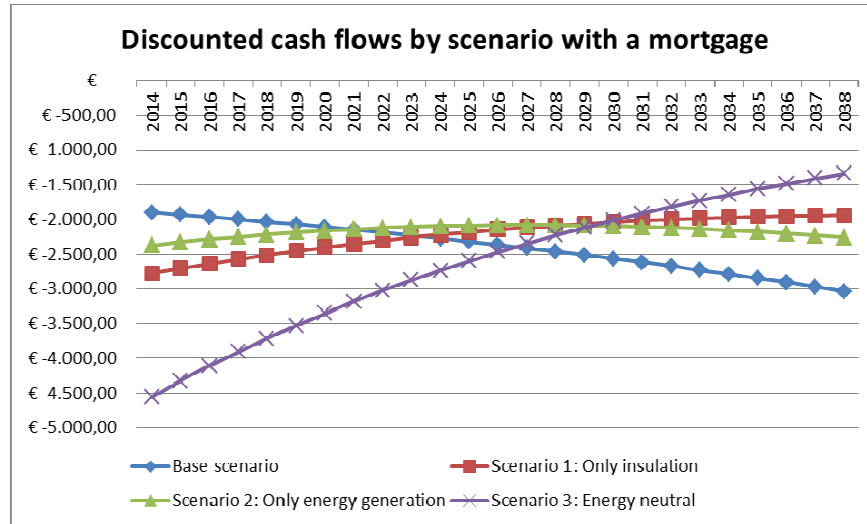
## APPENDIX 8: OVERVIEW INVESTMENT COSTS BY SCENARIO

Scenario 1: Only insulation				
Measure	Costs per unit	Unit	Amount	Total
<b>Isolation</b>				
Facade insulation (cavity)	€ 19,00	m2	98,8	€ 1.877,20
Floor insulation	€ 57,12	m2	52	€ 2.970,24
Roof insulation inside	€ 60,18	m2	65,5	€ 3.941,79
Replacing glass	€ 170,34	m2	27,4	€ 4.667,32
Closing seems and draft proofing	€ 2.933,52	Unit	1	€ 2.933,52
<b>Installations</b>				
Ventilation system	€ 4.733,82	Unit	1	€ 4.733,82
VAT insulation measures				6%
VAT				21%
<b>Total investment costs 2014</b>			<b>€ 23.101,39</b>	
Percentage interest				5,3%
Number of payment periods				25
<b>Total interest</b>				<b>€ -19.116,85</b>
<b>Yearly payments</b>				<b>€ -1.688,73</b>

Scenario 2: Only energy generation				
Measure	Costs per unit	Unit	Amount	Total
<b>Energy generation</b>				
Solar boiler	€ 8.485,86	Unit	1	€ 8.485,86
PV-panels	€ 599,40	Panel	13	€ 7.792,20
VAT insulation measures				6%
VAT				21%
<b>Total investment costs 2014</b>			<b>€ 19.696,45</b>	
Percentage interest				5,3%
Number of payment periods				25
<b>Total interest</b>				<b>€ -16.299,19</b>
<b>Yearly payments</b>				<b>€ -1.439,83</b>

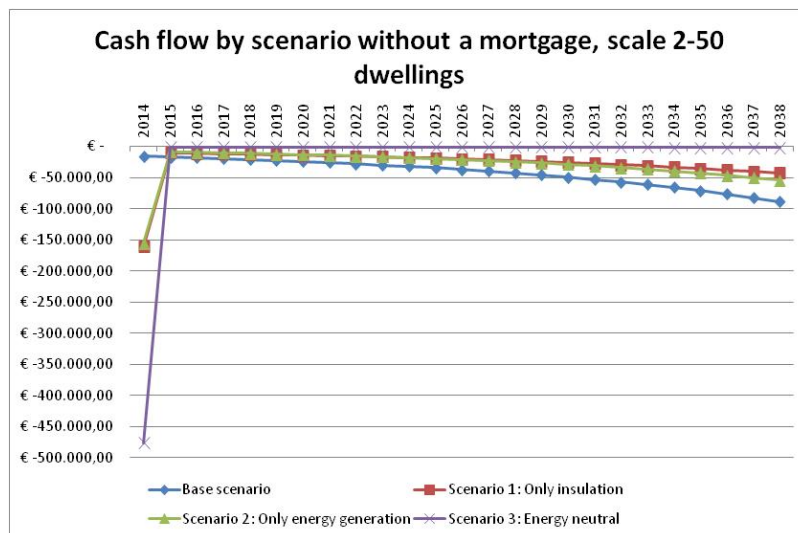
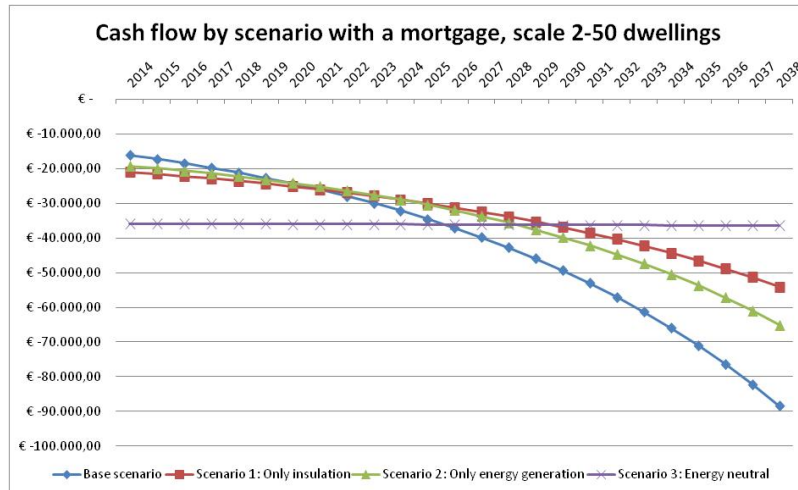
Scenario 3: Energy neutral				
Measure	Costs per unit	Unit	Amount	Total
<b>Isolation</b>				
Facade insulation (exterior)	€ 141,78	m2	98,8	€ 14.007,86
Floor insulation	€ 62,93	m2	52	€ 3.272,57
Roof insulation outside	€ 143,82	m2	65,5	€ 9.420,21
Replacing window fr. Large	€ 1.540,00	Unit	2	€ 3.080,00
Replacing window fr. Small	€ 1.330,00	Unit	4	€ 5.320,00
Replacing door frames	€ 500,82	Unit	2	€ 1.001,64
<b>Installations</b>				
Ventilation system	€ 4.733,82	Unit	1	€ 4.733,82
<b>Generating energy</b>				
Solar boiler	€ 8.485,86	Unit	1	€ 8.485,86
PV-panels	€ 599,40	Panel	13	€ 7.792,20
VAT insulation measures				6%
VAT				21%
<b>Total investment costs 2014</b>				<b>€ 63.692,80</b>
Percentage interest				5,3%
Number of payment periods				25
<b>Total interest</b>				<b>€ -52.707,01</b>
<b>Yearly payments</b>				<b>€ -4.655,99</b>

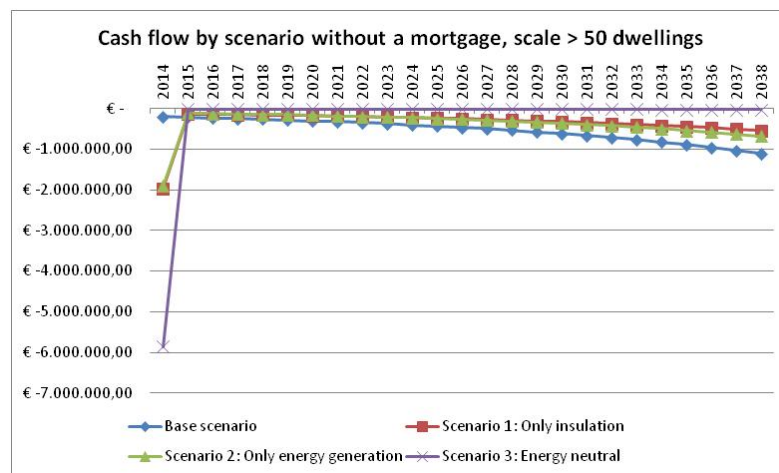
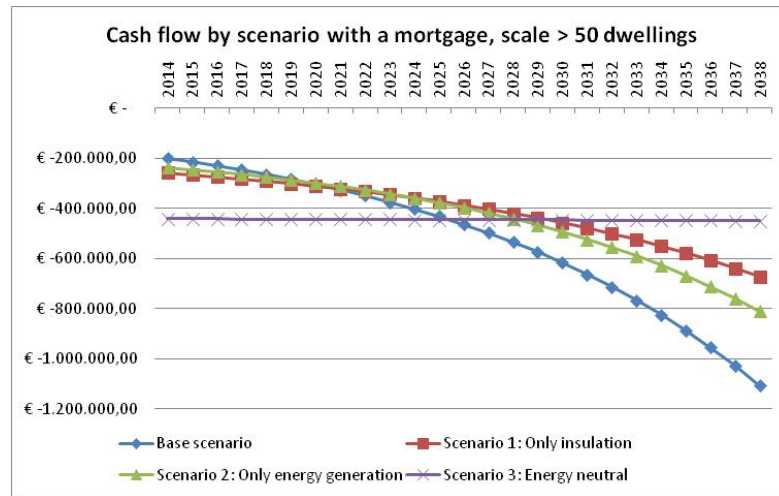
## APPENDIX 9: DISCOUNTED CASH FLOWS BY SCENARIO



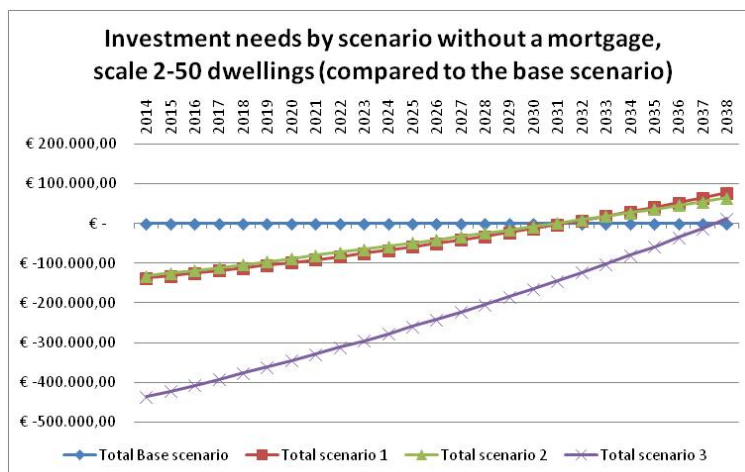
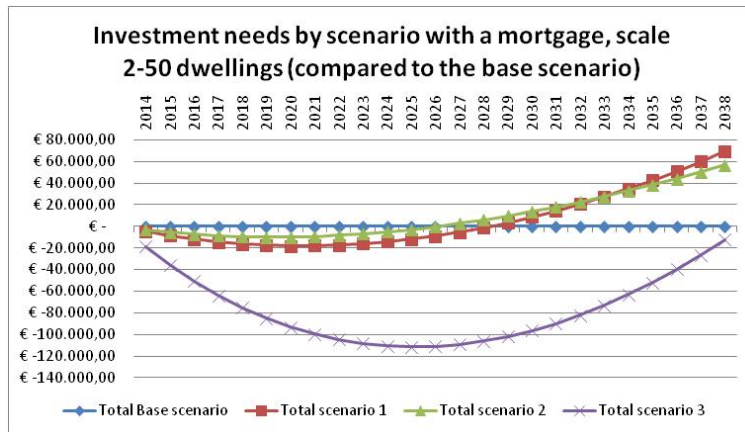


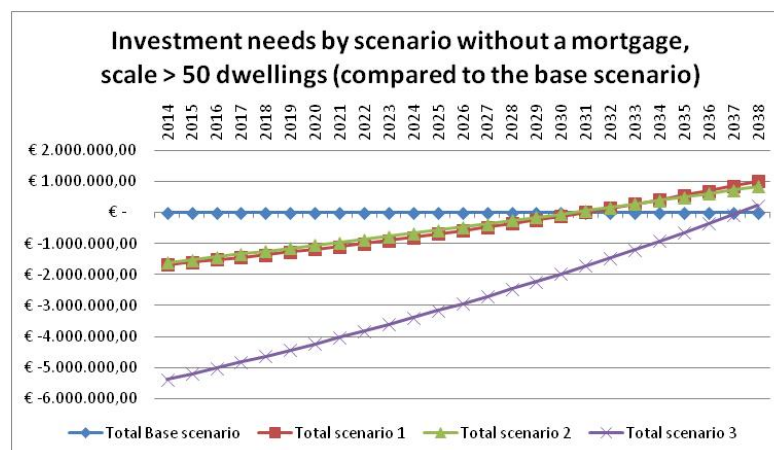
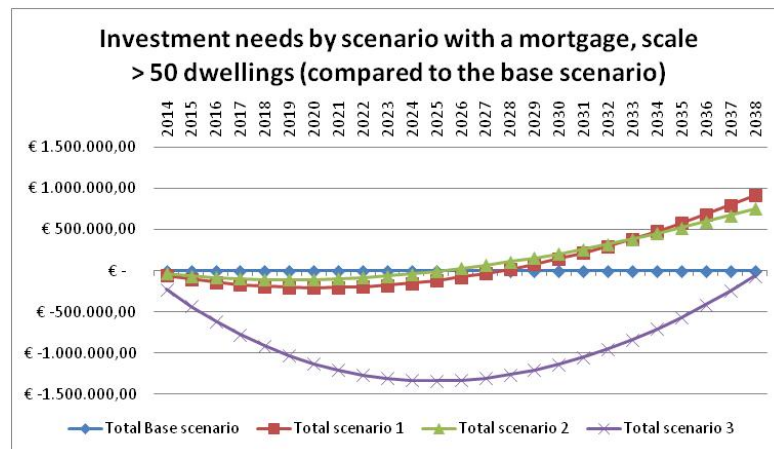
## APPENDIX 10: CASH FLOWS FOR LARGER SCALES





## APPENDIX 11: INVESTMENT NEEDS BY SCENARIO FOR THE LARGER SCALES





## WHAT'S IN IT FOR YOU?

### Consumers making their dwelling energy neutral collectively

#### Graduation program:

Construction Management and Urban Development 2012-2013

#### Graduation committee:

Prof. dr. W.F. Schaefer

Dr. P.H.A.M. Masselink

Dr. Q. Han

ARCADIS:

C.W.J. Goorts MSc.

#### Date of graduation:

12-03-2013

#### ABSTRACT

*By making existing dwellings more sustainable large energy savings can be realized. Consumers are often unaware of the benefits that are in it for them and don't take the step to make their dwelling more sustainable. The research makes the benefits of making a dwelling energy neutral insightful, by means of a total cost and benefits of ownership approach. The research also focusses on the added benefits when consumers make their dwelling energy neutral as a collective.*

**Keywords:** Energy neutral dwelling, consumers, collective renovation, existing dwellings.

#### INTRODUCTION

Sustainability policies and measures are made and carried out by governments and businesses. The government have set in their regulations that from 2020 new built dwellings should have an Energy Performance Coefficient(EPC) of 0, this means that in 2020 only near-zero energy buildings are allowed to be built (Agentschap NL, 2010). Besides this, municipalities have set goals to make districts or even entire cities energy neutral. To reach these goals dwellings can play a large part in it, because in the Netherlands 35% of the energy usage is for the account of buildings and almost half of this amount is used by households (Agentschap NL, 2012).

When all the new built dwellings will be energy neutral in the future, there will be a difference with the existing dwellings that are less energy efficient regarding energy usage and energy costs. An energy neutral dwelling will have low housing costs and a dwelling with low additional costs will have more value than the same dwelling with a lot of additional costs. This difference will be increasing in the future, because the forecast about energy prices indicates that they will increase in the future, but how much is still uncertain. To make the difference smaller or disappear it is necessary to make existing dwellings more energy efficient. When a dwelling is renovated to energy neutral added value can be created, the dwelling will be more independent from uncertain increasing energy costs, the lifespan of the dwelling is prolonged and the quality of the building will also be improved.

But not all consumers want to make the investment to make their dwellings more sustainable, because of the costs or ignorance about the topic. A solution can be that consumers renovate their dwellings as a group, where they can have collective benefits. There are already some initiatives to renovate dwellings with a group of people from the neighbourhood. But it is not certain what the added value of renovating as a group is and what the benefits are for the consumers. When the benefits and the created value are known, then people who are hesitating can be persuaded to renovate their dwelling. The participation of consumers is needed to realize energy neutral districts.

This have led to the following research question:

*What are the benefits when consumers make their dwelling more sustainable into an energy neutral dwelling as a collective?*

The main research objectives are to show the added value and benefits that consumers can gain by making their homes energy neutral and showing the added value when consumers renovate their dwellings as a collective. The research is limited to one group of stakeholders the private home owners and the existing dwellings that can be made energy neutral. The research will also be limited to the dwelling and the measures that can be carried out to make the dwelling energy neutral. The building process and materials are excluded from the research.

#### **ENERGY NEUTRAL DWELLING**

In the research first the energy neutral dwelling and the measures to make a dwelling energy neutral were examined. The definition of an energy neutral dwelling used in this research was based on a definition by PeGo(2009). The used definition is: *'A dwelling is energy neutral during the use phase when on a yearly basis there is no net import of fossil or nuclear fuel from outside the property needed for the exploitation building. This means that the energy usage from inside the property is equal to the amount of sustainable energy that is generated within the property or on basis of external measures may be contributed to the project.'*

In this research the dwelling needs to be energy neutral on a yearly basis and use 100% renewable energy on a yearly basis. This means that it is possible to extract energy from the net during peak hours when the renewable sources are not sufficient and it can resupply the sustainable energy back to the net on other hours.

The Trias Energetica principle is often used as a guideline to make buildings more sustainable. Dobbelsteen (2008) developed an updated version of that strategy, the "new steps strategy". This strategy was used to determine the measures that are needed to make a dwelling energy neutral. These steps are:

- *Step 1: Reduce energy demand.*
- *Step 2a: Use of energy from residual flows.*
- *Step 2b: Use of energy from renewable sources.*
- *Step 3: If usage of finite (fossil) energy sources is inevitable, use them very efficiently and compensate them on a yearly basis with 100% renewable energy.*

To deal with the energy usage as efficient as possible these steps should be completed in the correct sequence. In the research for each of the steps measures were identified. Important factors were that it must be possible to apply the measures for existing dwellings.

### **Reduce energy demand**

The first step to make a dwelling energy neutral is reducing the energy demand. This is done by insulating the entire dwelling. From several building insulation measures a selection was made of the measures that can be applied best to realize an energy neutral dwelling. These measures are exterior wall insulation, exterior roof insulation, floor insulation from the bottom and replacing window and door frames with better insulated frames. For all these measures it is possible to realize high insulation value and this is needed to reach energy neutrality. Another advantage of these measures is that with these measures also the chances for draft and thermal bridges are minimized.

### **Use energy from residual flows**

A lot of energy is wasted through residual flows of a dwelling and by their residents. Air and water are heated, but they are simply discarded while these flows contain residual heat or in other words energy. The heat and energy of these flows can be used to heat new water or air, resulting in less energy that is needed to heat these air or water flows.

### **Use energy from renewable sources**

When the energy demand is reduced as much as possible and energy from the residual flows is used, the remaining part of the energy usage should be generated sustainably. In the research several options to generate renewable energy were examined. The best options to apply in an energy neutral dwelling are a solar boiler and PV-panels.

### **Ventilation**

When a dwelling is well insulated it is necessary to install a ventilation system to provide a healthy and comfortable indoor climate. The ventilation system that can be best applied for an energy neutral dwelling is a decentralized CO<sub>2</sub> demand regulated ventilation system. Because this system provides the most healthy and comfortable indoor climate and it only ventilates the rooms where it is necessary.

### **VALUE CREATION**

Value creation also plays a role in investment decisions, it determines the profitability of an investment for the involved stakeholders. For consumers the created value can be a reason to make the investment and therefore it is important that the value creation is insightful. To determine the added benefits for consumers when a dwelling is made energy neutral the Triple P approach was used. The triple P stand for the dimensions People, Planet and Profit, they represent a social-cultural, ecological and economical dimension (Puylaert and Werksma, 2011). In sustainable development it is important that value is created on all three of the dimensions and that these values are in balance with each other. Future value is an important part of the value creation and future value can be maximized when value is created on all three parts of the triple P. Because if the investments in the renovation have a low or no future value then the added value and benefits are lower than if the investments have high future value. Renovating the dwelling is also increasing the future value of the

dwelling, because the future value of a dwelling is increased when the condition and the building quality of a dwelling are increased (Otter, 2008).

There are several studies that show that the financial benefits of an energy efficient dwelling are most important for consumers and they are followed by the factors comfort and health (Groenestein, 2011). Another important characteristic is the environmental awareness, but this is not valued financially (Groenestein, 2011). This indicates that most important value for consumers is the financial value, followed by the user-related value and then the environmental value.

#### **Profit**

The added value for the profit aspect are an increased value of the dwelling, a decrease in housing costs and more stable housing costs. Evidence from literature states that an energy neutral dwelling has a higher value than a standard dwelling (NWBO, 2008, Groenestein, 2011 and Brounen & Kok, 2009). This value can be between € 5.000 and € 10.000, but it can also be higher when the difference is larger. But the remark should be made that the value of a dwelling is hard to predict and that future prices are uncertain. The housing costs also have decreased and have become more stable, because the energy costs have decreased. When housing costs are more stable consumers know exactly what their future expenses are and they have more certainty about their financial situation.

#### **People**

The most important added value for people aspect is the improved indoor climate, since draft is limited and a healthy indoor climate can be regulated by a CO2 demand regulated ventilation system. This improves the living quality of the consumers, because the quality of the indoor climate is increased. It is also possible to create added value during the renovation, by making sure the inconvenience for consumers is minimized.

#### **Planet**

The added value for planet aspect is that a the dwelling is no longer depending on fossil fuels, the energy usage has decreased and for the remaining amount of energy renewable energy is generated. Consumers no longer depend on suppliers of energy and changes in the energy market, they generate their own energy and are more independent. Another added value for planet are the decreased CO2 emissions.

#### **RENOVATING DWELLINGS AS A GROUP**

Benefits that arise when consumers renovate their dwelling as part of a collective can be categorized in organizational, financial and other benefits. There are major organizational benefits for consumers when they renovate as part of a collective. Because it is possible to outsource management, so they don't have to figure out the details of the renovation themselves. They can also cooperate with a business that takes care of the entire renovation for them. The financial benefits concern lower renovation costs, because the measures can be carried out in serial and if the scale is larger than 50 dwellings there are even more financial scale benefits. When consumers are part of a collective they can be part of favourable financing regulations. There are several cooperation forms and financing regulations examined in the research. This indicated that there are several option that would



be interesting for consumers to explore, because they can have a lot of benefits for them both organizational and financial.

Other benefits that occur when dwellings are renovated as a collective besides the organizational and financial benefits are that it is possible to improve the quality of the neighbourhood. The exterior of the dwellings will be improved by the renovation and when all consumers work together they can improve the entire neighbourhood together. Another benefit is that there can be group pressure in a neighbourhood to renovate the dwellings, so more consumers will take part of the renovation. The final benefit could be that collective energy generation can be applied, but these options are very expensive and not always applicable for existing dwellings. Therefore the collective energy generation was not taken in account in the case study.

### **CASE STUDY**

A case study was carried out to gain insight about the value creation for consumers when they renovate their dwelling individually or as a collective. The goal of the case study was to create an overview of the benefits for the consumers and what the added value is when the renovation is done as a collective. The case that was selected for the case study is the district Venne-Oost in Drunen. This district was selected, because a large amount of the dwelling are owned by private home owners, the district was built before 1990 and there is added information available about the dwellings.

### **Method**

To determine the costs and benefits there was chosen to use the Total Cost of Ownership approach. This method gives an overview of all the costs involved with the ownership of a product or service. Included costs cover the initial investment and other occurring costs during the life of a product, but these costs can differ by industry the method is applied for. The TCO approach is stakeholder-based and addresses the costs from the point of view of the stakeholders. The approach can be used to support management decisions that involve costs over a longer period of time. It can also be used to determine the total economic value of an investment or display the cash flows for several scenarios. This makes the approach suited to make financial comparisons between several alternatives. This method was chosen because the method can give insight in the different cash flows, it is possible to include only the different costs and benefits that are influenced by the renovation, the examined period can be determined up from and it is possible to make a comparison between several scenarios. The Discounted Cash Flow method was used to construct the cash flows and convert the cash flows into the present value. The DCF method is uses the time value of money to discount all the estimated future cash flows to their present value. The Net Present Value of a project can be determined based on the DCF's and it represents the current value of the project. The NPV will be used to make comparisons between the total value of the alternatives. Another method was needed to determine the energy neutrality of a dwelling. The method that was used was determining the energy savings in kWh. There was opted for this method, because it results in a universal unit for energy, it is easy to compare with other dwellings and it is easy to understand for consumers.

### **The scenarios**

In the model a base scenario and three renovation scenarios were incorporated. The base scenario will function as a reference scenario where no renovation was carried out. One of the renovation scenarios will be the scenario to energy neutral. In this scenario the entire building envelope is insulated very well, a ventilation system is applied and a solar boiler and PV-panels are applied to generate sustainable energy. There were two renovation scenarios added that are common options for consumers now. When consumers are making their dwelling more sustainable they often choose to insulate the dwelling or to generate sustainable energy. Because they often do not have the financial possibilities to realize the option to renovate to energy neutral and the costs of these options are considerably lower. These options were added, because it are options consumers take in consideration when they choose to make a dwelling more sustainable. Goal of adding these options is exploring if it is more profitable to make a dwelling energy neutral or do less than energy neutral by applying insulation or generating sustainable energy. The insulation option will be implementing relative good insulation, but not as much as for energy neutral, because that is relative expensive. The generating sustainable energy option will be a solar boiler and PV-panels on one side of the roof.

These four scenarios will be varied by certain scales to determine the added benefits of renovating as a collective. These following scales were taken in account in this case study: individually(1 dwelling), one row of dwellings(8 dwellings) and an large scale(100 dwellings). For the three renovation scenarios two different ways of financing were taken in account. These are making the investment at once in 2014 or financing the renovation by means of a mortgage. The option for a mortgage was added, because often consumers do not have the financial means to finance the renovation at once.

### **Model**

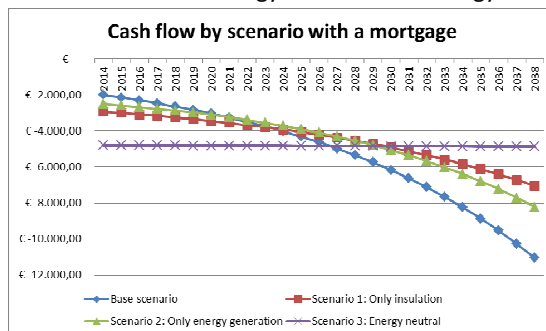
A model was developed in Microsoft Excel to determine the costs and benefits. To set up the model the Total Cost of Ownership approach was specified to fit the scope of the case study. The costs that are included in the model are all the costs that are influenced by the renovation. These costs are investment costs, energy costs and maintenance costs for installations. Other costs, such as costs for water, internet and television were left out, because they are not relevant for the investment that is made and are not influenced by the renovation. The value of the dwelling was also left out of the equation, because the value of a dwelling is very uncertain at the moment, because of the current crisis in the dwelling market and sustainability is not yet good reflected in the dwelling price. Leaving out an uncertain value of the dwelling provides a more certain outcome of the model. This does not mean the increased value of the dwelling is not an important factor, the increased value can be seen as an added benefit when the consumer wants to sell the dwelling. The examined period of time in the case study should not be too long or too short. It must be able to earn the investments back with the benefits, but also the examined period must not be longer than the lifespan of the installations. The examined period in the case study is 25 years, this is based on the guaranteed lifespan of the main installations of an energy neutral dwelling.

With these starting points and selected method the financial model was developed. In the model the total investment costs, the energy savings, energy costs were determined separately and were used as a base to construct the cash flows. To make these calculations

several kinds of data were needed as input, these were data about the investment costs, the dwelling and a set of parameters. A sensitivity analysis was carried out to determine how much the outcome of the analysis depends on these parameters and values. Because the future cash flows are determined by using the estimated values and parameters, and future predictions are inherent to some degree of uncertainty. Doing a sensitivity analysis leads to more certainty about the dependency of the benefits and profitability of the renovation on the set parameters and values, and how certain it is that they occur after the renovation.

## RESULTS

The results from the case study have showed that the renovation to energy neutral has the highest investment costs, but it also has the highest benefits. The measures to make the dwelling energy neutral have high costs, but when the dwelling is energy neutral there are no energy costs left, because it is no longer necessary to extract energy from the net. Both the other scenarios generating energy and only insulation have both lower investment costs, but the benefits are also lower than for the renovation to energy neutral. The energy costs for the energy generation scenario are only costs for gas, because in that scenario no electricity will be extracted from the net. The energy costs for the only insulation scenario are mostly costs for electricity and a small part costs for gas. The base scenario in the case study showed that the energy costs will double in within ten years.



Analysing the Net Present Values have showed that the scenario to energy neutral is the option with the highest costs over 25 years. The most profitable option is the scenario generating sustainable energy, followed by the scenario only insulation. These both options are also better than the base scenario of doing nothing. The energy neutral scenario is the least profitable option for one dwelling. The benefits for the energy neutral scenario over 25 years are not high enough to compensate the high investment costs, thus this scenario is not profitable over 25 years. The costs for the scenarios energy generation and only insulation are lower and the benefits are high enough to make the investment of these two scenarios profitable over 25 years. There are also some differences for the profitability when a mortgage is used or when the investment is paid at once. Mortgage costs are very high, so they have a major influence on the profitability when a mortgage is used. It is more profitable to make the investment for the renovation at once if that is possible for the consumers. The case study showed that when dwellings are renovated on a larger scale there are added financial benefits. The first are the benefits in costs when measures are carried out in serial. These benefits are the highest for the insulation measures and therefore have the most influence on the profitability of scenario only insulation and energy generation. Second are the added scale benefits when the scale is larger than 50 dwellings, these benefits are the same for all renovation scenarios.

	NPV mortgage	NPV without
Base scenario	€ -60.100,71	€ -60.100,71
Only insulation	€ -55.638,05	€ -54.475,30
Energy generation	€ -54.295,39	€ -53.304,02
Energy neutral	€ -65.989,48	€ -62.783,67
<b>NPV by scenario for a single dwelling</b>		

The sensitivity analysis showed that the profitability of the scenarios is influenced by parameters, some of them more than others. The parameters inflation rate, interest and discount rate and increase and electricity and gas price do not influence the energy neutral scenario, but they influence the other scenarios a lot. This has as result that when these parameters change the energy neutral scenario becomes relatively better or worse. A change in the parameters change percentage scale benefits and energy usage have the same influence all the renovation scenarios. The influence of a change investments costs becomes larger when costs are higher and influences all the renovation scenarios. The sensitivity for the investment moment shows that now is the best moment to make the investment, but when longer is waited with the investment the better option the energy neutral scenario becomes.

### CONCLUSION

Through the literature research and the case study the benefits for consumers when they renovate their dwelling to energy neutral individually or as a collective have been analysed. The case study have showed that renovating a dwelling to energy neutral is not profitable in a period of 25 years. When the scale becomes larger the renovation for energy neutral will be more profitable in a period of 25 years. Thus the scale benefits have a positive influence on the profitability of a dwelling. Also when there are scale benefits the renovation to energy neutral without a mortgage pays itself back within the period of 25 years.

Besides this financial analysis there are also a lot of benefits that consumers can gain from renovating their dwelling to energy neutral as mentioned before. Some of these added benefits such as increased comfort levels and a healthier indoor climate are also valued financially by consumers. Thus do these benefits weigh up to the high investment costs? This depends partly on the perception of the consumers if they think it is worth it. But the literature also have showed that consumers are willing to pay between the €5000,- and €10.000,- more for energy efficiency measures when they buy a dwelling (Luijten et. al, 2010). So the increase in living quality is worth a certain amount of money. Besides that when the added value of a dwelling would be added to the financial equation the renovation would be profitable in 25 years, even if only the average added value of € 8395,- ( Brounen & Kok, 2009) would be taken in account. This added value can go up to € 30.000,- when there is a large difference before and after the renovation, so then the financial benefits are also higher. Thus by adding these benefits up, it can be concluded that renovation to energy neutral is a good renovation option and besides the costs there are a lot of benefits that can be gained for the consumers.

The profitability of a scenario can also be influenced by a change in the parameters. The sensitivity analysis have showed that changes in parameters do have an influence on the profitability of the energy neutral scenario compared to other scenarios. Thus if a couple of parameters would change the profitability can increase or even decrease. This is still an uncertain factor in the model, because it is hard to predict the future exactly. As indicated before when consumers renovate their dwelling as a collective there can be a lot of added benefits, that concern organizational, financial and other benefits. Mainly the organizational and financial benefits are directly beneficial for the consumers. Financial benefits concern lowered investment costs, because the renovation can be carried out in serial. The financial benefits can even increase more with 2-3% when the scale is larger than 50 dwellings.

The case study have showed that the scenario to energy neutral is less profitable than the scenarios only insulation and energy generation over a period of 25 years. Even though the yearly benefits are smaller, because both these scenarios still have energy costs. The difference in profitability was mainly caused by the fact that these two scenarios have much lower investment costs than energy neutral and the benefits of these scenarios weigh up to the costs. Thus the scenarios only insulation and energy generation can be more profitable than the scenario energy neutral, but their other benefits are a lot less than the energy neutral scenario. The added benefits for the energy neutral dwelling weigh up to the higher costs and the lower profitability over 25 years. Both the scenarios only insulation and energy generation will still have costs for energy at the end of the examined 25 years and the energy neutral scenario does not. Thus after the 25 years the benefits are only increasing more for the energy neutral scenario and for the other two scenarios the costs are increasing. Also the increased value for an energy neutral dwelling will be more than for the scenarios only insulation and generating energy, because the dwelling has been renovated more extensively and it is more energy efficient. Thus the energy neutral scenario will have more added benefits, but it will also have more costs than both the other renovation scenarios.

## **DISCUSSION**

The sensitivity analysis have showed us that the accuracy of the parameters have an influence on the outcome. Because the model is very sensitive for a change in certain parameters. This results in the fact that the results have a degree of uncertainty in them and that the outcome can differ a bit from the reality. The value of a dwelling was not taken in account in the financial model, while literature indicated that a more sustainable dwelling has more value than an unsustainable dwelling. Adding the value of the dwelling to the financial model would increase the profitability of the renovation to energy neutral, but the outcome of the model would also be more uncertain. To provide the outcome with more certainty it was best to let the value of the dwelling out of the equation. The renovation scenario will not lead to energy neutrality if the consumers use more energy than the average amount. It is not possible to keep saving energy, while consumers still use a lot. Part of making a dwelling more sustainable is also using less energy.

## **RECOMMENDATIONS**

Recommendations for further research are:

- Incorporating different future scenarios with each a different set of parameters. By doing this the outcome can be predicted with more certainty for different future scenarios and it will depend less on one set of parameters.
- Examine possible business models and earning models further for consumers renovating their dwellings as a collective, because there are several interesting options that can be applied in the research.
- Expanding the model so different types of dwellings and different sets of energy efficiency measures can be analysed.
- Further examine the options to generate collective energy.

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*'The graduation research was a very interesting and inspiring period where I gained a lot of knowledge and experience and I hope my research contributes to convincing consumers to invest in energy efficiency for their dwelling.'*

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## WAT ZIT ER IN VOOR JOU?

### Consumenten die de woning verduurzamen tot energie neutraal als collectief

#### Afstudeer programma:

Construction Management and Urban Development 2012-2013

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#### Datum van afstuderen:

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#### ABSTRACT

*Grote energiebesparingen kunnen behaald worden door bestaande woningen te verduurzamen. Consumenten zijn zich vaak niet bewust van de voordelen die er kunnen zijn voor hen en nemen niet de stap om de woning te verduurzamen. Het onderzoek maakt de voordelen van een renovatie naar energie neutrale woningen inzichtelijk door middel van een Total Cost of Ownership benadering. Het onderzoek richt zich ook op de extra voordelen wanneer consumenten de woning energie neutraal maken als collectief.*

**Kern woorden:** Energie neutrale woning, collectieve renovatie, voordelen, consumenten, bestaande woningen.

#### INTRODUCTIE

Er worden steeds meer doelstellingen vastgelegd door overheden om de gebouwde omgeving te verduurzamen. Vanaf 2020 moeten nieuwbouwwoningen een Energie Prestatie Coëfficiënt (EPC) hebben van 0, dit betekent dat vanaf dan alleen nog maar bijna-nul-energie-woningen gebouwd mogen worden (Agentschap NL, 2010). Doordat woningen in de toekomst energie neutraal zullen zijn, zullen er verschillend ontstaan met bestaande woningen. Veel van de bestaande woningen zijn niet energie efficiënt en hebben hoge energiekosten. Een energie neutrale woning zal weinig woning kosten hebben en hierdoor zal de waarde hoger zijn dan voor dezelfde woning met hogere extra kosten. Dit verschil zal groter worden in de toekomst door onzeker stijgende energieprijzen. Om dit verschil te verkleinen zullen bestaande woningen energie efficiënter gemaakt moeten worden. Wanneer een woning wordt gerenoveerd naar energie neutraal kan extra waarde gecreëerd worden, omdat de kosten minder afhankelijk zijn van onzeker stijgende energiekosten, de levensduur van de woning wordt verlengd en de kwaliteit van de woning zal verbeterd worden. Maar niet alle consumenten zijn bereid de investering maken voor de verduurzaming, dit kan komen door de kosten of door onwetendheid over het onderwerp. Een oplossing voor de kosten kan het renoveren als groep zijn, waardoor collectiviteitsvoordelen kunnen ontstaan. Maar het is niet zeker wat de toegevoegde waarde is van renoveren als groep en wat de voordelen zijn van de renovatie tot energie neutraal. Wanneer de voordelen en gecreëerde waarde wel bekend zijn, dan zouden mensen

overtuigd kunnen worden om de woning te renoveren. Dit leidt tot de volgende onderzoeksvraag: *Wat zijn de voordelen wanneer consumenten de woning verduurzamen tot energie neutrale woning als collectief?*

#### **ENERGIE NEUTRALE WONING**

De gehanteerde definitie voor energie neutrale woning in dit onderzoek is: *‘Een woning is energie neutraal in de gebruiksfase, wanneer er op jaarbasis geen netto import van fossiele of nucleaire brandstoffen nodig is voor exploitatie van de woning van buiten het kavel. Dit betekent dat het energieverbruik van binnen het kavel gelijk is aan de hoeveelheid duurzame energie die opgewekt is in de woning of op basis van externe maatregelen toegekend kan worden aan de woning.’* In het onderzoek moet de woning op jaarbasis energie neutraal zijn en 100% hernieuwbare energie gebruiken. Dit betekent dat het mogelijk is om energie van het net te halen gedurende piekuren als de duurzame bronnen niet genoeg energie opwekken en de duurzame energie kan terug geleverd worden aan het net tijdens de andere uren. Om de woning te verduurzamen tot energieneutraal kan het beste de nieuwe stappen strategie van Dobbelsteen(2008) toegepast worden. Dit betekent dat om tot een energie neutrale woning te komen moet de schil eerst zo goed mogelijk geïsoleerd worden, dit kan het beste door de wanden en het dak van de buitenkant te isoleren, de vloer van onder te isoleren, raam- en deurkozijnen te vervangen door beter geïsoleerde. Als een woning zo goed isoleert wordt moet ook ventilatie toegepast worden, het systeem dat zorgt voor het meest gezonde en comfortabele binnenklimaat is een CO<sub>2</sub> vraag gestuurde decentrale ventilatie, waarbij iedere ruimte afzonderlijk geïsoleerd wordt. Een zonneboiler en PV-panelen kunnen het beste toegepast worden om energie op te wekken.

#### **CASUS, METHODE EN MODEL**

Voor de casus is een Total Cost of Ownership methode gebruikt om inzicht te krijgen in de voordelen van de renovatie voor consumenten en de toegevoegde waarde wanneer dit individueel of als collectief wordt gedaan. De TCO methode geeft een overzicht van alle kosten behorende bij het in eigendom hebben van een product of service. De TCO aanpak is stakeholder gebaseerd en richt zich op de kosten vanuit het oogpunt van de stakeholder. Voor deze methode is gekozen, omdat de methode inzicht geeft in de verschillende kasstromen, het is mogelijk alleen de kosten en baten beïnvloed door de renovatie mee te nemen, de onderzochte periode vooraf bepaald kan worden en de methode is geschikt om vergelijkingen tussen scenario's te maken. Met behulp van de Discounted Cash Flow methode worden de kasstromen geconstrueerd en met de Net Present Value wordt de totale huidige waarde van de kasstromen bepaald.

Er is een financieel model gemaakt om de kosten en baten te bepalen. In het model zijn alleen de kosten die beïnvloed worden door de renovatie meegenomen, dit zijn de investeringskosten, de energiekosten en de onderhoudskosten. De woning waarde is uit het model gelaten, omdat deze erg onzeker is door de huidige marktomstandigheden en doordat duurzaamheid nog niet goed wordt gereflecteerd in de woningwaarde. De periode die onderzocht wordt in deze casus is 25 jaar. In het model worden drie renovatie scenario's en een basis scenario met elkaar vergeleken. Het basis scenario dient als referentie scenario, waarbij niets wordt gedaan. Een scenario is de renovatie tot energieneutraal, hierbij wordt de gebouwschil zo goed mogelijk geïsoleerd, wordt een ventilatiesysteem toegepast en een zonneboiler en PV-panelen om duurzame energie op te wekken. Twee extra renovatie



scenario's zijn toegevoegd, die consumenten nu vaak kiezen om toe te passen. Wanneer de consumenten de woning verduurzamen kiezen ze vaak voor of alleen isolatie of alleen duurzame energie opwekken. Dit kan komen doordat ze vaak niet de financiële mogelijkheden hebben om de renovatie tot energieneutraal te betalen. Het ene scenario is alleen isolatie toepassen, dit is relatief goede isolatie maar niet zo veel als voor energie neutraal, omdat dit er duur is. Het andere scenario is alleen duurzame opwekken met een zonneboiler en PV-panelen op het dak. Deze vier scenario's worden vergeleken op drie schaalniveaus, 1 woning, een rij van 8 woningen en een grotere schaal van 100 woningen. Voor de scenario's zijn twee financieringswijzen meegenomen, de investering in een keer maken in 2014 of met behulp van een hypotheek of lening die in 25 jaar wordt afbetaald.

## RESULTATEN

Uit het financiële model blijkt dat de renovatie tot energie neutraal de hoogste investeringskosten heeft, maar ook de hoogste baten heeft. Dit komt doordat de maatregelen om de woning energie neutraal te maken hoge kosten hebben, maar dat wanneer de woning energie neutraal is er geen energie kosten meer zijn. De beide andere scenario's met alleen isolatie en alleen energie opwekking hebben lagere investeringskosten, maar de voordelen zijn ook lager dan bij energieneutraal, doordat zij nog steeds energiekosten houden. Uit de analyse van het basis scenario blijkt dat als er niets gedaan wordt dat de energie kosten zullen verdubbelen binnen tien jaar. Na analyse van de Net Present Value's van de scenario's blijkt dat het scenario renoveren naar energie neutraal de hoogste NPV heeft in de geanalyseerde periode van 25 jaar. Het scenario met de laagste NPV is het opwekken van duurzame energie, gevolgd door alleen isolatie. Dat de NPV van het scenario naar energie neutraal zo hoog is komt mede door de hoge kosten en dat dat de financiële baten over 25 jaar niet genoeg zijn om de hoge kosten te compenseren. De kosten van de scenario's energie opwekking en alleen isolatie zijn lager en de baten zijn hoog genoeg om de investering winstgevend te maken over 25 jaar. Hypotheek kosten hebben ook een grote invloed op de winstgevendheid, omdat de hypotheek kosten zo hoog zijn. De winstgevendheid van de scenario's is hoger als er geen hypotheek gebruikt wordt en dus de investering in één keer betaald wordt aan het begin. Uit de casus blijkt ook dat wanneer de woningen worden gerenoveerd op een grotere schaal er extra financiële baten zijn. Dit zijn baten doordat de maatregelen seriematig worden uitgevoerd, deze zijn het hoogst voor isolatie maatregelen en daarom hebben deze baten de meeste invloed op de scenario's alleen isolatie en energie neutraal. Daarnaast zijn er de extra schaalvoordelen als de schaal groter is dan 50 woningen, deze baten zijn gelijk voor alle renovatie scenario's. Er is ook een gevoeligheidsanalyse uitgevoerd om te bepalen hoe gevoelig de uitkomsten van het financiële model zijn voor veranderingen in de parameters. Hieruit blijkt dat veranderingen in de parameters een invloed hebben op de winstgevendheid van het energie neutrale scenario vergeleken met de andere scenario's. Een verandering in de parameters kan de winstgevendheid van de scenario's vergroten of verkleinen.

## CONCLUSIE

Uit het literatuur onderzoek is gebleken dat de voordelen van een renovatie in te delen zijn in financiële, sociaal-culturele en ecologische voordelen, de voordelen van een renovatie door consumenten naar energieneutraal zijn weergegeven in tabel 1. Hieruit blijkt dat er veel baten zijn voor consumenten, maar zijn dit voldoende baten tegenover de hoge investeringskosten? Dit hangt deels af van of de consumenten denken dat de voordelen het

waard zijn. Het literatuuronderzoek heeft laten zien dat consumenten bereid zijn tussen de 5000,- en € 10.000,- meer te betalen voor energie efficiëntie als zij een woning kopen (Luijten et. al, 2010). Dus een betere woningkwaliteit is een bepaald bedrag waard. Als de extra woningwaarde aan de financiële vergelijking toegevoegd wordt dan zou het scenario energie neutraal winstgevend zijn in 25 jaar. Gemiddeld is deze extra waarde € 8395,- (Brounen & Kok, 2009) en dit kan oplopen tot € 30.000,- als het verschil voor en na de renovatie groot is. Dus als deze baten opgeteld worden kan geconcludeerd worden dat de renovatie naar energie neutraal een goede renovatie optie is en dat er naast de kosten veel voordelen behaald kunnen worden door de consumenten. De baten van collectieve renovatie voor consumenten die zijn gebleken uit het literatuuronderzoek zijn weergegeven in tabel 2. Naast deze voordelen is gebleken uit de casus dat de kosten van een collectieve renovatie inderdaad lager zijn, doordat de renovatie seriematig uitgevoerd kan worden. De financiële baten kunnen zelfs hoger 2-3 % hoger worden wanneer de renovatie schaal groter is dan 50 woningen.

Tabel 1: Overzicht van de waarde creatie	
<b>People</b>	Verbetering van het binnenklimaat en een hogere woningkwaliteit.
	Extra waarde tijdens de renovatie bij minder overlast voor de consumenten.
<b>Planet</b>	Geen gebruik meer van fossiele brandstoffen en minder CO2 uitstoot.
	Minder energie gebruik en alleen nog maar gebruik van energie uit hernieuwbare bronnen.
<b>Profit</b>	Lagere woningkosten door een daling in energiekosten.
	Stabieler woningkosten, onafhankelijk van de stijgende energie kosten.
	Stijging in woningwaarde

## DISCUSSIE EN AANBEVELING

De gevoeligheidsanalyse heeft laten zien dat de nauwkeurigheid van de parameters invloed heeft op de uitkomst, doordat het model gevoelig is voor een verandering in bepaalde parameters. Dus de resultaten zullen een mate van onzekerheid in zich hebben en de uitkomst kan verschillen van de realiteit. De woningwaarde was niet meegenomen in het financiële model, terwijl de literatuur laat zien dat de een duurzamere woning meer waard is dan een niet duurzame woning. Door de woningwaarde toe te voegen aan het model zou de winstgevendheid van de renovatie naar energie neutraal vergroot worden, maar de uitkomst van het model zou ook onzekerder zijn. Om de uitkomst met meer zekerheid te presenteren is de keuze gemaakt om de woningwaarde uit het model te laten. De renovatie zal niet naar energieneutraliteit leiden als de consumenten meer energie gebruiken dan gemiddeld. Het is niet mogelijk om energie te blijven besparen terwijl consumenten nog veel verbruiken. Een deel van de woning verduurzamen is ook minder energie gebruiken.

Tabel 2: Baten van collectieve renovatie	
<b>Organisatorisch</b>	Uitbesteden van management
	Hulp met het uitzoeken van de details
<b>Financieel</b>	Lagere renovatie kosten
	Gunstige financieringsregelingen
<b>Andere</b>	Verbetering kwaliteit van de buurt
	Groepsdruk in deelname aan de renovatie
	Collectieve opwekking van energie

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