# Consequences of renovation strategies for the housing stock of housing associations towards energy neutral

A research into the process of the sustainable transformation of housing associations

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# Contents

## Preface

This report is the result of a research into the process of the sustainable transformation of the housing stock of housing associations. With this report I complete my study Construction Management and Engineering at Eindhoven University of Technology. This research was conducted in collaboration with Atriensis, a consultancy company for housing associations in the fields of energy savings and durability.

The purpose of this research is to provide insight in the consequences of a chosen renovation strategy, focused on housing associations and their housing stock. Housing associations are required to increase the energetic performance of their housing stock which has to be energy neutral in 2050, but this process is going too slow. Barriers and solutions for accelerating this process have been determined by performing a literature research and interviews. To examine what renovation strategy is best in order to achieve an energy neutral housing stock, three renovation strategies have been determined and are applied on a case study, a housing association with approximately 3000 houses. With the software VABI results are generated and interpreted with a long term perspective, taken into account innovations of existing and new products.

I would like to thank my graduation committee for their time, input and guidance during this research. Qi, thanks for your academic guidance and your ability to identify bottlenecks and to help me continue. Thanks Paul, for your practical knowledge and for learning me to approach from different perspectives, and then specific the perspective of the future. Thanks Dyon, for your enthusiasm which made me even more enthusiastic, all your knowledge and the opportunity to conduct this research in collaboration with Atriensis. Thanks to all my colleagues of Atriensis for making it a great time, and special thanks to Jessica for her help with discovering the use of VABI and the interpretation of the data. I want to thank all the interviewees for their time, I have learned much from those conversations and it has broadened my view towards the research topic. And finally I want to thank my family and friends that have helped and supported me during this research and my whole study period in Eindhoven. Thank you!

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## Summary

Sustainability in general is currently a much discussed topic, as well in the building sector. The pollution of the environment, the finiteness of raw materials, independency of suppliers, changing costs of energy, the property value and its comfort, are all aspects which are discussed in relation to a sustainable built environment.

A part of the Energieakkoord (Energy Agreement) is that the built environment has to be energy neutral in 2050; therefor a rigorous transition of the built environment lies ahead with improving the energy performance which will ensure a durable relation with the environment. Looking at the housing market, three segments can be distinguished: private homeownership (56%), commercial rental sector (13%) and social housing (31%) (CBS, 2014). In particular in the social housing sector much influence can be exerted on sustainability by the housing associations which have the responsibility for a high number of houses. A milestone specific for the housing associations is set at the end of 2020 with the “Convenant Energiebesparing Huursector”, which requires that housing associations have to achieve an average energy label B (Haytink & Valk, 2013). The process to be able to fulfill those set requirements is going slow and therefor acceleration is needed.

By conducting a literature review and interviews with experts an overview is given of the overall theme and its players. The themes discussed concern mainly the route towards energy neutral; how the regulations do interfere with it, how housing associations approach the task, what barriers and solutions there are for accelerating the process. The information from the interviewees is broadly in line with literature but they refer to different barriers and solutions. This can be owed to the interests and perspective of each interviewee and its organization. In general it can be concluded that energy neutral as a goal is difficult to describe, and that it is important for housing associations to define for themselves what energy neutral is. The current way of dealing with sustainable renovation can be summarized in three strategies: at once, stepwise with a predefined goal and stepwise with ad decisions.

Legislation such as the Convenant Energiebesparing Huursector is implemented to accelerate the process of the sustainable renovation, this covenant implies that an average energy-index of 1,25 has to be achieved in 2020 but this seems not to be feasible for which several barriers are indicated. The housing associations are seen as a barrier for the following reasons; some organizations are large and therefor it is difficult to realize major changes in the daily routine and management decisions; there is a lack of trust in partners and or techniques, therefor is always chosen for existing options; their scope is very short, this short-sighted approach results in short-term decisions which can be obstructive on the long term. Another barrier that is indicated is that rules and regulations were made that required that housing associations had to adapt their focus on the core tasks. Some indicate as a solution that the government has to make conditioning laws instead of prescribing. Also the construction sector is blamed for the slow process, that there are not enough applicable and affordable products to make an energy neutral house.

All the themes lead to the conclusion that the same overall goal is being achieved, a more sustainable built environment which is energy neutral in 2050. Nevertheless the thoughts on the road towards that goal are very diverse. Therefor different renovation strategies are

applied what leads to inefficiency and indistinctness towards housing associations which can result in wrong strategic decisions on the long term.

In order to examine what strategy might be best for obtaining an energy neutral housing stock in 2050, three renovation strategies have been defined and compared. These three strategies represent the approaches that are used today and are as follows: regular maintenance (1), stepwise (2) and at once (3). To compare the effects of a chosen renovation strategy, a housing association has been selected which is representative for a housing association in the Netherlands. The renovation strategies are applied on the case study with VABI, software that is used for examining what influence certain renovation strategies have on the energy-index of a housing association. Next to that, external factors have been discussed such as trends of energy consumption, costs and efficiency of installations. Combining these external factors with the output of the renovations strategies can provide insight in the consequences of a renovations strategy and therefor contribute to a faster process of the sustainable transformation.

Applying renovation strategy 1 does not result in an energy neutral housing stock, strategy 2 and 3 do result in an energy neutral housing stock. Strategy 3 is more expensive than 2, but the advantage of strategy 3 is that it immediately can take the benefits of the energy savings. On the other hand, strategy 2 can take advantage of all the innovations of the installations which enhance the efficiency and decreases the costs; namely, developments are expected in the installations. With strategy 2 the most efficient installations can be integrated which makes this strategy most suitable for the case study. Moreover, the investments can be spread and it fulfills all the requirements of the laws, the Convenant Energiebesparing Huursector as well as the Energieakkoord. Strategy 3 is based on the plans of the Stroomversnelling in which construction firms and housing associations collaborate to make existing houses energy neutral at once. This strategy is not yet a good alternative in a financial perspective, but is a promising option when the costs have decreased.

The results of this research make housing associations aware of the need of a proper renovation strategy, a long term vision is required. The provided insight created with this research can therefore be used for housing associations in order to determine proper renovation strategies. This results eventually in a better environment in general, houses are healthier, more comfortable and more affordable.

The results of this research concerning the case study can be applied on other housing associations in the Netherlands when the following aspects are taken into account. The research applies a generic strategy for all houses, therefor caution is needed for interpret and compare the results of the case study. Important is to have an overview of the housing types within a housing stock, the location and the demographic characteristics. These factors are not taken into account in this research, but might have much influence on implementing a renovation strategy.

## Samenvatting

Duurzaamheid in het algemeen is momenteel een veelbesproken onderwerp, zo ook in de bouwsector. De vervuiling van het milieu, de eindigheid van grondstoffen, onafhankelijkheid van leveranciers, veranderende energiekosten, de waarde en comfort van onroerend goed, het zijn allemaal aspecten die worden besproken in relatie tot een duurzame gebouwde omgeving.

Een deel van het Energieakkoord is dat de gebouwde omgeving energieneutraal moet zijn in 2050; er staat dus een rigoureuze overgang van de gebouwde omgeving te wachten met het verbeteren van de energieprestatie die zal zorgen voor een duurzame relatie met de omgeving. In de woningmarkt kunnen drie segmenten worden onderscheiden: particulier woningbezit (56%), de commerciële huursector (13%) en de sociale huisvesting (31%) (CBS, 2014). Vooral in de sociale huisvesting sector kan veel invloed op duurzaamheid worden uitgeoefend door de woningcorporaties die de verantwoordelijkheid hebben voor een groot aantal huizen. Een mijlpaal specifiek voor de woningcorporaties is geïmplementeerd met het "Convenant Energiebesparing Huursector" welke vereist dat corporaties een gemiddelde energielabel B hebben in 2020 (Haytink & Valk, 2013). Het proces om aan deze gestelde eisen te voldoen gaat te langzaam en daarom is versnelling noodzakelijk.

Door het uitvoeren van een literatuurstudie en interviews met experts is een overzicht gecreëerd van het algemene thema en zijn spelers. De besproken thema's betreffen voornamelijk de route naar energieneutraal; hoe wordt dit verstoord door regelgeving, hoe pakken woningcorporaties de taak aan en wat zijn barrières en oplossingen voor het versnellen van het proces. De informatie van de geïnterviewde experts is grotendeels in overeenstemming met de literatuur, maar ze verwijzen naar andere barrières en oplossingen. Dit kan worden geweten aan de belangen en het perspectief van elke geïnterviewde en zijn of haar organisatie. In het algemeen kan worden geconcludeerd dat energieneutraal als een doel moeilijk te beschrijven is en dat het belangrijk is voor woningcorporaties om voor zichzelf te bepalen wat energieneutraal is. De huidige manier van het met duurzame renovatie kan worden samengevat in drie strategieën: in een keer, stapsgewijs met een vooraf gedefinieerd doel en stapsgewijs met ad hoc beslissingen.

Wetgeving zoals het Convenant Energiebesparing Huursector wordt uitgevoerd om het proces van de duurzame renovatie te versnellen. Het convenant houdt in dat een gemiddelde energie-index van 1,25 moet worden bereikt in 2020, maar dit is niet haalbaar waarvoor verschillende barrières zijn aangegeven. De woningcorporaties worden gezien als een barrière om de volgende redenen; sommige corporaties zijn groot waardoor het moeilijk is om grote veranderingen te brengen in de dagelijkse routine en beslissingen van het management te realiseren; er is een gebrek aan vertrouwen in partners en of technieken waardoor er altijd wordt gekozen voor de bestaande mogelijkheden; de tijdspanne waarin wordt gekeken is zeer kort, deze kortzichtig aanpak resultaat in korte termijn beslissingen die beperkend kunnen worden op de lange termijn. Een andere barrière is de regelgeving, regels en voorschriften werden gemaakt waardoor de woningcorporatie zich moesten focussen op de kerntaken. Sommigen geven aan dat de overheid wetten moet maken conditioneren in plaats van het voorschrijven. Ook de bouwsector wordt verweten voor het trage proces, er zouden niet genoeg toepasbare en vooral betaalbare producten en processen zijn om een energieneutraal huis te maken.

Alle besproken thema's leiden tot de conclusie dat hetzelfde algemene doel wordt nagestreefd, een duurzame gebouwde omgeving die energieneutraal is in 2050. Toch zijn de gedachten over de weg naar dat doel zeer divers. Dit leidt tot toepassing van verschillende renovatie strategieën wat resulteert in inefficiëntie en onduidelijkheid richting de woningcorporaties. Hierdoor kunnen verkeerde strategische beslissingen worden gemaakt op de lange termijn.

Om te onderzoeken welke renovatie strategie het beste is voor het verkrijgen van een energie neutrale woningvoorraad in 2050, zijn renovatie strategieën gedefinieerd en vergeleken. Deze drie strategieën zijn representatief voor de benaderingen die tegenwoordig worden gebruikt: regulier onderhoud (1), de woning bouwtechnisch verbeteren; stapsgewijs (2), de woning in twee stappen, eerst bouwkundig en daarna installatietechnisch naar energieneutraal brengen; en in één keer(3) alle maatregelen toepassen. Om de effecten van de strategieën te vergelijken, is er een woningbouwcorporatie geselecteerd die representatief is voor een gemiddelde woningcorporatie in Nederland. De renovatie strategieën worden toegepast op deze casestudy met behulp van VABI, dit is software die wordt gebruikt voor het onderzoeken van de invloed van maatregelen op de energie-index van een woningcorporatie. Daarnaast zijn externe factoren besproken zoals trends van het energieverbruik en de kosten en efficiëntie van installaties. Het combineren van deze externe factoren met de resultaten gegenereerd met VABI kunnen inzicht verschaffen in de gevolgen van een renovatie strategie en bijdragen aan een sneller proces van de duurzame transformatie.

Het toepassen van strategie 1 leidt niet tot een energie-neutrale woningvoorraad, met strategie 2 en 3 wordt dit wel bereikt. Strategie 3 is duurder dan 2, maar het voordeel van de strategie 3 is dat het onmiddellijk kan profiteren van de energiebesparing. Anderzijds kan strategie 2 profiteren van alle ontwikkelingen van de installaties waardoor ze efficiënter en goedkoper zijn, ontwikkelingen worden namelijk verwacht in de installaties. Strategie 2 kan dus de meest efficiënte installaties integreren waardoor deze het meest geschikt is voor de casestudy. Bovendien kunnen de investeringen worden verspreid en wordt voldaan aan alle eisen van het Convenant Energiebesparing Huursector evenals het Energieakkoord. Strategie 3 is gebaseerd op de Stroomversnelling waarin bouwbedrijven en woningcorporaties samenwerken om bestaande woningen in een keer energieneutraal te maken. Deze strategie is financieel nog niet een goed alternatief maar is een veelbelovend alternatief. De resultaten van dit onderzoek maakt woningcorporaties bewust dat voor een goed renovatiestrategie een langetermijnvisie nodig is. Het door dit onderzoek verkregen inzicht kan dan ook goed worden gebruikt voor woningcorporaties om een goede renovatie strategieën te bepalen. Dit resulteert uiteindelijk in een beter milieu, huizen worden steeds gezonder, comfortabeler en betaalbaarder.

De resultaten van dit onderzoek kan op andere woningcorporaties in Nederland worden toegepast wanneer er met een aantal aspecten rekening wordt gehouden. Het onderzoek past namelijk een algemene strategie toe voor de hele woningvoorraad, daarom is voorzichtigheid geboden voor het interpreteren van de resultaten. Het is belangrijk om een goed overzicht te hebben van het type woningen, de locatie en de demografie. Deze zijn in dit onderzoek niet meegenomen, maar kunnen veel invloed hebben op de implementatie van renovatiestrategieën.

## Abstract

Housing associations are facing the task to renovate their housing stock in a sustainable way. Goals for achieving a certain energy performance of the housing stock are set with the Convenant Energiebesparing Huursector which is a part of the Energieakkoord. This process is going too slow, acceleration is needed. Barriers and potentials for this acceleration are found in different areas; the organization of housing associations, governmental regulations, technical barriers and the societal environment. This division in barriers, potentials and also in the right renovation strategy might lead to inefficiency and indistinctness towards housing associations.

Insight is needed in which renovations strategy is most suitable for the housing stock of a housing association looking at the long term. Literature research has been performed and experts have been interviewed in order to obtain a clear image of how the process is going and which factors are holding back and can improve the progress. Subsequently, three generic renovation strategies have been determined in order to provide insight in the effects of a chosen renovation strategy; regular maintenance, stepwise and at once. These strategies are with use of VABI software applied on a case study, a housing stock of a carefully selected housing association that represents a general Dutch housing association.

Conclusions are that with regular maintenance no energy neutral housing stock can be achieved. The stepwise and at once strategies both achieve an energy neutral housing stock, the latter is more expensive but achieves a higher score. This at once strategy requires high investments in the start phase but brings also immediately the advantage of lower energy costs. The stepwise strategy has two moments of investments what can give the advantage of implementing innovative and more efficient techniques. For the selected case study the stepwise strategy is most suitable, the at once strategy is not yet a good alternative because of the higher costs.

In general, the best approach might differ per housing association. Important is to determine a goal and a strategy on the long term. A short-sighted approach results in short-term decisions which can be obstructive on the long term, with the result that an energy neutral housing stock cannot be achieved.

# 1. Introduction

Sustainability in general is currently a much discussed topic, as well in the building sector. The pollution of the environment, the finiteness of raw materials, independency of suppliers, changing costs of energy the property value and its comfort, are all aspects which are discussed in relation to a sustainable built environment. This has required the development of sustainable strategies to reduce the energy consumption of buildings.

In the Energieakkoord (Energy Agreement) the goal of the government of the Netherlands is set for an energy neutral built environment in 2050, while at the moment less than ten percent of the built environment is energy neutral (Haytink & Valk, 2013). A rigorous transition of the built environment lies ahead with improving the energy performance which results in a durable relation with the environment. Looking at the housing market, three segments can be distinguished: private homeownership (56%), commercial rental sector (13%) and social housing (31%) (CBS, 2014). In particular in the social housing sector much influence can be exerted on sustainability by the housing associations, because a high number of houses can be approached. Energy saving techniques such as good insulation and glass types is being integrated in new buildings; the challenge is to renovate the existing social housing in a sustainable way, to make it energy neutral. Several solutions have been developed for such a transformation of existing houses but are often limited to pilot projects (Platform31, 2014). Upscaling is needed in order to achieve the requirements that are set for housing associations in terms of sustainability. This chapter dives into the context of this research, and describes the problem definition with its research questions and design, and gives an insight in the expected results.

## 1.1. Context

Housing associations are faced with the enormous task to renovate their housing stock in a sustainable way; in 2020 each association has to have an average energy label B. An energy label is related to the energy-index, a calculated number which indicates how energy efficient a house is compared with similar houses. The calculation of this energy-index has been changed since 2015 whereby labels and the corresponding energy-index have been changed. Because this calculation method is implemented recently, the information available is calculated according to the old method. In this report is clearly indicated when which calculation method is applied. Label A refers to the color green which represents a very sustainable house while label G refers to the color red and thus stands for an energy consuming house. An energy efficient house has good insulation, double glazing, energy efficient heating and solar panels. (Energielabel.nl, 2015) In 2008, the “Convenant Energiebesparing Huursector” is prepared in order to achieve a higher energy performance of the social rent houses of the housing associations. This covenant is part of the Energy Agreement and is adapted in 2012 with the goal to achieve an average energy label B of the social rent houses, which corresponds with an energy-index of 1,25 according to the old calculation method (Hazeu, Kamminga, Laurier, & Spies, 2012). This covenant is just a milestone towards the end goal of energy neutrality which is set for 2050. Thus the goal is known; however, the process towards this goal is doubtful. Haytink and Valk state that many housing associations have defined clear objectives for the short term till 2020, but not for the long term process to energy neutral in 2050. Housing associations are aware of the goal of energy neutral in 2050 but do not have policies yet, many experience it as a small dot at the horizon (Haytink & Valk, 2013).

Although the goals for the short term are quite clear, it is expected that a substantial part of the housing associations will not be able to achieve this goal. Atriensis states that the current rate of the decreasing the average energy-index is too low which results in an average energy-index of 1,35 in 2020, which is energy label C (Atriensis, 2014). This trend can be seen in Figure 1.1.

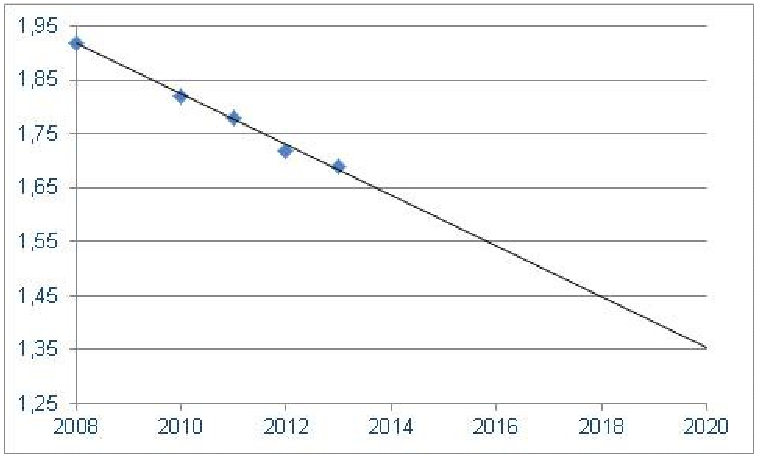

**Figure 1.1 Decrease average energy-index of housing associations (Atriensis, 2014)**

Also the research of the Woonbond shows the uncertainty of the feasibility of the Convenant Energiebesparing Huursector for 2020. 52 housing associations were asked whether they expect to achieve the goal of the covenant 2020, to have an average energy label B. Only 27 percent of the respondents indicate to be able to meet the target, 33 percent is still insecure and 40 percent indicates that they will not achieve the objectives of the covenant. (Woonbond, 2013) So acceleration is needed in order to stay on track towards energy neutrality. Several strategies for sustainable renovation are available for implementation which will be described later. What important is to take into account is that most associations see energy saving adjustments as an additional part. Anyhow, housing associations that are behind of track have to make a decision towards a higher energy performance. This research focuses on the strategies for sustainable renovation which can be followed and what the consequences are when a strategy has been chosen.

Several strategies are applicable for housing associations to make the existing housing stock energy neutral. The at once step towards energy neutral strives for a total makeover of a house to achieve a high energy performance at once. The advantage is that the house as a whole is transformed into energy neutral and the energy costs are decreased to zero. A disadvantage is that this sort of renovations is still relatively expensive. Next to that, it is difficult to predict how the used techniques will develop; it can occur that the used technology is not adaptable to new technologies in the future. Another strategy is to perform stepwise adjustments in the house, and achieve energy neutral in two or three steps. A less high investment is needed at one moment, and it is possible to respond to innovations in sustainable techniques. A disadvantage can be seen in the fact that energy costs are still present. In this research a number of these strategies of sustainable renovation towards energy neutrality will be determined.

The strategies differ in type of process. Different processes can be the already mentioned renovation at once or stepwise. Another example of difference in process is when a whole house block is being renovated at once or one house at a time. The latter can occur for instance when mutation takes place and tenants are moving. The type of process depends mainly on the property of an association. In the case of a flat building it would be undesirable to renovate one single apartment at a time by mutation; that would imply that at any time an apartment is being renovated which may cause nuisance. Renovation at mutation can be a nice opportunity for an association that has soil-bound houses, but then other questions can arise. For instance when the aesthetics committee does not allow to make adjustments on the outside of the house with PV-panels or a new thicker facade , then the adjustments have to be performed on the inside of the house by implementing other renovation techniques. In short, these different processes ask for different techniques of renovation; therefor, process and technique are related to each other and result in a renovation strategy. Within the used techniques a distinction can be made between so called hard- and software. A window frame can be seen as hardware when it can be used for multiple types of glass, the glass is then the software which can be easily assembled.

The research provides insight in the behavior of the energy performance after a chosen strategy. Therefore it is also important to investigate the trend of the energy performance of housing associations so far, as well as the renovation techniques. By analyzing how these aspects have developed in the past, assumptions can be made about the behavior in the future. For modeling this behavior, the factors that have influenced those trends have to be determined. Thought can be of governmental policies, subsidies and breakthroughs of techniques or materials. The main question is how the renovation strategy will influence the process towards energy neutral.

## 1.2. Problem definition

Housing associations are facing the task to become more sustainable. Targets have been set, and strategies are being implemented, though these strategies are in most cases shortsighted and therefor it is uncertain whether goals will be achieved. The problem is that most housing associations do not have a policy for sustainable renovation on the long term. This deficiency is risky because made renovation decisions can have a great influence on the further process towards energy neutral. This research will give an answer to that problem and will give insight into the behavior of several renovation strategies. In other words, it will provide insight in the consequence of a strategy towards energy neutrality. The goal is not to give the best strategy because that differs per association. The purpose is to give insight into the strategy that is most suitable for the aimed scenario of an association. The term scenario stands for the goal that an association strives for, for example when an association wants to achieve a certain energy label in a certain amount of time. In this research the scenario is to achieve an energy neutral housing stock in 2050. This research can then give insight in which strategy is most suitable to comply with that scenario.

## 1.3. Research question

The research exists of a main research question supported with several sub questions. The main research question is:

- What are the effects of the strategies for sustainable renovation of housing associations in the process towards energy neutrality of the housing stock?

The following sub questions are defined in order to answer the main question:

1. What are the regulations, agreements for housing associations concerning sustainability; which actors are involved?
2. What is the trend of the average energy performance of housing associations; which factors are responsible for this process, what barriers and potentials can be determined?
3. What is the trend of the techniques used for sustainable renovation; is new knowledge expectable?
4. Which strategies can be applied for sustainable renovation?
5. What are the effects of the strategies for the average energy performance of housing associations?

## 1.4. Research boundaries and limitations

Since this research has a limited timeframe, certain limitations and boundaries are defined:

- This research will only focus on the existing housing stock of a housing association, since this target group is the main problem defined in this research.
- Though the behavior of the occupant may not be underestimated, this research will focus on the house as a physical object and the occupants' behavior will not be taken into account.
- The topic of this research can be approached from different perspectives. This research will be aimed to the housing associations, since they are the decision makers for implementing a renovation strategy.
- Since January 1 of 2015, the regulations and calculation concerning energy labels for housing associations has changed; the label will be abolished so the energy performance will be indicated with the number of the energy-index (Atriensis, 2014). The results will be calculated according to the new methodology, but in some parts will be spoken about the old energy-indexes. It will be indicated clearly when which method is used.

## 1.5. Research relevance

The research contributes to stimulate sustainable renovation of housing associations by providing insight in the effect of several renovation strategies. The trend of the process of the average energy performance and the factors that withhold the process will be analyzed. This will provide insight in the behavior of the strategies towards the future and therefore shows the consequence of the chosen strategy.

## 1.6. Expected results

The findings of this research should give an overview of the trend of the average energy performance of housing associations and what the consequences are when choosing one of the sustainable renovation strategies, energetically and financially. Next to that, this research will give an overview of the different thoughts about the route towards energy neutral, what the barriers and potentials are for improving the sustainable transformation.

## 1.7. Research design

This research will be executed by performing a literature research, interviews, software Vabi and Microsoft Excel. Vabi can be used for examining what influence certain renovation strategies have on the energy-index of the housing association.

The research frame of this research is shown in Figure 1.2. The first phase is a literature study about the current situation of sustainability of the housing associations in general. What are the regulations and goals set by the government, and what is the current behavior of the housing associations and why? Several actors who are involved in this field will be interviewed. The trend of the average energy performance of the housing associations will be analyzed, and the factors that were of great influence on the process will be determined. These factors can also include barriers for housing associations for not renovate in a sustainable way. Next to that the trend of the innovations will be analyzed and an assumption will be made how the innovation process will develop in the future. At this point, all the factors that had influence on the process, both technical and management factors, are determined and can be used for describing the process' behavior in the future.

Measures for sustainable renovation will be determined and converted into renovation strategies. Meanwhile a suitable dataset of a housing association will be adjusted so it is representative for a Dutch housing association. The created renovation strategies will be applied on the selected database so the effect of the strategies can be examined.

Finally, a conclusion will be given in which the influencing factors will be discussed and insight can be given into the consequences of a chosen renovation strategy.

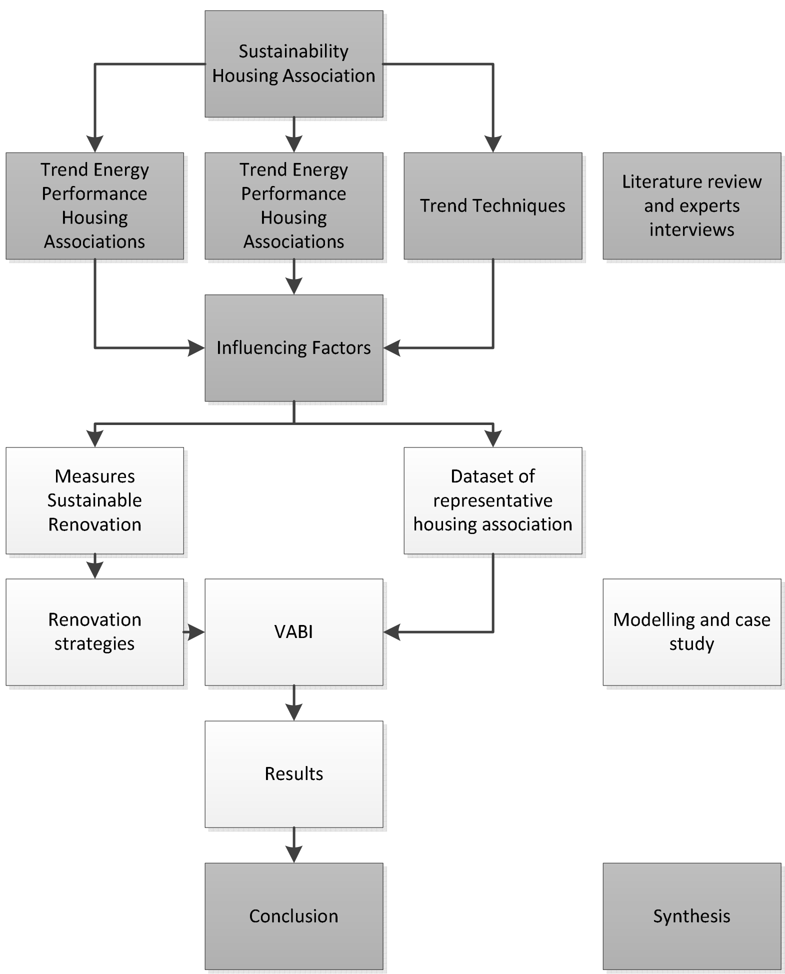


Figure 1.2: Research frame

## 2. Glossary

In this section terms that are used many times in this research are described briefly.

**Convenvant Energiebesparing Huursector:** In 2008, the “Convenant Energiebesparing Huursector” (covenant energy saving rental sector) is prepared in order to achieve a higher energy performance of the social rent houses of the housing associations. This covenant is part of the Energy Agreement and is adapted in 2012 with the goal to achieve an average energy label B of the social rent houses, which corresponds with an energy-index of 1,25 according to the old calculation method (Hazeu, Kamminga, Laurier, & Spies, 2012).

**Energieakkoord:** In September 2013 the Energieakkoord (SER, 2013) (energy agreement) is undersigned by more than 40 organizations, and is the base for a broad, robust and futureproof energy and climate policy. The agreement contains objectives for the short and the medium term, and therefor provides a perspective for the long term. The agreements imply energy savings on national level, an increase of renewable energy and the creation of full-time jobs. Therefor ten pillars are defined of which energy saving is the most important one. The appointments concerning energy saving are focused on the built environment as well as enlarging the energy efficiency in industry, the agricultural sector and remaining industry. Eventually, an energy neutral built environment in 2050 is set as a goal (SER, 2013)

**Herzieningswet:** The “Herzieningswet voor woningcorporaties” (revision act for housing associations) requires performance agreements of the housing associations for the next five years. These performances concern sustainability and energy saving measures. To ensure that the plans will be executed, the agreements have to be defined SMART (specific, measurable, acceptable, realistic, time) to be able to control. (Noy, 2015)

**Multifamily houses:** Multifamily houses refer to houses that have a collective roof, for instance apartments.

**Property Tax:** Property Tax (verhuurdersheffing) which implied that housing associations had to pay a certain amount of money in relation to their housing stock which resulted in less attention and financial possibilities for sustainable renovation.

**Rc-value:** An Rc-value indicates the heat insulating capacity of a construction (Kort, 2008).

**Renovation measure:** A renovation measure is an individual measure for improving the energetic quality of a house. Thought can be of insulation, new windows or installations.

**Renovation package:** A renovation package is a collection of several renovation measures which are applied at the same time. A renovation package is a part of a renovation strategy.

**Renovation strategy:** A renovation strategy implies the total collection of packages (and thus measures) that are executed by a housing association. Three renovation strategies towards an energy neutral housing stock are defined in this research: 1 regular maintenance, 2 stepwise, 3 at once.

**Single-family houses:** Single-family houses refer to houses that have an own roof, for instance detached houses or terrace houses.

**Split incentive:** Split incentive stands for the phenomenon that one party invests and that another party gains the benefits from that investment. In this case the housing association invests in the real estate and makes it more sustainable and the tenant receives a more comfortable house with a decrease of the energy costs.

# 3. An analysis of the sustainable renovation process of the existing housing stock of housing associations towards energy neutral

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**Abstract**
Housing associations are facing the task to renovate their housing stock in a sustainable way. Goals for achieving a certain energy performance of the housing stock are set with the Convenant Energiebesparing Huursector which is a part of the Energieakkoord. This research describes the process of the sustainable renovation of the existing housing stock of housing associations towards energy neutral. This process is going to slow, acceleration is needed. Barriers and potentials for this acceleration are found in different areas; the organization of housing associations, governmental regulations, technical barriers and the societal environment. This division in potentials and also in the right renovation strategy might lead to inefficiency and indistinctness towards housing association. Insight is needed in which renovations strategy is most suitable for the housing stock of a housing association looking at the long term. Literature research has been performed and experts have been interviewed in order to obtain a clear image of how the process is going and what are the factors holding back and can improve the progress.

**Keywords:** Housing associations, sustainable renovation, energy neutral, renovation strategies, barriers, potentials, Ishikawa.

## 3.1. Introduction

In this literature review knowledge in existing literature in relation with housing associations and its sustainable renovation towards energy neutral will be discussed. A part of the Energieakkoord (Energy Agreement) is that the built environment has to be energy neutral in 2050; therefor a rigorous transition of the built environment lies ahead with improving the energy performance which will ensure a durable relation with the environment. Looking at the housing market, three segments can be distinguished: private homeownership (56%), commercial rental sector (13%) and social housing (31%) (CBS, 2014). In particular in the social housing sector much influence can be exerted on sustainability by the housing associations which have the responsibility for a high number of houses. A milestone specific for the housing associations is set at the end of 2020 with the "Convenant Energiebesparing Huursector", which requires that housing associations have to achieve an average energy label B (Haytink & Valk, 2013). The process to be able to fulfill those set requirements is going slow and therefor acceleration might be useful. This literature review examines how the process is going, what barriers can be determined and what the potentials are for acceleration.

This literature is structured as follows; first the findings of the literature review will be discussed. After that the outcomes of the performed interviews will be described. Both sections are structured in the same way; first will be spoken about regulations and definitions, then renovation strategies, followed by the barriers and potentials for enhancing the process.

First will be described in chapter 3.2 what the goals are for are more sustainable built environment and what that means for the housing associations, definitions will be described, and the process of the transition to more sustainable housing stock will be discussed. Then the tasks of housing associations will be described in chapter 3.3, followed by defining several sustainable renovation strategies in chapter 3.4. Subsequently barriers and potentials for sustainable renovation will be described. In chapter 3.7 the findings of the interviewees will be discussed in the same sequence; first regulations and definitions, than the renovation strategies, followed by the barriers and potential solutions. Finally, a conclusion will be given in chapter 3.8 by using an Ishikawa-diagram.

## 3.2. Energy neutral built environment

In this chapter is described what regulations are determined for the built environment, and more specific, for the housing associations. Then the process of the housing associations towards energy neutral is discussed, after which is described what energy neutral implies for housing associations.

### 3.2.1. Regulations; Energieakkoord and Convenant Energiebesparing Huursector

In September 2013 the Energieakkoord (SER, 2013) is undersigned by more than 40 organizations, and is the base for a broad, robust and futureproof energy and climate policy. The agreement contains objectives for the short and the medium term, and therefor provides a perspective for the long term. The agreements imply energy savings on national level, an increase of renewable energy and the creation of full-time jobs. Therefor ten pillars are defined of which energy saving is the most important one. The appointments concerning energy saving are focused on the built environment as well as enlarging the energy efficiency in industry, the agricultural sector and remaining industry. Eventually, an energy neutral built environment in 2050 is set as a goal (SER, 2013)

A part of the Energieakkoord is the 'Convenant Energiebesparing Huursector' (covenant energy rental sector) which implies that housing associations have to achieve a certain average energy performance at the end of 2020. This covenant is prepared in 2008 and is adapted in 2012 as a part of the Energieakkoord. (Hazeu, Kamminga, Laurier, & Spies, 2012)

At the end of 2020 housing associations have to have an average energy label of B. An energy label is related to the energy-index, a calculated number which indicates how energy efficient a house is compared with similar houses. The relation between the label and the energy-index can be seen in Table 3.1. A refers to the color green which represents a very sustainable house while label G refers to the color red and thus stands for an energy consuming house. For example, an energy efficient house has good insulation, double glazing, energy efficient heating and solar panels. (Energielabel.nl, 2015) In the covenant is defined that housing associations have to achieve an average energy-index of 1,25 which corresponds with energy label B.

Since 2015 a new method is in use for determine the energy-index of a house. The new method implies a different calculation and therefor values the criteria in a different manner than the old method. Also the performance of a house is not expressed anymore with a label but with a number, the energy-index. In Table 3.1 is displayed how the old and new energy-index are different. In the covenant the goal for 2020 is set for an average energy label B, or an energy-index of 1,25. According the new methodology that goal can be interpret as an average energy-index between 1,21 and 1,40.

Table 3.1: Labels with Energy-indexes (Aedes, 2015) (Rijksoverheid, 2015)

| Label | Energy-index (old) (Aedes, 2015) | Energy-index (2015) (Rijksoverheid, 2015) |
|---|---|---|
| A++++ | | < 0,21 |
| A+++ | | 0,21-0,41 |
| A++ | < 0,51 | 0,41-0,60 |
| A+ | 0,51-0,70 | 0,61-0,80 |
| A | 0,71-1,05 | 0,81-1,20 |
| B | 1,06-1,30 | 1,21-1,40 |
| C | 1,31-1,60 | 1,41-1,80 |
| D | 1,61-2,00 | 1,81-2,10 |
| E | 2,01-2,40 | 2,11-2,40 |
| F | 2,41-2,90 | 2,41-2,70 |
| G | > 2,90 | > 2,70 |

As already discussed, a goal of the Energieakkoord is to ensure an energy neutral built environment. For housing associations a step towards that goal is set in 2020 with the covenant to achieve an average energy label B according to the old method. Next to that the Energieakkoord states that for 2030 is strived for an average label A, but this is not defined very clearly (SER, 2013). In Figure 3.1 these moments are made visible in a timeline together with the requirements for new houses. Notable is that between 2030 and 2050 no new milestones are placed. Therefor the importance of a conscious choice for a renovation strategy is important.

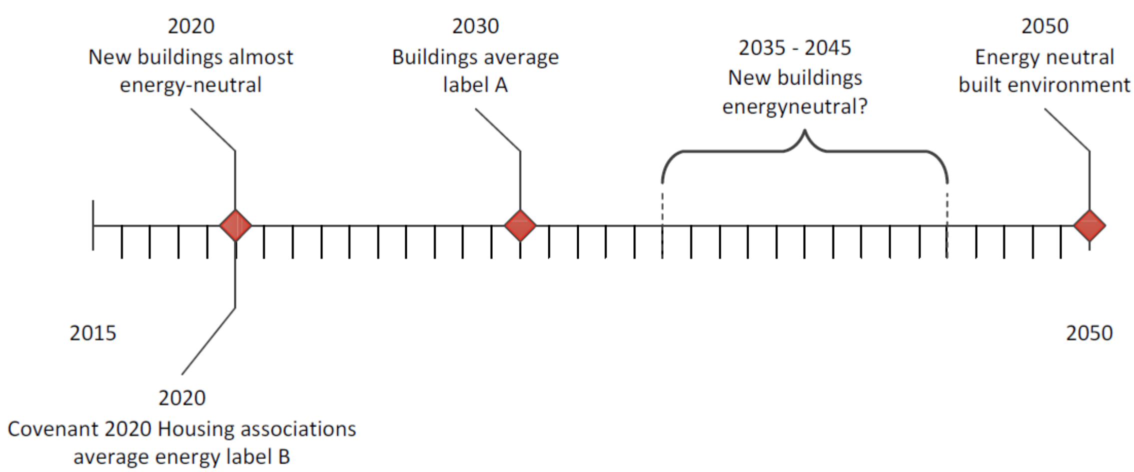

Figure 3.1: Timeline regulations sustainable built environment (Haytink & Valk, 2013)

### 3.2.2. Definitions energy neutral

So the goal of the Energieakkoord is an energy neutral built environment in 2050, but what does that mean for the housing associations. Several definitions of energy neutral are being used. For a housing association it depends on more factors how energy neutral is defined. Vision and ambition are important, as well as technical and financial resources, location, availability of renewables and the condition of the property. A guideline for housing associations to define the term energy neutral can be as follows (Haytink & Valk, 2013):

1. Define the energy demand, if it includes the energy demand of the building, the use and the materials.

2. Define the limits within which the building has to be energy neutral, parcel-, neighborhood- or city level and which sustainable measures can be applied.
3. Define the energy units and the timeframe.

In the report of Haytink and Valk several definitions of energy neutral are described. A theoretical definition is given as follows: “A project is energy neutral if on year basis no net import is needed of fossil or nuclear fuel from outside the system of the building in order to build, use and demolish it. This means that the energy consumption within the project is equal to the amount of renewable energy that is generated in the project or based on external measures which may be granted to the project. The energy consumption that results from the creation and demolition of the building will be at an annual contribution settled on the basis of the expected life of the building (PeGo, 2009)”.

As mentioned in the guideline of Haytink and Valk, it is crucial to define on which scale the building has to be energy neutral; on the scale of one house, a complex, a neighborhood or a housing association. When the housing association is considered as a system, it is difficult to distribute the energy between the houses which may be spread over the region. Therefor it might be an option to consider a neighborhood as a system, which makes it easier to transfer energy. In those cases building windmills can be an option for generating energy instead of improving the house. When the system is to be considered one house, all the energy has to be generated with the house itself.

Haytink and Valk indicate a report of Clocquet and Swinkels (Clocquet & Swinkels, 2010), in which is stated that it is difficult to integrate the consumption of creation and demolition of the building into the calculation for being an energy neutral building. Therefor the authors mention that only the energy of the users and the building has to be compensated and that the generated energy has to be related to the building itself. In the report ‘Huis vol energie’ of the Energiesprong (SEV Energiesprong, 2011) an energy neutral house generates as much renewable energy as it uses. In this report is stated that the process towards energy neutral houses consists of two steps, first decrease the energy demand and then try to generate the remaining energy in a durable way as close as possible to the object. In this report of the Energiesprong is mentioned that there is not a widely accepted definition of energy neutral, therefor they use the definition of Agentschap NL (Agentschap NL, 2010), which is as follows:

1. On year basis the house generates as much or more than it uses.
2. The building does not use more energy from the energy grid than it gives back in the form of locally generated renewable energy.
3. The boundaries have to be defined in which the building has to be energy neutral, desirable is to limit these boundaries close to the building.

Attention has to be paid that an energy neutral house is not the same as an autarkic house; the similarity is that in both cases no net energy is taken from the main energy grid. Though an energy neutral house remains to be connected to the energy grid for the exchange of energy flows while an autarkic house is disconnected of the energy grid (SEV Energiesprong, 2011).

### 3.2.3. Process of housing associations sustainability

For three years SHAERE is used as a monitor for the energy-index of Dutch housing associations. SHAERE (Sociale Huursector Audit en Evaluatie van Resultaten

Energiebesparing) stands for Social Housing Sector Audit and Evaluation of Energy saving results. For three years SHAERE is the official monitor of the Convenant Energiebesparing Huursector and contains data of 1.342.139 houses of 169 housing associations throughout the Netherlands. With use of the SHAERE monitor statements can be made about the total energy consumption, CO2 emissions and the average energy-index of the participating associations. The progress of the average energy-index of Dutch housing associations can be seen in Figure 3.2, the energy-index in this figure is according to the old method.

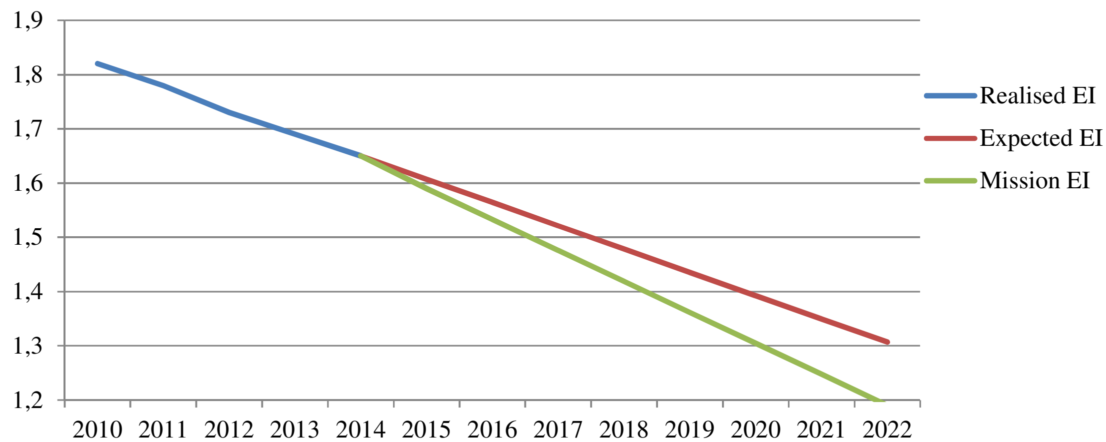


Figure 3.2: SHAERE Monitor (Aedes, 2015)

In the period of 2010 till 2014 the average energy-index has decreased from 1,82 to 1,65. When this trend is extrapolated towards 2021, an energy-index of 1,35 is expected which is too high. The mission is to increase the speed of energy saving and therefor action is needed. (Aedes, 2015) Especially when is taken into account the overall goal of energy neutral in 2050, a transition towards more sustainable houses is needed.

Few shortcomings of SHAERE are mentioned by Itard et al (2014). They mention that the available information from SHAERE is only the energy-index and the energy label without any house characteristics. Implementing this could be very useful in order to determine the energy label for a house of which the characteristics are known. Another useful feature of SHAERE would be the coupling of the houses with their annual gas and electricity consumption. Large discrepancies were found between actual and theoretical energy consumption, thus insight in the effectiveness of the energy consumption before and after an implemented renovation measurement would be very useful. The dataset is defined by Itard et al (2014) as the first of its kind on European scale and offers great opportunities, but still has many weaknesses which should be upgraded. (Itard, Majcen, & Visscher, 2014)

## 3.3. Housing associations; its role and target group

In this chapter the phenomenon housing associations will be described as well as its role, which has been a much discussed topic. The target group, the tenants will be described as well.

### 3.3.1. Role of housing associations

Housing associations are foundations or associations that focus on building, manage and rent affordable housing. In total there are 388 housing associations which manage 2.319.778 houses. The size of housing associations are very diverse, some manage more than 50 thousand houses, others a few hundred, the average size is approximately 6000 houses (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2014). The tasks are expanded to preserve the quality of life in neighborhoods and the management of social real estate, which is a real estate with a public function such as education, sport and culture.

The government sets rules for these organizations and is supervising. The rules are stated in the so-called BBSH (Besluit Beheer Sociale Huursector) which stands for Decision Management Social Housing Sector, but will be replaced by the Herziene Woningwet (Revised Housing Law) which is implemented on July 1 of 2015 (Rijksoverheid, 2015). The BBSH determines the following six performance fields (Koning & Leuvensteijn, 2010):

- Appropriate housing of the target group, namely people with incomes up to the limit at which someone might be qualified for rent subsidies (huursubsidie).
- Qualitative maintaining housing property.
- Involve residents in policy and management.
- Ensuring financial security.
- Promote livability.
- Housing for elderly, disabled people and those who need care or assistance.

These performance fields can be distinguished in roughly two main objectives; improving livability and appropriate housing of the target groups. The first aims at the livability of the neighborhoods and implies limiting the negative external effects. The second main objective concerns the affordability of housing of sufficient quality for people with the lower incomes (Koning & Leuvensteijn, 2010). The Herziene Woningwet describes accurately the core tasks of housing associations, strengthens the positions of municipalities and tenants. Next to that it offers tools for making agreements between the parties with performance agreements (Gelissen, 2015)

Housing associations have become private organizations with public purposes (Aussems, 2010). According to the minister Stef Blok of Housing and Civil Service, controlling this sector is difficult because the ownership is not clear. Furthermore, the citizen has little to choose between the parties and state guarantees can ensure for imprudent policy and moral hazard and misconduct (Nyenrode Business Universiteit, 2013).

In the recent past several incidents have occurred in which the image of housing associations has not improved. Most discussed example is the Vestia-affair, Vestia is a housing association in Rotterdam and manages 90.000 houses and is the largest association of the Netherlands. Vestia had large liquidity problems caused by abundant and speculative use of derivatives with a gross volume of 24 milliard euros. Due to rent decreases Vestia had to pay a large amount of that money but was not able doing that. 2 milliard euros was eventually paid by the whole housing association sector (Pruijm, 2013). A commission concluded that Vestia had a lack of internal administration, risk management and supervision (Hoogduin, Hoekstra, & Schaar, 2012).

### 3.3.2. Target group: Tenants

The target group of housing association are households which have a lower income than average and people who can use some extra help for finding a house. Thought can be of students, younger people, labor migrants, status holders, homeless, and ex-detainees (Aedes, 2015). The limit of income per year per household is 34.911 euros (Rijksoverheid, 2015). Whether a rent house belongs to the social or commercial sector depends if the monthly rent is respectively below or above 710,68 euros (Aedes, 2014). When a household has an income below 34.911 and rents a house in the social sector, they are eligible for a rent subsidy. The renting sector is becoming the domain of the lower incomes. Households with a higher income are more inclined to buy a house. Due to the lower incomes, the rent sector houses relatively many single people and one parent families. More specific, much people younger than 30 years and elderly people older than 65 years are living in a rent house. Because elderly people are staying longer in an independent house, the number of people older than 75 years living in a rent house has increased. (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2013)

Risky is to consider the target group as one group of tenants. Many types of tenants can be distinguished. Mostly a distinction is made in age, income, household composition or geographical diffusion. These aspects say nothing about tenant's characters and preferences, while knowing these aspects might be very useful in order to collaborate with tenants and to provide suitable housing. This knowledge is already used in many other sectors, but is not applied often in the strategies of housing associations. Motivaction has developed a model which can be used as a segmentation tool for defining the target group in order to find what motivates this group. This tool is called the Mentality-model and is displayed in Figure 3.3. The model distinguishes eight social milieus which are based on norms and values and looks to the motivation of a group (Motivaction, 2015).

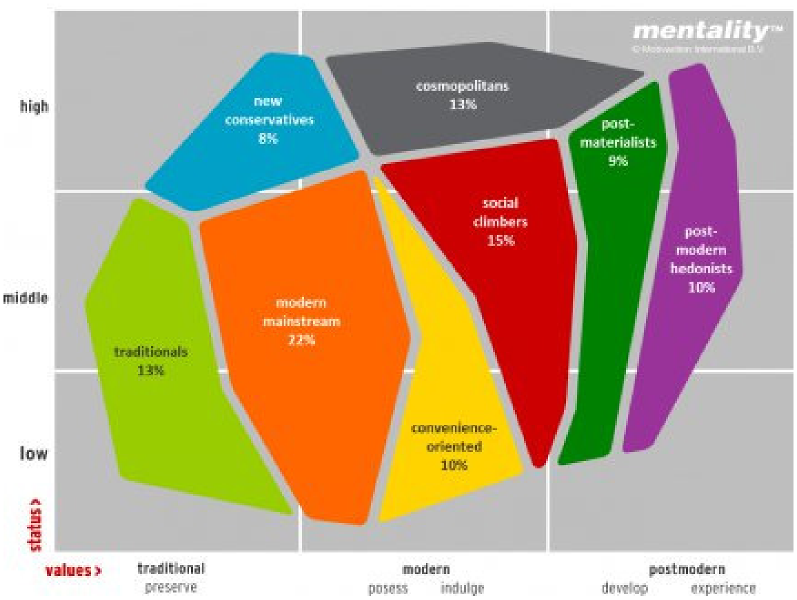


**Figure 3.3: Milieus in the Netherlands (Motivaction, 2015)**

With use of the Mentality-model housing associations can discover more about their type of tenants and therewith the approach to and the contact with the tenants can be improved. In this way it can become clearer what tenants really want and which aspects they find more important in a house. Thought can be of comfort, luxury, affordability, durable etcetera. An example of such customer segmentation is Ymere, a large housing association which manages houses in the surroundings of Amsterdam. They started with customer segmentation based on perception. Four perception worlds are distinguished; ambitious residents, quirky residents, cozy residents and salvaged residents. These perceptions are used for communication, predicting residents' attitudes, preferences of living and how to deal with residents. (Burhs, Eerde, & Ponec, 2015)

## 3.4. Renovation strategies

The scope of this research focuses on the existing housing stock and therefor the renovation process has to be analyzed. First the Trias Energetica principle is described which is an important guideline for many executed renovation strategies is. Then several renovation types are described.

### 3.4.1. Trias Energetica

The Trias Energetica principle is developed by the Delft University of Technology and is a guideline for achieving energy sustainability in the building sector. The principle of the Trias Energetica is displayed in Figure 3.4.

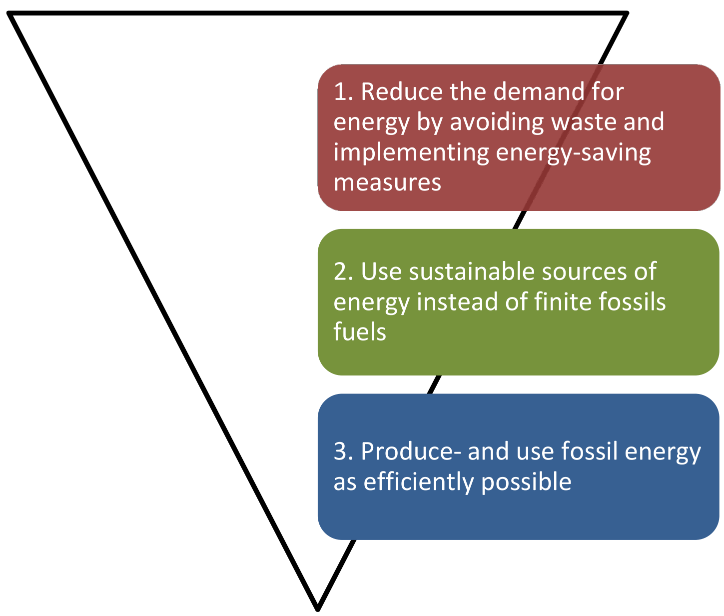


**Figure 3.4: Trias Energetica concept (Eurima, 2015)**

Energy saving is the most important element according to the guideline. It states that only when a building has minimized its energy loss, the focus should shift towards renewable energy sources such as solar panels to meet the remaining energy demand. Only then fossil fuels should be used, as efficiently and cleanly as possible. (Eurima, 2015)

Dobbelsteen (2008) makes the Trias Energetica more specific and claims that step 2 consists of two steps. First the residual flows of energy have to be used, after which energy should be used from renewable sources (Dobbelsteen, 2008). Remarkable is that the Trias Energetica is approached in different ways. For single family houses sustainable transformation is approached in most cases according the steps of the Trias Energetica; first reduce the energy demand by applying good insulation, and then look further for installations. The opposite may be concluded for multi-family houses where in most cases first sustainable sources will be applied and reducing energy demand is one of the subsequent steps. This contradiction can be the result of that it is easier to insulate a single family house more easily and that the installations for those dwellings are less feasible.

### 3.4.2. Renovation approaches

In existing literature, many renovation strategies towards energy neutral are used which generally are comparable. Claessens and Groenland (2014) state in their report that two ways of sustainable renovation of social housing can be perceived; stepwise and the at once strategy. The latter one is under the associations they have surveyed the strong minority. Haytink et al add one strategy and distinguish three routes; energy neutral at once, in predefined steps or with steps made by ad hoc decisions (Haytink & Valk, 2013). In Figure 3.5 an example can be seen of those three strategies.

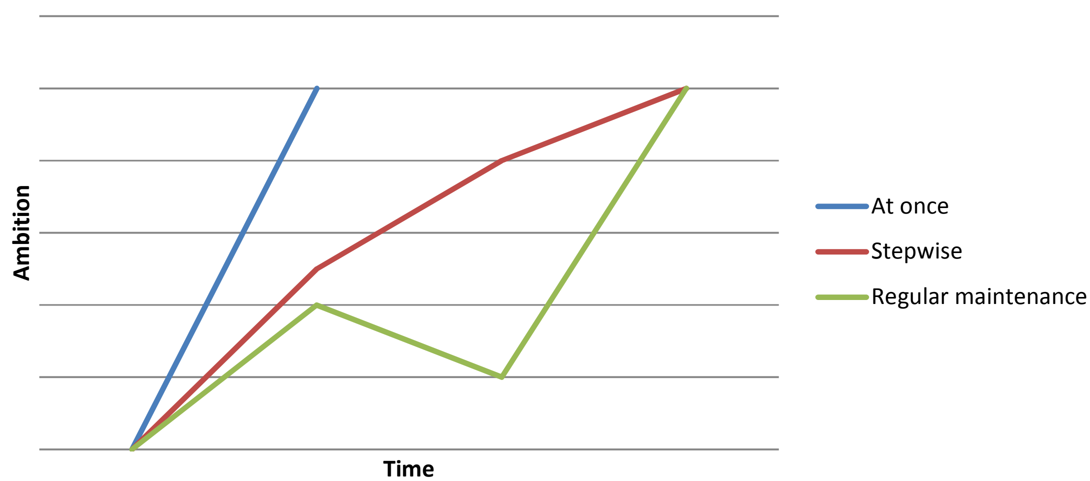


Figure 3.5: Examples renovation strategies (Haytink & Valk, 2013)

In the figure can be seen how the ambition levels differ per strategy. The green line represents the regular maintenance, because no long term goal is determined the ambition level is fluctuating. The opposite is the case in the other two strategies, strived is to achieve a predetermined goal which results not in a decrease of ambition.

In the research of Elkink et al (2013) four scenarios were described for which the costs and benefits were analyzed for making an energy neutral house. The base scenario is a reference scenario where no renovation is carried out. The opposite is the renovation scenario to energy neutral with good insulation, ventilation system, solar water heaters and PV-panels. The two other scenarios used differ in the way of making the house more sustainable; insulate the house or generate sustainable energy. Investigated was which scenario is most profitable in a period of 25 years. The scenario to energy neutral is less profitable than the other scenarios with only insulation and energy generation. But the authors state that with the last two scenarios still costs are made and the energy neutral scenario with no costs over 25 years has therefore more benefits. To complement, the profitability of the scenarios is influenced by parameters; inflation rate, interest and discount rate and increase electricity and gas price did not influence the energy neutral scenario, but did influence the other scenarios. (Elkink, Han, Glumac, Masselink, & Schaefer, 2013)

## 3.5. Barriers

This chapter discusses the barriers for the slow progress of sustainable renovation that are identified by literature. Main areas which are seen as barriers are the housing associations with its business and policies, the government with the regulations and subsidies and the techniques for sustainable renovation.

### 3.5.1. Barriers within Housing associations

A major crux for sustainable renovation of the social housing stock is the split incentive that is experienced by the housing associations. Split incentive stands for the phenomenon that one party invests and that another party gains the benefits from that investment. In this case the housing association invests in the real estate and makes it more sustainable and the tenant receives a more comfortable house with a decrease of the energy costs. Many housing associations do want to recoup the investments via a rent increase or receive a percentage of the saving of the tenant. For housing association investing in energy saving measurements is financial not attractive since the association is not the one who receives the benefit. (Haas, Hal, Oel, & Thomsen, 2010) Next to that there needs to be found a balance in how much of the investments has to be recouped by increasing the rent price, importance is to keep it below the monthly social rent of 710,68 euros.

Although the efficiency requirements for housing associations are lower than other landlords, financial feasibility seems to be the largest barrier for sustainable transformation of the housing stock, followed by the problems with financing those investments (Hoogervorst, Middelkoop, & Vringer, 2014).

All associations do have experience with the rule that 70 percent of the tenants have to agree with the adaptions before the adaptions can be performed and a rent increase can be applied. The experiences are diverse, but in general tenants are willing to cooperate with renovations, because the house will be improved. It can be ascertained that a part of the housing associations choose for the individual instead of complex wise improvement, or do not ask for rent increase in order to obtain a smoother cooperation of the tenant.

Strategic stock management is for almost all housing associations leading for determine the complexes which are being renovated in a sustainable way. Thus, the sustainable measures are going to be integrated in that planning. A minority, a quarter of the housing associations, is looking at the features of a house in combination with its affordability and will use that as a base for the type of measurements. (Claessens & Groenland, 2014)

Sustainable renovation projects seem to be considered as high ambitious projects. To find out in what way sustainable renovation projects actually become sustainable, Volker (2011) evaluated 21 leading Dutch real estate renovation projects of which many were developed by housing associations. Therefor the client, consultant, architect and contractor were interviewed. The conclusion was that it is not necessary to have a pre-defined sustainable ambition for realizing a sustainable project. Mentioned is that the ambition developed throughout the project because of the parties involved in the project. Half of the respondents considered preservation and recycling of the building already as sustainable solutions. Volker concludes that sustainable projects seem not to be different than regular projects, so the only question that remains unasked is why not always perform a sustainable renovation. (Volker, 2011)

### 3.5.2. Governmental regulation

In a report written of Companen written by Claessens and Groenland (2014) commissioned by the Ministry of Home Affairs, barriers are determined for the implementation of energy savings in social housing. Research has been performed by interviewing twenty housing associations. From the government regulation, there are hardly barriers for housing associations for energy saving measures. New legislation has little or no influence on the effort to make the housing stock more sustainable. The knowledge of new laws and its estimation of the consequences is an aspect which is not sufficiently available. Therefor it is important to inform and communicate well towards the housing associations. The latter has the challenge to convince the tenants that energetic improvements leads to higher comfort and the same or lower costs, so for the association the approach towards tenants is important, informative as well as communicative. Almost all housing associations follow the Convenant Energiebesparing Huursector though some indicate that the ambitions possibly cannot be achieved in the time limit and that more time is needed. The majority indicates that finance is not the major bottleneck. A minority is concerned about the availability of sufficient manpower to handle the large number of houses that has to be improved energetically. (Claessens & Groenland, 2014)

### 3.5.3. Technical barriers

When is spoken about the technical barriers according to Claessens and Groenland (2014), associations indicate that the house itself is no barrier for sustainable renovation. Three quarter of the housing associations uses proved techniques for current and future sustainable renovation, of this group less than half indicates using more innovative techniques in the past. This reluctance is caused by applying less conventional techniques (Claessens & Groenland, 2014). So Claessens and Groenland wrote in their report that proved techniques are used, Hoppe (2012) states the same: "In practice, conventional energy systems and middle-of-the-road insulation materials are preferred for a number of reasons that are related to different barriers that block the adoption of more innovative and sustainable alternatives." Van Hal et al (2011) agree on this phenomenon of traditional choices: "Housing associations, looking for suppliers and constructors, are cautious and often do not dare to opt for a new party on the market, especially not when that party operates differently to the usual. Often, after a long period of preparation and many meetings, they still chose a traditional party." (Hal, Steen, & Werf, 2011)

According to Hoppe (2012), the barriers for adopting IES (Innovative Energy Systems such as solar heating, heat pumps, geothermal, biomass plants) in social housing is lack of trust between project partners, delay in project progress, financial feasibility considerations, lack of support from tenants, lengthy legal permit procedures, over-ambitious project goals, poor experiences in previous projects, and IES ambitions that are not taken serious by key decision-makers. During the projects that were analyzed, ambitions were high at the start but reduced during the project. Next to that, the research of Hoppe shows that IES is applied more in new construction and less on existing housing, while the major challenge is to concentrate on the current existing housing stock. Another aspect that Hoppe mentions is that local authorities have an initiating role for adopting IES, and become over-ambitious as they concentrate on achieving their political climate goals. This results in little attention for the feasibility of the plans which may lead to distrust of the parties and may be the reason that local authorities tend to lose influence and interest during the projects. (Hoppe, 2012)

## 3.6. Potentials and enabling factors

In this section potentials and enabling factors for the process towards a sustainable housing stock of housing associations are discussed. First the collaboration between the housing association and its target group, the tenants. Then the importance of an integrated sustainable policy is discussed and is described how space can be given for innovation within a housing association.

### 3.6.1. Focus on target group; tenant

Solutions for overcoming the barrier for sustainable renovation are found in different approaches. Claessens and Groenland (2014) see the main challenge for reducing the gap between the housing associations and the tenant, who is sometimes inaccessible and unwilling. Trust of the tenant towards the association is therefore very important and therewith this has to be dealt with on local level and not on government level. In the report of Claessens and Groenland (2014) some options are given that can enhance the progress of improvement of the housing stock. Equivalence in communication and collaboration between the housing association and the tenants or tenants-organization to be able to explain the advantages and consequences of the improvement plans. The way in which uncertainties can be taken away from the tenant is significant, which can be done by using a warranty that the expenses will not increase, or the use of energy coaches. In the report also the option is given that it is conceivable that sustainability of the social housing will be a part of local performance agreements between the municipality and the housing associations. (Claessens & Groenland, 2014)

Groep et al (2012) state that the focus of the renovation concepts should be on the end-user so that the tenant really wants to apply such a concept on their house. Groep et al mention that nowadays the technic solution is the main approach in Dutch and social housing sector, and not the end-user solution on which the focus should be (Groep, Leuftink, Savanovic, & Werd, 2012). From the perspective of the consumers, several studies have shown that for consumers the financial benefits of an energy efficient dwelling is most important, followed by the factors comfort and health. Environmental awareness seems not be valued financially (Groenestein, 2011). Groep et al (2012) state that the benefits for the residents are qualitative better dwellings and lower energy costs, and that the reduction of energy consumption is a gain for sustainable society.

Hoppe (2012) focuses more on the internal factors, and mentions that leadership is very important; a motivated project leader is needed within the housing association who is involved in social networks with interest in adopting Innovative Energy Systems in houses. Next to that, an inter-organizational project group needs to be present throughout the renovation project for continuity and to keep the initial sustainability ambitions on the project agenda. The last measure is aimed to the government; subsidies are required to recoup the extra investments. (Hoppe, 2012)

### 3.6.2. Integration of sustainable renovation

Energy in general is not the reason for energetic adjustments in the existing social housing; in the best case it is taken into account with a renovation. Therefore is not looked at the major steps and is reduction not seen as a recoup of the renovation. The necessary interventions can also be related to other discussed topics such as live ability and shrinkage. Those topics are not taken into account when a strategy is applied which focuses on small energetic improvements. Therefor it is important that housing associations are looking with an integral view to their renovation task. Many associations in the Netherlands are trying to find an answer to identical questions. (SEV, 2012)

### 3.6.3. Innovation space

It is difficult to predict new innovations and techniques and to predict its behavior. It is already discussed that housing associations mostly adapt existing technologies. In the study of Groep et al (2012) the innovation space is described: "According the basis of the Technological Innovation Systems (TIS) theory, innovation space is limited by the actors which are involved by the innovation, institutional boundaries (both formal as informal), technology and relationships and networks in and between networks." (Groep, Leuftink, Savanovic, & Werd, 2012) TIS distinguishes five main structures in the total innovation structure: supply, demand, knowledge, government and intermediary structure (Suurs, 2009). For the study of Groep et al (2012) a sixth structure is added: the housing association structure. This indicates that the housing associations have a very important role, when they are not asking for new applications, no innovation will take place.

To dive into the diffusion and adaption of innovative energy systems, Brand et al (2014) created an integrative framework which explains diffusion of innovations. A part of the framework presents a firms decision making process as a four steps process (Brand, Dieperink, & Vermeulen, 2004):

1. Serious occasion to innovate, and to allow oneself to distract attention for its core business.
2. Perception of technology.
3. Nature of decision making, mainly influenced by the firm's characteristics (procedural culture and organization).
4. Assessment of technology.

Overlap can be seen in this step process and the opinion of Hoppe (2012) that leadership is important; it needs some courage to implement new innovative techniques. Haas et al (2010) mentions that a large number of techniques used for reducing CO2 emission is developed in new construction or from the technique itself. Renovation of existing buildings comes with some specific preconditions which make some techniques less applicable. Implementation of those techniques in a renovation could be at the expense of comfort, energy saving and financial feasibility which can decrease the support of those measurements by decision makers. According to Haas et al it is important for creating innovative renovation to take distance from the conventional techniques and to approach the problem in another perspective. (Haas, Hal, Oel, & Thomsen, 2010)

## 3.7. Expert interviews

In order to obtain some more actual information, interviews with experts are conducted. The interviewees are representatives of institutions and companies which are more or less dealing with the same research topic, the sustainable renovation of the existing houses of housing associations.

The following people have been interviewed:

- Prisca Meesters and Niek Benschop of the Ministry of Home Affairs.
- Constan Custers of the Netherlands Enterprise Agency.
- René van Genugten of Aedes, national association of housing associations.
- Jan Willem van de Groep of Platform31, knowledge and network association of urban and regional development.
- Haico van Nunen of Bouwhulpgroep, advice and architecture.
- Jaap van Leeuwen of Woonbond, national association of tenants.
- Onno van Rijsbergen of Woonbond.

A few questions have been asked to all the interviewees, such as what strategy do you think is best, what do you think of energy neutral houses, what barriers are responsible for the slow process and what solutions do you think is best. In general the goal for every party is the same, energy neutral in 2050 which is agreed on in the Energieakkoord. The main thing is that there is much discussion about the process towards energy neutral and about the strategies that have to be implemented. Important to keep in mind is that the scope of this chapter is on national level. An overview can be seen in Table 7.1 in the Appendix.

### 3.7.1. Regulations and definition

Although the visions on the process towards a higher energy performance differ, everyone agrees on that attention has to be paid on the theme of energy saving measures. Although Van Rijsbergen of the Woonbond questions whether energy neutral is the right goal, and thinks it is more a part of the goal. According to Van Rijsbergen another goal might be a comfortable, healthy and nice house and does an energy neutral house fulfill to those requirements? If not, than it is not a sustainable house and a waste of money.

The Convenant Energiebesparing Huursector applicable till 2020 is created as a milestone in the process towards energy neutral built environment but is assessed as outdated and maybe even a limitation of the process. René van Genugten of Aedes mentions that on one hand the covenant has created awareness, a dot on the horizon and commitment of all involving parties, but that it is outdated and requires recalibration. Van de Groep states that the covenant suggests a limitation that is only looking five years ahead, and that decisions are based on a goal which never should have been a goal, the goal should be energy neutral in 2050. Van Rijsbergen states that the covenant might be a reasonable goal in the perspective of the end goal, but that those goals are not linked to each other which is shortsighted. As a conclusion, the covenant has made the housing associations aware of the energy saving, but might be considered as an outdated goal, insofar there is spoken about a goal.

### 3.7.2. Renovation strategies

When the interviews are being analyzed, three types of renovation strategies towards energy neutral can be distinguished; at once, with big steps, or a multitrack strategy. In general the at once strategy is admired but is not seen as realistic, excluding Van de Groep of Platform31, who is convinced of the strategy to renovate a house at once into energy neutral. Two parties do prefer the at once strategy but mention that it is not possible to apply that strategy on all houses, and therefor state that if the at once strategy is not possible, renovation in two or three big steps is a way to achieve energy neutral. The remaining parties believe that the at once strategy is not the only solution, but state that it is important to perform a multitrack strategy. The multitrack strategy implies that different concepts for different types of houses are applied. Underlined is the difference in associations, in types of houses and types of maintenance. Haico van Nunen of the Bouwhulpgroep states that the at once strategy is suitable for houses where not much maintenance has taken place in recent years, but this is a limited target group. For the vast majority of houses which have had some maintenance, it is destruction of capital when it will be made energy neutral at once. In that case all the performed maintenance and investments will be thrown away. In those cases, it is better to pursue a stepwise strategy. To conclude, the goal is for all parties more or less the same, a more sustainable built environment. Nevertheless the thoughts on the road towards that goal are very diverse.

### 3.7.3. Barriers

On the question what barriers are the cause of the slow progress, very diverse answers are given. Main areas which are seen as barriers are the housing associations with its business and policies, the government with the regulations and subsidies and the techniques for sustainable renovation, mainly because of the investment. All areas will be addressed shortly.

According to Custers of RVO housing associations go back to the core, and therefor want to decrease the operating expenses, decreasing of risks and concentrate on the core business. Van Genugten states that directors of housing associations are the barriers, in addition the financial position, difficult housing types and that regulations do reduce enthusiasm for energy saving. Van de Groep is even more suspicious towards the housing associations. He blames the directors and the organization and speaks of an unconscious incompetence in terms of sustainable renovation. In his opinion associations do think they have to create the solutions by themselves which leads to a configuration of existing solutions. Van de Groep states that in that way innovative solutions are not being created and that is why the investments are still high. A view that is shared by many others is that sustainability is not yet integrated in the policies of associations. Van Rijsbergen agrees on that and addresses the many departments within an organization whereby integration of sustainability is difficult. Van Nunen indicates that the scope a housing association has with its stock, is determinative for the progress of sustainable renovation, it is difficult to look beyond 20 years. Technically there are many possibilities, but the conditions determine whether a house will be renovated in a sustainable way. Van Nunen addresses the difference in regulation for the at once strategy and the stepwise strategy; the same goals are pursued but only for the at once strategy regulations are adapted and not for the stepwise strategy. For the at once strategy, housing associations can figure as an energy supplier and therefor manage to finance the renovation without a high rent increase. This leads to the second area that is addressed as a barrier, the government with its regulations. Some mention that the government is not facilitating in the right way, that legislation is prescribing and not conditioning, that there is thought in restrictions instead of opportunities. Thought can be of the Property Tax (verhuurdersheffing) which implied that housing associations had to pay a certain amount of money in relation to their housing stock which resulted in less attention and financial possibilities for sustainable renovation. Next to that, some argue that the overview is difficult to control; sometimes previously set resources or subsidies by the government are rejected, which can cause troubles in a long term renovation strategy.

### 3.7.4. Solutions

Because interviewees have different opinions about the strategies and barriers, several solutions are given from different perspectives. For the housing associations it is considered to be important that energy saving is being integrated in the strategic stock management and thus becomes an integrated factor instead of an additional factor. In other words as Van Leeuwen of the Woonbond states, long term strategies for the housing stock towards energy neutral have to be made by the housing associations. Meesters and Benschop from the Ministry state that collaboration of parties is important and expect much from the innovation of techniques. Van de Groep states that the building sector has to be challenged to achieve innovation and industrialization in order to make the at once renovations more affordable. Therefor it is important that the government sets regulations that condition and not prescribe. Van Rijsbergen states that techniques can be applied standardized, but that it is impossible to apply standardized concepts. Therefor he argues that it is important to involve the residents in the process and that it is also important to take the location into account due to demographical and geographical differences. Think of shrinkage regions, or areas which have many possibilities for renewables. Van Nunen states that it is not important to look at how a house can be renovated, but the main question is how to apply the renovation concepts, and how can be guaranteed what is promised. To make an energy neutral house work, the behavior of the tenant is important; therefor emphasis should be placed on dealing with residents. To conclude, solutions are found in organization of housing associations, legislation of government, and the innovation of builders and the behavior of tenants. Different approaches are applied, one looks at the physical home and lets residents' behavior omitted while the other acts particularly from the interests of the resident.

## 3.8. Conclusion

The information gathered from the interviews is broadly in line with what is mentioned in the literature. Interesting is that the interviewees refer to very different barriers and solutions, which can be owed to the interests of each interviewee and its organization. In this conclusion the information from the literature review and the interviews is merged in order to obtain one clear image.

Energy neutral as a goal is difficult to describe, one general definition is lacking. Concluded can be that housing associations have to define for themselves what energy neutral exactly implies, particular the level of energy neutral; parcel- neighborhood or city level.

The renovation strategies that are defined in researches differ in small aspects. In general three strategies are defined; at once, stepwise with a predefined goal or stepwise with ad hoc decisions.

Looking more at the process of the sustainable transformation of the current housing stock, can be concluded on the basis of the average energy-index of the Dutch housing associations that the process is going to slow. The milestone of the Convenant Energiebesparing Huursector at the end of 2020 seems not to be feasible, not even spoken about the overall goal of the Energieakkoord, an energy neutral built environment in 2050. In Figure 3.6 an

Ishikawa diagram can be seen that visualizes which factors are influencing the process as it is now, based on the literature research and the performed interviews. An Ishikawa diagram can help to understand the main problems and relations between different factors. Relationships between cause and effect can be indicated (Enarsson, 1998).

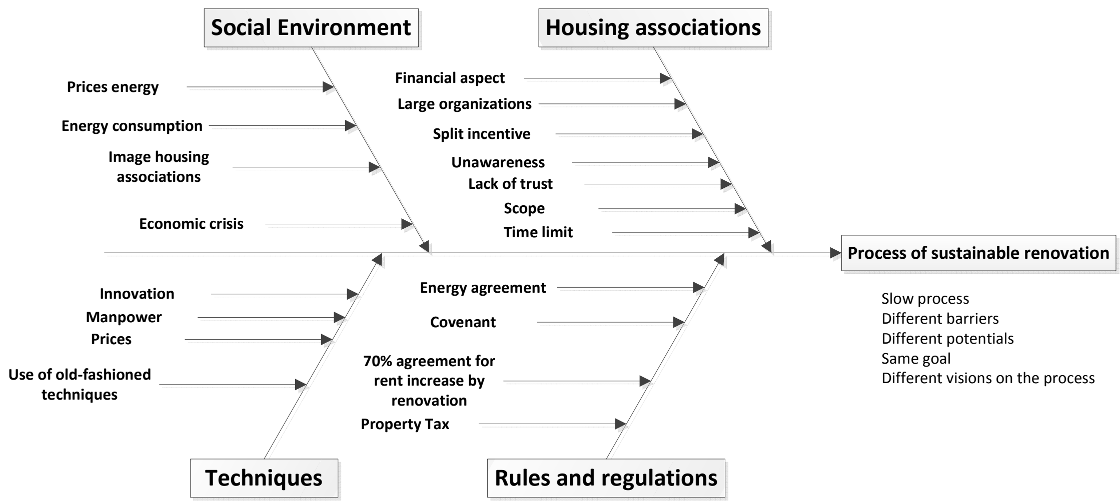


Figure 3.6: Ishikawa process of sustainable transformation

The Ishikawa is divided into several themes which are considered as the main influencing factors for how the current process of the sustainable transformation is going; rules and regulation, techniques, environment and the housing associations. Each factor has subdivided factors which will be discussed in this section.

*Housing associations*

Logically, the housing associations are seen as a large influencing factor for the process of the sustainable renovation, they are the decision makers for implementing certain renovation procedures. Most housing associations are large and therefor it might be difficult to realize major changes in the daily routine. Next to that, some managers of housing associations do have a lack of trust in partners and or techniques, and therefor choose for existing options instead of innovative and new techniques. All this in combination with the scope used by housing associations, results in a relatively short-sighted approach on how to make the housing stock more sustainable and therefor short-term decision are made. Another aspect is the balance between the split incentive and the rent; when the housing association wants to recoup some investments via a rent increase, caution must be taken in order to not exceed the maximum rent price of 710 euros.

*Rules and regulations*

The Energieakkoord (Energy Agreement) and the Convenant Energiebesparing Huursector defined by the government have made the housing associations aware of the need to make the housing stock more sustainable. On the other hand, some regulations have forced the housing associations to adapt their focus. Thought can be of the Property Tax which implied that housing associations had to pay a certain amount of money in relation to their housing stock which resulted in less attention and financial possibilities for sustainable renovation.

*Social environment*
External aspects are classified in the theme environment. A large influencing factor is the economic crisis which stopped more or less the innovation in the construction sector. Next to that, the image of the housing associations was not that good because of some incidents within organizations. This has led to distrust in the sector.

*Techniques*
As discussed in chapter 3.5.3 housing associations are eventually inclined to choose for existing and traditional techniques instead of new innovative techniques. Reasons for those decisions are lack of trust in partners, financial feasibility considerations and lack of support from tenants. The construction sector is currently challenged to come with more innovative solutions as happens in the Stroomversnelling, a project of the Energiesprong in which construction firms and housing association collaborate to make existing houses energy neutral at once.

All the themes lead to the conclusion that the same overall goal is being achieved, a more sustainable built environment which is energy neutral in 2050. Nevertheless the thoughts on the road towards that goal are very diverse. The interviewees point out very different barriers and see solutions in different areas from different perspectives. As a result, different renovation strategies are used what can lead towards inefficiency and indistinctness towards housing associations which can result in wrong strategic decisions on the long term. As literature has revealed that housing associations prefer to choose for traditional techniques, large steps towards an energy neutral built environment are not made. In chapter 4 "Consequences of a renovation strategy for a housing stock of a housing association towards energy neutral. ," three of these renovation strategies are examined in order to provide insight in the consequences toward energy neutral in 2050.

# 4. Consequences of a renovation strategy for a housing stock of a housing association towards energy neutral

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**Abstract**
Housing associations are facing the task to renovate their housing stock in a sustainable way. Goals for achieving a certain energy performance of the housing stock are set with the "Convenant Energiebesparing Huursector" which is a part of the "Energieakkoord". As concluded in the Chapter 3 Literature Review "An analysis of the sustainable renovation process of the existing housing stock of housing associations towards energy neutral," the process of the sustainable renovation of the existing housing stock of housing association is going too slow. In the same report is concluded that all concerning parties do have the same overall goal, but that there is disagreement about what renovation strategy towards that goal is best. Therefor the aim of this research is to provide insight in the consequences of a renovation strategy in order to determine what the best strategy for a housing association is. Three generic renovation strategies have been determined; regular maintenance, stepwise and at once. According to the Trias Energetica these renovation strategies have been created and applied on the dataset of a housing stock of a carefully selected housing association that represents a general Dutch housing association. Conclusions are that with regular maintenance no energy neutral housing stock can be achieved without discarding previous investments. The stepwise or at once strategies both achieve an energy neutral housing stock, the latter one is more expensive but achieves a higher energetic score. This at once strategy requires high investments in the start phase but brings also immediately the advantages of lower energy costs. The stepwise strategy has two moments of investments what can give the advantage of implementing innovative and more efficient techniques. For the selected case study the stepwise strategy is most suitable, the at once strategy is not yet a good alternative because of the higher costs. The best solution in general depends on the financial situation of the housing association, point is that these organizations do need to determine a goal and a strategy on the long term; a short-sighted approach results in short-term decisions which can be obstructive on the long term with the result that an energy neutral housing stock cannot be achieved.

**Keywords:** Housing associations, sustainable renovation, energy-index, Vabi, trends techniques.

## 4.1. Introduction: Renovation process housing association sector

Housing associations are challenged to make their housing stock more sustainable due to governmental regulations. A part of the Energieakkoord (Energy Agreement) is that the built environment has to be energy neutral in 2050; therefore a rigorous transition of the built environment lies ahead with improving the energy performance which ensures a durable relation with the environment. A milestone specific for the housing associations is set at the end of 2020 with the Convenant Energiebesparing Huursector, which requires that housing associations have to achieve an average energy label B (Haytink & Valk, 2013). The process to be able to fulfill those set requirements is going slow and therefor acceleration is needed to improve the effect of sustainable renovations.

This research provides insight into the consequences of a chosen renovation strategy. Three renovation strategies are defined and compared on several aspects such as energetic improvement and financial aspects. The strategies are applied on an existing housing stock of a housing association, selected to be representative for a Dutch housing association. Therefor a generic approach is maintained to examine what the effect is of a renovation strategy for the whole housing stock, so no distinction is made in housing types.

First is described in chapter 4.1 what approaches of sustainable renovation in general are used. In chapter 4.2 the research design is explained, as well as the renovation strategies, the data selection, the software, how the renovation measures are converted into strategies and how other factors can have influence. In chapter 4.3. the results are described after which in chapter 4.4 a conclusion and discussion is given, followed by some recommendations for further research.

#### 4.1.1. Approaches sustainable renovation housing associations

So the goal of the Energieakkoord is an energy neutral built environment in 2050. This vision encounters for the housing stock of housing associations three routes which are determined by Haytink and Valk (2013); stepwise, at once or extern. An extra route can be determined because the latter can also be applied in steps. These scenarios are illustrated in Figure 4.1.

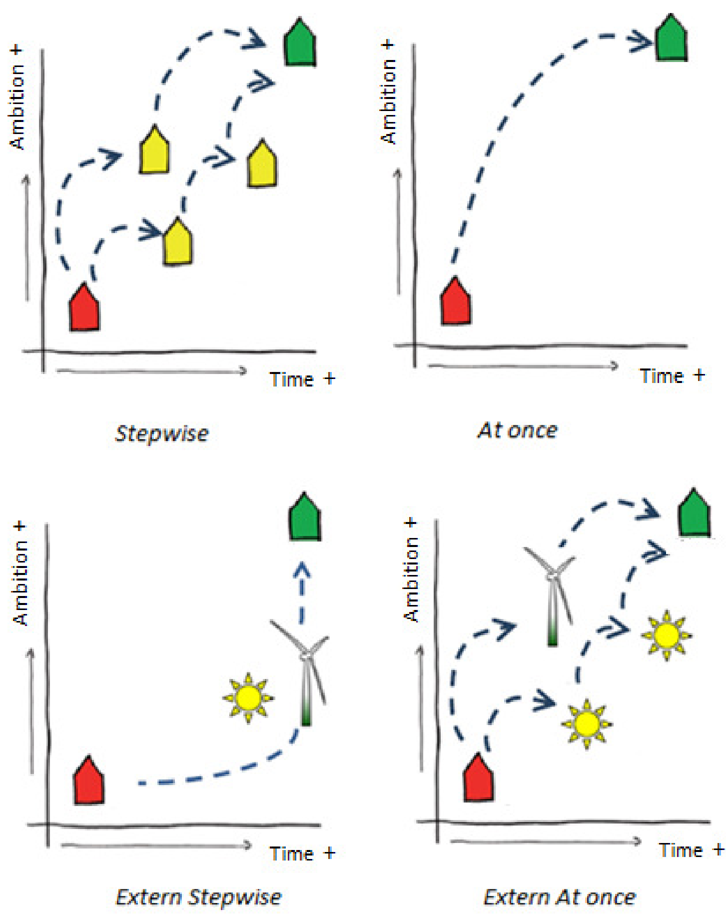



**Figure 4.1: Approaches for sustainable renovation (Haytink & Valk, 2013)**

The first scenario 'stepwise' is based on the principle of backtracking from a long term perspective to now. With backtracking insight can be given for what steps are needed for achieving a certain goal. With this scenario it is possible to make the housing stock as a whole to the same level of energy neutral. With the second scenario 'at once' certain complexes are brought to energy neutral at once. The third scenario 'extern stepwise' is characterized by using territorial energy saving measurements, for instance a windmill or another extern source. The fourth scenario is the same as the third, but then with smaller steps, for instance smaller windmills or a number of PV-panels. The first two scenarios are applicable on complex level or house level, the third and fourth are focused on the area in which the houses are located. In this research is focused on the house as a physical object which has to be renovated, therefor scenario three and four are not taken into account because that is not specific related to the house but to the surroundings. The different approaches can be distinguished as displayed in the matrix in Figure 4.2.

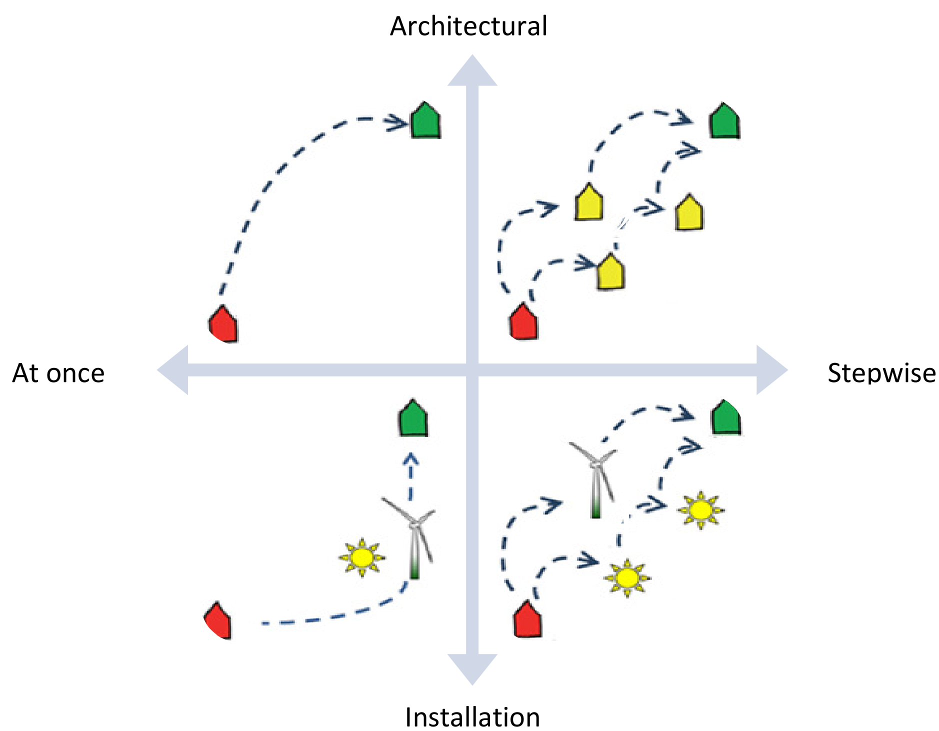



Figure 4.2: Matrix approach

Distinction can be made in whether the measures are executed at once or stepwise, and whether the focus is on the house as an architectural physical building (e.g. insulation) or on the installations (e.g. PV-panels). The at once approach that focuses on the house can be placed at the top left, the at once strategy at the top right. The external approaches at once and stepwise can respectively be placed at the bottom of the matrix, respectively left and right.

### 4.1.2. Approach of sustainability: Trias Energetica and Urgenda.

The Trias Energetica is a common approach for sustainable renovation and is shown in Figure 4.3.

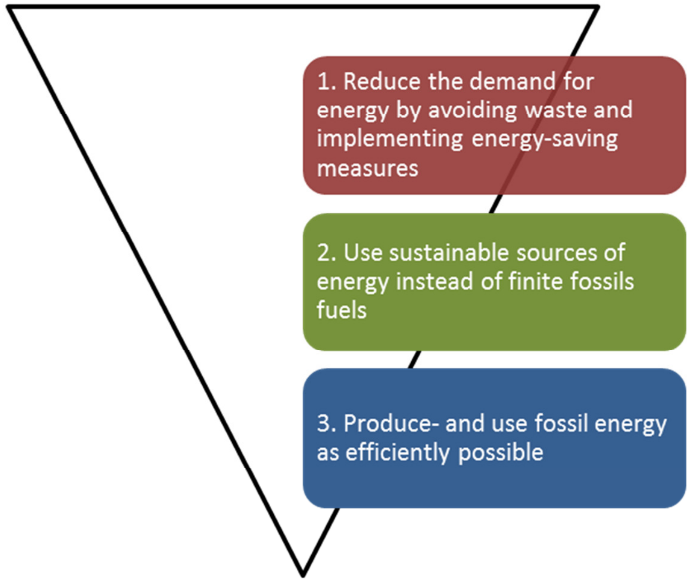



Figure 4.3: Trias Energetica (Eurima, 2015)

The first step is to reduce the demand for energy by avoiding waste and to apply energy saving measures. The second step is to use other sustainable sources for energy, for instance installations such as PV panels. If not enough sustainable energy can be generated or used, the last step is to use as few as possible of fossil energy. Distinction can be made how the Trias Energetica is used in practice, which is made visual in Figure 4.4. .

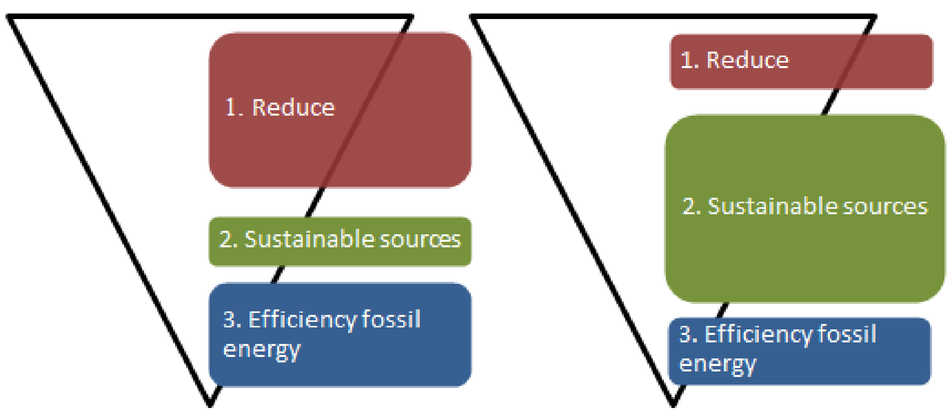



Figure 4.4: Trias Energetica: Single family house (left), Multifamily house (right)

For renovation of single family houses it seems to be more common to focus on step 1 of the Trias Energetica by applying insulation measures whereby a large decrease of the energy use can be achieved. For multifamily houses such as apartments this seems more difficult and a solution is most of the times found in applying installations which can be used by all the houses in the building, thought can be of a collective heating system. Applying insulation is more difficult with a multifamily house because of the difficulty of renovate a whole apartment building as well as the nuisance it can give to the tenants. In those situations the focus is more on step two of the Trias Energetica. Referring to the matrix discussed in chapter 4.1.1, these approaches of the Trias Energetica can be placed in that matrix. In Figure 4.5 these approaches of the Trias Energetica are placed in the matrix.

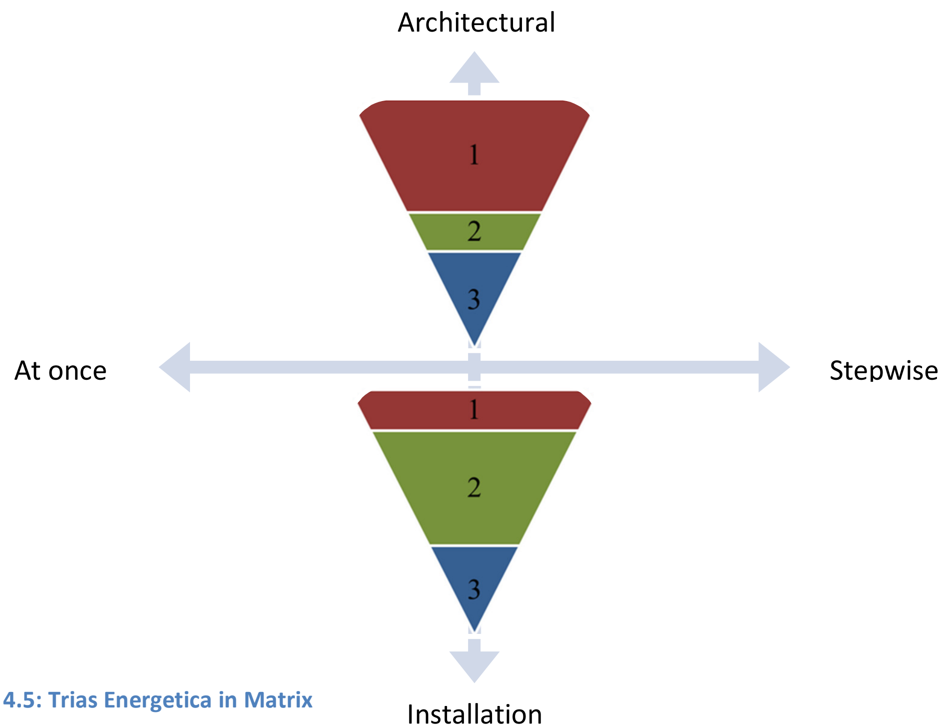



Figure 4.5: Trias Energetica in Matrix

On top the focus on the characteristics of the house and at the bottom of the matrix the focus on the installations. Both approaches can be applied at once or stepwise, that is why the figures are placed in the middle of the horizontal axis. Urgenda, a platform for innovation and sustainability, shows that an energy neutral house can also be achieved by only using installations so without any energetic adjustments to the house (Urgenda, 2015). Such a house should be placed in the left bottom of the matrix in Figure 4.5. In the report published by Urgenda several options and installations are described which prove to be energy neutral, the focus is mainly on step 2 of the Trias Energetica, the use of sustainable sources. In this research the approach of the renovation strategies is mainly focused on the original Trias Energetica, therefor the first step is always to reduce the demand for energy by applying energy saving measures.

### 4.1.3. End goal

The end goal is to have an energy neutral built environment in 2050, for housing association this means an average energy neutral housing stock. According to the old label method this corresponds with label $A^{++}$ or higher, which can be translated to an energy-index smaller than 0,6 (Rijksoverheid, 2015). Energy neutral in this case means that the house uses almost no energy. The division of the energy-indexes is shown Table 4.1.

Table 4.1: Energy-index (Rijksoverheid, 2015)

| Label | Energy-index |
|---|---|
| A++++ | < 0,21 |
| A+++ | 0,21-0,41 |
| A++ | 0,41-0,60 |
| A+ | 0,61-0,80 |
| A | 0,81-1,20 |
| B | 1,21-1,40 |
| C | 1,41-1,80 |
| D | 1,81-2,10 |
| E | 2,11-2,40 |
| F | 2,41-2,70 |
| G | > 2,70 |

## 4.2. Method: Applying renovation strategies on case study

This section describes in detail how the study was conducted. Chapter 4.2.1 describes the research design after which the renovation strategies for a housing association is described more in detail. A renovation strategy consists of several renovation measures. Timespans are linked to those strategies in chapter 4.2.3. Subsequently, the renovation measures are explained. In chapter 4.2.5. the selected data is argued and described after which some information is given about the software that is used. Then the renovation measures are described and the corresponding scenarios in respectively chapter 4.2.7 and 4.2.8. In chapter 4.2.9 the external effects that can influence the process of sustainable renovation is addressed. In chapter 4.3 the results are discussed, after which is finished with a conclusion and discussion in chapter 4.4.

### 4.2.1. Research Design: Flowchart

The research is structured as can be seen in Figure 4.6. Renovation measures have been determined in collaboration with Atriensis which are implemented in renovation scenarios. These scenarios are applied on the database of 3062 houses in the Vabi software. Those results are inserted in an Excel document together with the costs of the measures and installations. Next to that, external influencing factors are defined. Combining these external factors with the results of the renovation measures provides insight in the possible consequences of a renovation strategy.

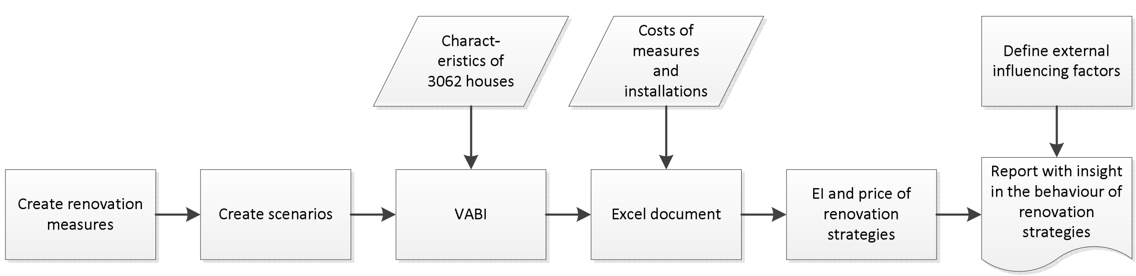



Figure 4.6: Flowchart

### 4.2.2. Renovation strategies

In the research three renovation strategies are examined for renovations which are considered to be representative as currently used strategies. In this chapter the renovation strategies that are defined in chapter 3.4.2 are described briefly which are used as a base for the research.

#### *4.2.2.1. 1: Regular maintenance*

Implementing this strategy implies to continue with the regular maintenance activities, and when a measurement will be applied, it will be performed on a higher level than normal. This renovation strategy can be seen as how housing association are currently working, a goal is set on the short term for which measures will be applied, sometimes more extensively. Eventually, it might be the case that some applied measures in a later stadium seemed to be unwise and a waste of capital. For example, when all the single glazing is replaced by double glazing in 2020, and when as a result of a new strategy in 2030 all the facades will be renewed together with the replacement of the window frames with triple glazing, the investment in 2020 was unnecessary. An example of such a strategy is displayed in Figure 4.7.

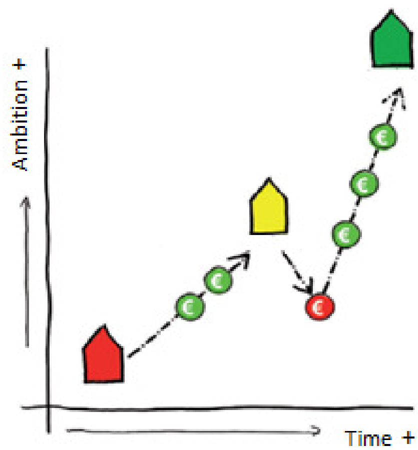



**Figure 4.7: Regular maintenance (Haytink & Valk, 2013)**

#### *4.2.2.2. 2: Stepwise*

The strategy of big steps implies that the energy neutral goal will be achieved in two or three steps. At those renovation moments, large elements of the house are improved, thought can be of a new roof, façade insulation or new installations. In this strategy the steps are determined with the end goal as a starting point, on which the steps are based.

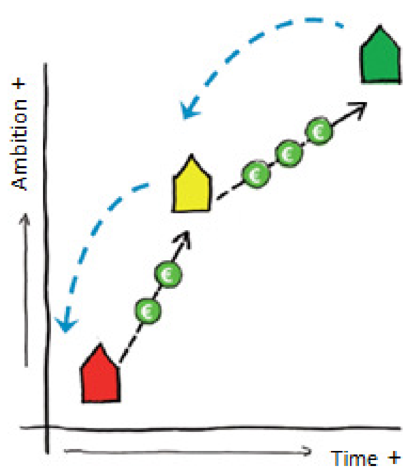



**Figure 4.8: Stepwise (Haytink & Valk, 2013)**

### *4.2.2.3. 3: At once*

In this strategy the house is made energy neutral in one renovation. Energetic measurements are applied on the house which can last till 2050. These measurements are in some cases that extensive, that is chosen for a prefab construction which is made in a factory and can be assembled on the house.

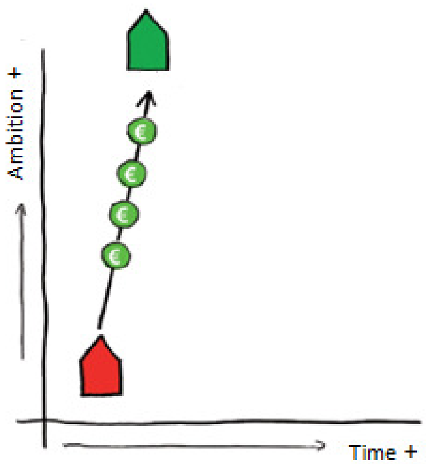



**Figure 4.9: At once (Haytink & Valk, 2013)**

An example of applying this strategy is the Stroomversnelling, which is an agreement between several parties to make at once renovations possible. An example of the result of such a collaboration can be seen in Tilburg, where housing association Triwos and constructor Ballast Nedam have transformed a row house of the fifties into a zero on the meter house. This means that the house is energy neutral when is looked to the meters that measure how much electricity and gas is used. This pilot house has been transformed in one and a half week, but this term will be shortened to five days. An example of such a house can be seen in Figure 4.10.

**Figure 4.10: Example at-once strategy house in Tilburg (Energiesprong, 2015)**

After the renovation all the required energy is generated by the heat pump and the solar panels. Gas is not needed anymore and this connection can be closed. The following measures have been applied (Energiesprong, 2015):

- Good insulating façade elements
- New windows in the facade elements with triple glazing
- Well insulated crawl space below the floor
- New insulated attic floor
- New roof with 27 solar panels
- Installation unit in the attics.
- Heat pump with ground source

Looking at the costs, the Energiesprong indicates that the average renovation price is 60.000 euros per house if the scale benefits are taken into account. When these benefits are not included, it will cost 80.000 (Elp & Hardeman, 2013)

### 4.2.3. Decisions for renovation; timespan of measures

Haytick and Valk (2013) determined four different decisions outcomes for what to do with a house. These outcomes define different scenarios which are listed in Table 4.2. The scenarios differ per house whether there are plans for upgrading or demolishing the house. Because in this research a general approach will be used for examining the best strategy for a housing association, no distinction will be made between the different types of housing or complexes. More explicit, the scenarios will be applied on the whole housing stock and not on specific parts. The link between the research of Haytink and Valk and this research is that the time periods are used as a condition in the renovation strategies which will be defined in chapter 4.2.8.

**Table 4.2: Decisions for renovation with timespan**

| Decisions (Haytink & Valk, 2013) | Term (years) | In this research |
|---|---|---|
| **Delayed decision** | 15 | 1. Regular maintenance |
| **Life extension** | 25 | 2. Stepwise |
| **New start** | 50 | 3. At once |
| **Demolish and built new** | 0-10 | Not taken into account |

The first decision that Haytink and Valk distinguish implies that the decision will be delayed; at that moment no decision is made to demolish the house or to improve it extensively so it can last for a long time. Measurements are applied for making it possible to exploit the house fifteen more years after which a new decision will be made. In this research, renovation strategy 1 is based on this decision and time period, regular maintenance with some measures will be applied because it is not totally clear what the overall plan is with the house.

Extend the lifespan of the house is the second decision that is determined by Haytink and Valk. The quality has to be equal to houses built in 1985-1990, of which the exploitation term started 20-25 years ago. This is more or less equal to a renovation towards energy label B or higher. In this research this decision is used as a base for the renovation strategy 2, the stepwise renovation strategy. The plan with the house is clear, the lifespan has to be lengthened extensively and in 25 years a new decision will be made for what measures will be applied. In this research is chosen for that when a part is renovated, it will be done in an extensive way.

A new start is the decision that Haytink and Valk have determined for houses that will be extensively renewed so that a new exploitation term can be started of 50 years, energetic will be strived for a label A++ or higher. In this research this is the base for the renovation strategy 3, at once which is described in chapter 4.2.2.3.

Last, Haytink and Valk have determined the decision to demolish the house for which a new house will be built. The new house should fulfill the requirement to be energy neutral, in this way the average energy performance of a housing association can be drastically improved. This scenario will not be taken into account in this research, because the focus of this research is on the renovation of existing houses, assuming that all existing houses will be needed now and in the future.

### 4.2.4. Measures for sustainable renovation

The measures for sustainable renovation can be categorized in two categories as already discussed in chapter 4.1.1 using the matrix; architectural measures and installations. Improving the energetic quality of a house with architectural measures implies improving houses' characteristics; floor, façade and roof. When is spoken about installations it concerns heat pumps, ventilation system, solar water heater and PV-panels. Notable is that some aspects are related, in technical and as in a user friendly way. In technical way; for example renewing the façade implies as well renewing the window frames. When the new façade is thicker than before due to insulation, the roof may be too short and has to be adapted. The other way around might be possible, than the roof protrudes slightly, later a new and thicker façade can be applied.

Another important aspect is the user friendliness of the measures, a renovation or maintenance measure can provide much nuisance for the tenant. For instance, applying wall insulation on the inside of the house means much nuisance for the tenant, furniture has to be moved as well as construction workers have to work in the house for a certain period. Applying insulation external means much less nuisance, the tenant does not have to remove its furniture for instance. The aspect of nuisance is important for the tenant, but there is a balance in what situations a tenant does accept the measures or not. A tenant wants to have a comfortable, healthy and affordable house in a good neighborhood. When a renovation measure will enhance one of those criteria, a tenant might be more willing to cooperate and will accept the nuisance it might bring. For instance, applying a new façade with new window frames will lower the energy costs and will give the house a new and fresh appearance which is in favor of the tenant and the neighborhood.

In this research is chosen to compose the renovation strategies with the measures that are currently applied. The technical and user-friendly relations are taken into account.

### 4.2.5. Data selection: Representative housing association

In this section the selection of the case study will be described in order to investigate the effect of a chosen renovation strategy. Three approaches can be used for examining the main topic of this research, investigation the whole Dutch social housing stock, just one housing association, or investigation by using reference housing types. In

Table 4.3 the pros and cons can find for each type.

**Table 4.3: Pros and cons different approaches**

| | Dutch stock social housing | Housing association | References |
|---|---|---|---|
| **Scale** | 2,4 million houses | 3000/4000 houses | 4 housing types |
| **Pros** | General | Data available via Atriensis<br>Realistic | Feeling with the house<br>Specific |
| **Cons** | Difficult to obtain data<br>Time extensive | | Too technical and specific |

For this research has been chosen for examining one house association and applying the renovation measures over the total housing stock because this is considered to be most useful for a housing association and will contribute most to this research.

For providing a realistic insight in the behavior of the chosen renovation strategy, a case study in the form of a housing association has to be analyzed which is representative for social housing in the Netherlands. Because of the time frame in which this research has to be performed, analyzing the national stock as a whole would be comprehensive. Therefor is chosen for obtaining the data of a housing association which represents the Dutch social housing sector. Preferred requirement is that this housing association is in management of Atriensis so that the data is already available and no time is wasted obtaining it. The selected housing association has to represent a typical Dutch housing association and therefor has to satisfy several requirements. First, the size of the housing association has to be approximately between 4000 and 6000 houses. The number of houses per housing associations is very diverse, the average number of houses is around 6000 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2014). In Figure 4.11 is the number of housing associations displayed by size, so there are five housing associations which manage less than 50 houses.

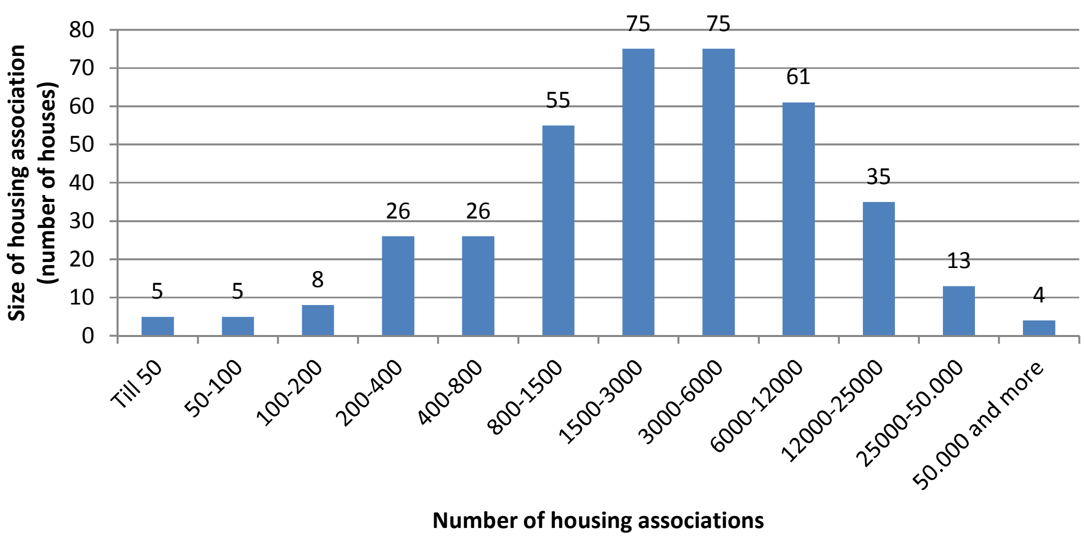



**Figure 4.11: Size of housing associations (Rijksoverheid, 2011)**

Though the software in which the calculations will be made might work faster with fewer houses, a housing association with 3075 houses is selected. Thirteen houses have been deleted because of missing characteristics, which results in a database of 3062 houses. This number of houses is lower than the average of 6000, but looking at Figure 4.11 it is representative for a Dutch housing association because there are many associations with a comparable size. The year of construction of the total housing stock of the Netherlands and the housing stock of the selected housing association is divided as can be seen in Figure 4.12.

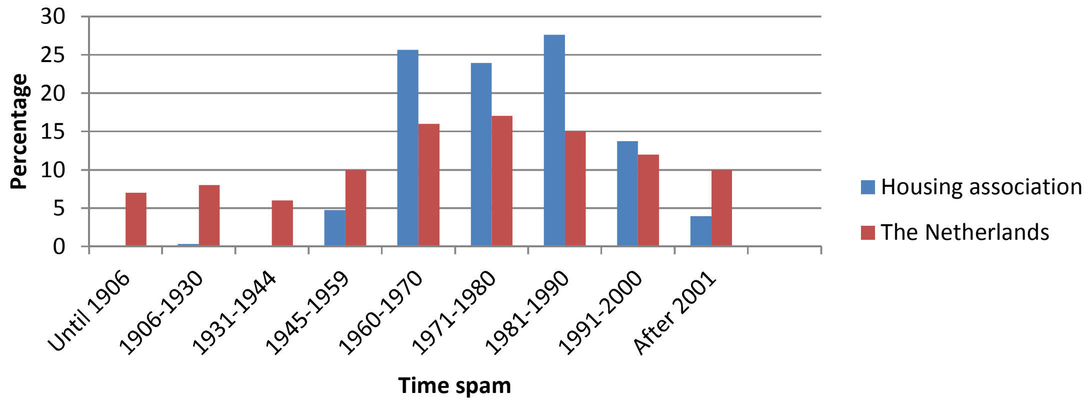



**Figure 4.12: Year of construction**

As can be seen, the year of construction of the housing association is newer than average in the Netherlands, but the ratio is quite the same and most houses have been built in the sixties, seventies and eighties. The average construction year of the housing association is 1979. In order to examine a housing association that is representative the structure of the housing stock is important. In general distinction is made between single-family and multifamily houses. Single-family houses refer to houses that have an own roof, for instance detached houses or terrace houses. Multifamily houses refer to houses that have a collective roof, for instance apartments. The distribution of single family homes and multifamily houses in the Netherlands is respectively 71 and 29 percent. In the social housing sector this distribution is the opposite, assumed is that the percentage of multifamily houses is almost 60 percent and the single family houses thus 40 percent (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2013). For the selected housing association, the division of single family houses and multifamily houses is respectively 46 and 54 percent, which is comparable with national standards. In Table 4.4 a division can be seen of the housing types of the housing association.

**Table 4.4: Type of houses of database**

| Division of types of house | |
|---|---|
| **Detached house** | 13 |
| **Semi-detached house** | 37 |
| **Terraced house** | 712 |
| **End of terrace house** | 865 |
| **Multifamily house with one floor** | 1422 |
| **Multifamily house with more floors** | 13 |
| **Total** | 3062 |

A detached house stands on its own and has no direct connections with other houses or buildings. A semi-detached house is attached to one other house. A terraced house is part of a row of houses that are joined together. Multifamily housing stands for a building in which several separate housing units are collected, for example apartments or studios. Distinction is made between multifamily houses with one or more floors. Looking at Table 4.4 most houses concern a multifamily house, mostly with one floor. The other 46 percent of single-family houses consist mostly of terraced houses; the number of detached and semi-detached houses is relatively small.

The energy-index has to be in the same range as the average energy-index of Dutch housing associations which is 1,65 and represents label D according to the old calculation method (Aedes, 2015). In the new methodology label D corresponds with an energy-index between 1,8 and 2.1 (Rijksoverheid, 2015). The energy-index of the selected housing association is 1,69 according to the old methodology and 2,1 according to the new, so the selected housing association is representative for an average Dutch housing association. Thus, one house can have different energy-indexes according to the old and new methodology. When in the following chapters is spoken about the energy-index, it is concerning the new methodology.

### 4.2.6. Software: Vabi Assets Energie

Vabi Assets Energie is the software that is used for examining what influence certain renovation strategies have on the energy-index of the housing association. Vabi Assets Energie is a software program that can help housing associations with energy policies. The software is a solution for managing energy-indexes, and can be used for determining a strategy for sustainable renovation based on energy saving measures. (Vabi, 2015)

In Vabi the housing stock of the selected housing association is inserted with all its characteristics, thought can be off: construction year, housing type, roof type and surface, ventilation/heating/water system, sun boiler, PV-panels, insulation and types of window frames. Next to that, the defined renovation strategies with its measures can be inserted as well and can be applied on the total housing stock. In this way can be discovered what the effect is of the renovation strategy on the characteristics of the housing stock. In the following sections is described carefully what executions are done with VABI.

### 4.2.7. Renovation measures

In order to examine how renovation strategies influence the housing stock, specific requirements have to be made which can be implemented in Vabi. In Vabi individual measures can be created with use of rules. For example, a rule can be set for a wall that when there is in the current situation no insulation or the insulation is below a certain Rc-value, it has to be upgraded and renovated towards a higher value. An Rc-value indicates the heat insulating capacity of a construction (Kort, 2008). Table 4.5 shows the boundaries which are set for upgrading an aspect of a house and show to what extend upgrades will be applied.

**Table 4.5: Boundaries Rc-values**

| | Before 1992 (Atriensis, 2015) | New building code (Nieman, 2014) |
|---|---|---|
| **Floor** | 2 $m^2K/W$ outside (1.3 ground) | 3,5 $m^2K/W$ |
| **Façade** | 2 $m^2K/W$ | 4,5 $m^2K/W$ |
| **Roof** | 2 $m^2K/W$ | 6,0 $m^2K/W$ |

In this research has been chosen to consider everything below an Rc-value of 2 as insufficient. An Rc-value indicates the thermal resistance of a construction, the higher the Rc-value the better the thermal insulation (Ek bouwadvies, 2015). The argumentation for this value is that in 1992 the building code (Bouwbesluit) was introduced, and that before that period the Rc-value was 2,0. In other words, all what is built before 1992 is considered to be renovated and energetically improved (Atriensis, 2015). This higher level is based on the building code for new constructed buildings which is implemented in the beginning of the year 2015 (Nieman, 2014). This value is considered to be the target line that housing associations currently pursue.

The measures that are determined are based on Rc-values, these measures are listed in Table 4.6. The Rc-value which indicates in what extend a part has to be upgraded might differ from the predefined requirements due to limitations of Vabi. In some cases has to be chosen from existing values that are predefined in Vabi.

Table 4.6: Renovation measures

| Measures for renovation | | Old | New |
|---|---|---|---|
| **1** | Insulate floors with little or no insulation | Rc<2 | Rc=3,71 |
| **2** | Insulate flat roofs with little or no insulation | Rc<2 | Rc=6 |
| **3** | Insulate pitched roofs with little or no insulation | Rc<2 | Rc=6 |
| **4** | Insulate walls with little or no insulation, indoor or outdoor | Rc<2 | Rc=4,5 |
| **5** | Insulate cavity walls with little or no insulation | Rc<2 | Rc=4,5 |
| **6** | Insulate panels | Rc<1,29 | Rc=4,5 |
| **7** | Insulate cavity wall panels | Rc<1,29 | Rc=4,7 |
| **8** | HR++ glazing for single glazing or glazing with U>5 | U>5 | - |
| **9** | Triple glazing for all other types of glazing or glazing with U>1,75. Replace all windows | U>1,75 | - |
| **10** | HR107 boilers in individual and collective systems | - | - |
| **11** | Heat pump electric in all individual systems, outside air, auxiliary gas HR107 | - | - |
| **12** | Ventilation: Mechanical exhaust, CO2-controlled individual ventilation, DC (Direct Current) | - | - |
| **13** | Sun boiler | - | - |
| **14** | 12 PV-panels (19,2m2) | - | - |
| **15** | Insulated door | - | - |
| **16** | 27 PV-panels (43,2m2) (Stroomversnelling) | - | - |

These measures are concerned to be all the energetic renovation measures that housing association choose nowadays. Each measure is applied on the case study individually with the use of VABI. VABI calculates in what extend each measure must be applied in units. In this way is clear to what extend each measure is applied on the houses in the dataset and can later on be calculated what the expenses of a certain measure. The results can be seen in Table 7.2, the energy-index improvement per measure can be seen, as well as the number of applications and how many units are needed. By multiplying the number of units with the costs of a measure, the costs of a renovation strategy can be calculated. The costs of measures are based on benchmark numbers of Atriensis and can be found in Table 7.3 in the Appendix.

### 4.2.8 Renovation strategies

The renovation measures have been converted into three renovation strategies which will be applied on the whole housing stock of the selected housing association. The renovation strategies consist of packages that are related to certain moments in time. It must be emphasized that these renovation strategies are based on previous research and assumed to be quite common for Dutch housing association. More strategies are possible which will lead to much diversity but also to obscurity. The three determined renovation strategies are considered to be representative for the way of working nowadays and can be seen as a summary. These renovation packages are also applied on the housing stock in VABI. In this way the energy-indexes are generated which show the effect of a renovation package. The results of this will be discussed in chapter 4.3

The first renovation strategy is based on the principle as discussed in 4.2.2.1; regular maintenance with the corresponding timespans as described in 4.2.3. Three rounds of interventions are described which are listed in Table 4.7. In the first column the renovation packages are given with the moment of execution. In the second and third column the measures are listed which are the part of the packages. The fourth column shows the Rc-values which determine when a measure will be applied and if a measure will be applied it will be upgraded to the Rc-value that is showed in the last column.

**Table 4.7: Renovation strategy 1: Regular maintenance**

| Package | Measure | Description | Old | New |
|---|---|---|---|---|
| **1.1: 2020** | 1 | Insulate floors with little or no insulation | Rc<2 | Rc=3,71 |
| | 8 | HR++ glazing for single glazing or glazing with U>5 | U>5 | - |
| | 10 | HR107 boilers in individual and collective systems | - | - |
| **1.2: 2030** | 2 | Insulate flat roofs with little or no insulation | Rc<2 | Rc=6 |
| | 3 | Insulate pitched roofs with little or no insulation | Rc<2 | Rc=6 |
| **1.3: 2040** | 4 | Insulate walls with little or no insulation, indoor or outdoor | Rc<2 | Rc=4,5 |
| | 5 | Insulate cavity walls with little or no insulation | Rc<2 | Rc=4,5 |
| | 6 | Insulate panels | Rc<1,29 | Rc=4,5 |
| | 7 | Insulate cavity wall panels | Rc<1,29 | Rc=4,7 |
| | 9 | Triple glazing for all other types of glazing or glazing with U>1,75. Replace all windows | U>1,75 | - |
| | 15 | Insulated door | - | - |

Package 1.1 will be applied in 2020 and implies the floor, the glazing and heating. Ten years later in package 1.2 the roofs will be renovated, and ten years after that the façade will be renovated with all the sub elements. In this strategy no exceptional installations such as installations are placed, these are considered to be not taken into account in regular maintenance. The sequence of this strategy is determined as follows. The major components of the shell of the house are divided over the renovation moments.

Renovation strategy 2, as described in chapter 4.2.2.2 is the strategy where the goal is known, and the steps towards that goal are defined clearly. This strategy is based on the Trias Energetica; first the energy demand will be reduced by enhancing the Rc-value of the house. This is done by performing package 2.1 in 2020 in which the whole shell of the houses are adjusted. Twenty years later the installations will be integrated. The timespan of twenty years is determined in chapter 4.2.3.

**Table 4.8: Renovation strategy 2: Stepwise**

| Package | Measure | Description | Old | New |
|---|---|---|---|---|
| **2.1: 2020** | 1 | Insulate floors with little or no insulation | Rc<2 | Rc=3,71 |
| | 2 | Insulate flat roofs with little or no insulation | Rc<2 | Rc=6 |
| | 3 | Insulate pitched roofs with little or no insulation | Rc<2 | Rc=6 |
| | 4 | Insulate walls with little or no insulation, indoor or outdoor | Rc<2 | Rc=4,5 |
| | 5 | Insulate cavity walls with little or no insulation | Rc<2 | Rc=4,5 |
| | 6 | Insulate panels | Rc<1,29 | Rc=4,5 |
| | 7 | Insulate cavity wall panels | Rc<1,29 | Rc=4,7 |
| | 9 | Triple glazing for all other types of glazing or glazing with U>1,75. Replace all windows | U>1,75 | - |
| | 10 | HR107 boilers in individual and collective systems | - | - |
| | 15 | Insulated door | - | - |
| **2.2: 2040** | 11 | Heat pump electric in all individual systems, outside air, auxiliary gas HR107 | - | - |
| | 12 | Ventilation: Mechanical exhaust, CO2-controlled individual ventilation, DC (Direct Current) | - | - |
| | 13 | Sun boiler | - | - |
| | 14 | 12 PV-panels (19,2m2) | - | - |

The last renovation strategy is as described in chapter 4.2.2.3 according to the Stroomversnelling. All measures are applied at the same moment so the house is energy neutral at once. These measures are adopted from the Energiesprong and are converted into the VABI software and therefor might be slightly different (Energiesprong, 2015). The main difference with renovation strategy 2 is that the amount of PV-panels is much higher and that no solar water heater is applied.

**Table 4.9: Renovation strategy 3: At once (Energiesprong, 2015)**

| Package | Measure | Description | Old | New |
|---|---|---|---|---|
| **3: 2020** | 1 | Insulate floors with little or no insulation | Rc<2 | Rc=3,71 |
| | 2 | Insulate flat roofs with little or no insulation | Rc<2 | Rc=6 |
| | 3 | Insulate pitched roofs with little or no insulation | Rc<2 | Rc=6 |
| | 4 | Insulate walls with little or no insulation, indoor or outdoor | Rc<2 | Rc=4,5 |
| | 5 | Insulate cavity walls with little or no insulation | Rc<2 | Rc=4,5 |
| | 6 | Insulate panels | Rc<1,29 | Rc=4,5 |
| | 7 | Insulate cavity wall panels | Rc<1,29 | Rc=4,7 |
| | 9 | Triple glazing for all other types of glazing or glazing with U>1,75. Replace all windows | U>1,75 | - |
| | 10 | HR107 boilers in individual and collective systems | - | - |
| | 11 | Heat pump electric in all individual systems, outside air, auxiliary gas HR107 | - | - |
| | 12 | Ventilation: Mechanical exhaust, CO2-controlled individual ventilation, DC (Direct Current) | - | - |
| | 15 | Insulated door | - | - |
| | 16 | 27 PV-panels (43,2m2) | - | - |

### 4.2.9 External factors

The renovation strategies defined in chapter 4.2.8 uses the techniques and its costs that are currently available and describe only one route. Also the price for energy is based on current data. Because this research examines what the consequences are on the long term, bandwidth has to be given to the factors that can have influence. In this chapter those factors are determined, and scenarios are described which can provide insight in the consequences of a chosen renovation strategy. The external factors are based on the conclusions of chapter 3 in which an Ishikawa diagram has been made and includes trends in consumption and prices of energy, efficiency and prices of installations and governmental regulations.

A moment of influence is when a new decision has to be made about the renovation plan for a house. Most housing associations do have a regular maintenance program which implies the frequency of repair and renovation measures. In this research the moments at which influence can be exerted on the decision making are coupled with the defined renovation strategies in chapter 4.2.3. The number of influencing moments and the frequency depends therefor on those predefine timeframes: renovation strategy 1 has three decision moments with a timespan of ten years; strategy 2 two decision moments with a timeframe of twenty years and strategy 3 has one decision moment with a timespan of 50 years. Those moments can be used for choosing another technique and at those moments techniques or installations might be cheaper or more efficient.

#### *4.2.9.1 Trends in energy consumption*

The trends in the energy consumption can have influence of a chosen strategy. For example when the consumption of electricity is increasing, a renovation strategy which implies installations that can generate electricity might be preferred. In Figure 4.13 the average energy usage of households of several countries is displayed.

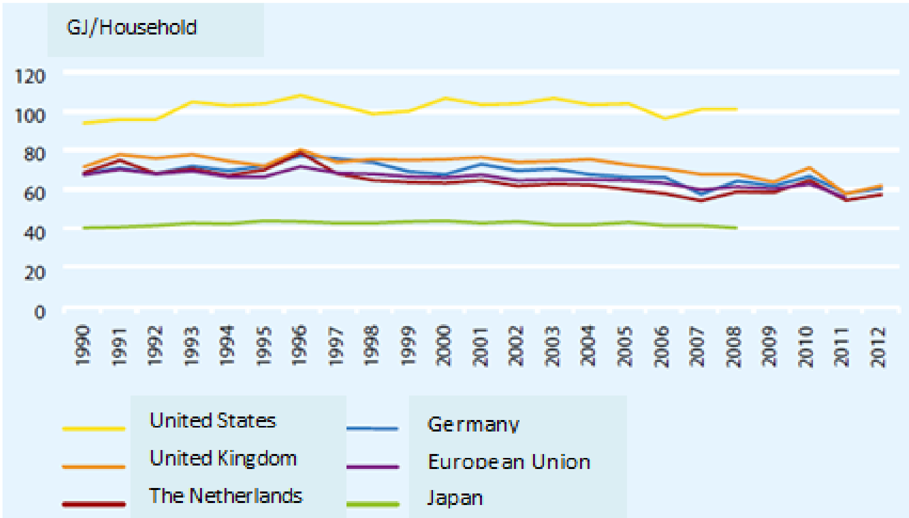



**Figure 4.13: Average energy consumption per household in diverse countries (Boelhouwer, Gerdes, & Marbus, 2014)**

Dutch, German and British households do follow the line of the average use in Europe. Remarkable is the difference between different cultures and climates; Japan has a relatively low usage per household while the United States has a very high average energy usage. (Boelhouwer, Gerdes, & Marbus, 2014) For fifteen years the energy consumption is slowly decreasing for the Netherlands, but households have an increasing number of electricity consuming appliances. Therefor it is difficult to predict whether and to what extend the consumption will decrease. More specific, the average consumption of gas and electricity per household can be seen in Figure 4.14.

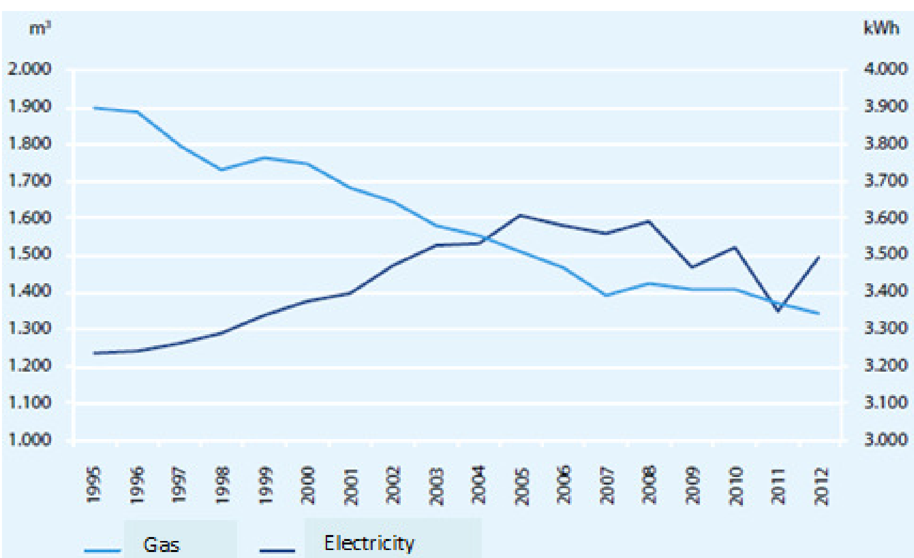



**Figure 4.14: Average consumption of gas and electricity per household (Boelhouwer, Gerdes, & Marbus, 2014)**

The declining of the gas consumption can be seen here, while in the period 1995 to 2005 the electricity consumption increased. Since 2008 the electricity consumption is fluctuating but seems to be decreasing. (Boelhouwer, Gerdes, & Marbus, 2014) In the report of Boelhouwer et al (2014) is concluded that the energy consumption for heating has decreased since twelve years which is the result of energy saving measures. The insulation of houses has improved and the gas consumption is decreased because heating boilers have become more efficient. Next to that, electric equipment such as refrigerators and washers has become more economical. Although the energy consumption is decreasing, another trend can be seen in the costs of energy displayed in Figure 4.15. The increase of the costs can be owed to a higher delivery price of gas and electricity, but also for a higher energy tax (Boelhouwer, Gerdes, & Marbus, 2014). Expected is that the costs of energy will increase for some sources; for example gas is becoming more scarce and hard to obtain.

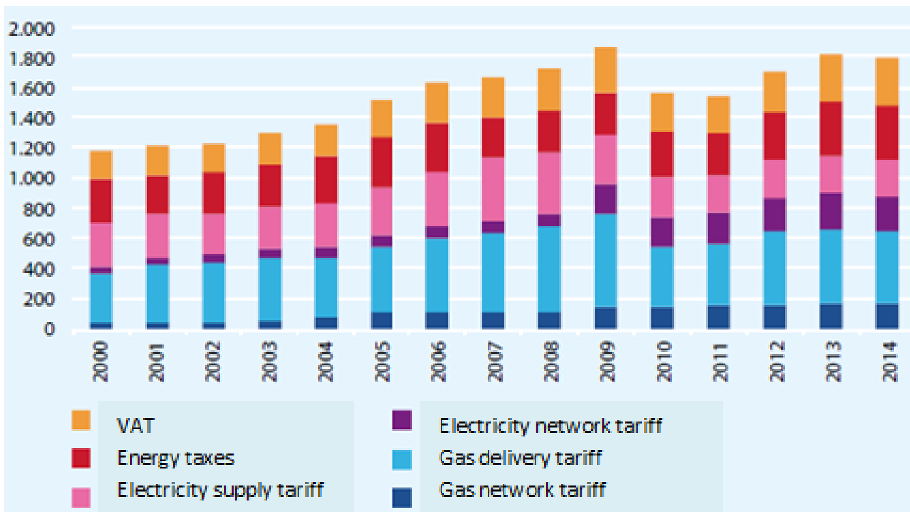



Figure 4.15: Average costs energy per household (Boelhouwer, Gerdes, & Marbus, 2014)

#### *4.2.9.2 Trends in prices and innovation of techniques*

The price of PV-panels was halved during the last five years which has led to higher sales (Milieucentraal, 2015). In Figure 4.16 the price development of PV-panels in the Netherlands is displayed.

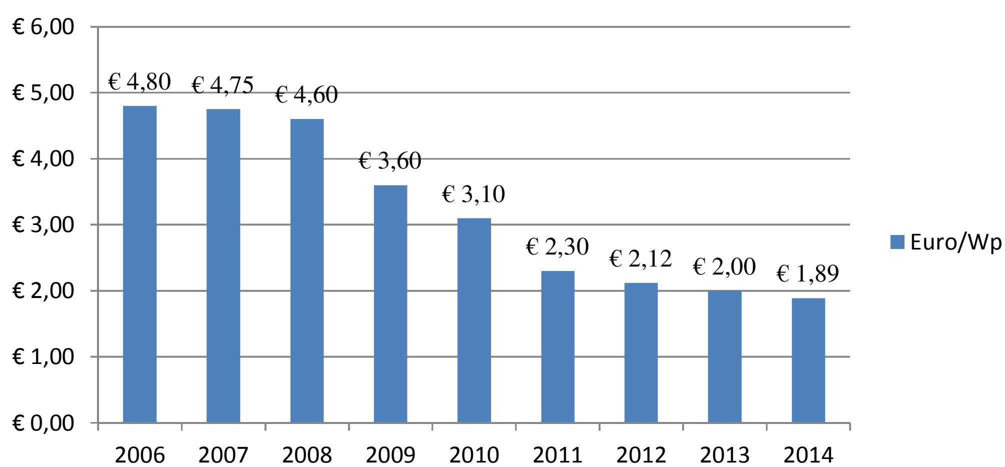



Figure 4.16: Price development of PV-panels. Average price of ten PV-panels inclusive installations and convertor per watt peak (Milieucentraal, 2015)

The decline in the price is visible but it seems that the price will remain stable in the future. Not only the affordability of PV-panels becomes better, also on the technical field progress is made and panels are being developed with a high efficiency. An example is Nano-coating which ensures that raindrops and dirt cannot adhere to the panels which enhance the efficiency (Brisk, 2015). The price that is used in this research is per set and is based on the benchmark of Atriensis as can be seen in Table 7.3 in the Appendix. Two sets of PV have been distinguished, 12 panels and 27 panels for respectively 4200 and 9600 euros.

Heat pumps are applied more often lately, specific in new constructed houses. Heat pumps can extract heat from several sources; air, ventilation, ground and groundwater. In this research it concerns an electric heat pump that uses air as source. In 2010 is measured that more than 52 thousand houses are heated with a heat pump. This number is less than one percent of the total housing stock, but it is said to be that the number of heat pumps is increasing with 20 percent per year. As discussed in the previous section, the electricity consumption is slowly decreasing, but is fluctuating which can also be caused by the increasing number of heat pumps. Heat pumps require much electricity for heating instead of gas. (Boelhouwer, Gerdes, & Marbus, 2014) Based on key figures of Atriensis as explained in Table 7.3 in the Appendix the price of a heat pump is 23.500 euros.

There are also heat pumps which extract warmth and cold from the ground. According to Dowlatabadi et al (2007) ground source heat pumps are much more efficient in heating and cooling than conventional techniques. They have also defined some reasons why the market diffusion seems to be limited, one of the main reasons is that the initial capital cost for a heat pump is significant. Dowlatabadi et al mention that the system costs for conventional systems are well established and considered to be normal, as well as the life expectancy and costs for maintenance. Although the initial investment for a heat pump is significant and variable, the maintenance costs are almost free and the lifetime expectancy is known to be very long, more than 25 years for ground source heat and is almost maintenance free. (Dowlatabadi, Hanova, & Mueller, 2007)

A solar water heater is much more affordable than for instance a heat pump, and thought is that by innovation the price will even more decrease (OK Energy, 2015). Also because the gas price is increasing, a solar water heater might become interesting. Next to that prevention of CO2-emmisions is achieved by using solar energy instead of fossil fuels. With a solar water heater almost half of the energy consumption for warm water can be saved per household because half the amount of gas is used. (Milieu Centraal, 2015). Based on key figures of Atriensis as explained in Table 7.3 in the Appendix the price of a sun boiler is set at 2750 euros.

There are several other techniques that are not taken into account in this research but can be used for sustainable renovation. Thought can be of a heat and cold storage system which is mostly applied for larger building complexes. It is a relatively high investment, but when the quality of the design and the construction are good and all the circumstances such as the soil are good, it is economically viable (RVO, 2015). These so-called circumstances are very important when applying a heat and cold storage. Many projects have failed because the installation is not properly regulated. A system that works properly can deliver an energy saving of 80 percent for cooling and 50 percent for heating (Energie Vastgoed, 2015).

Infrared heating can also be used for heating a house, it is already adopted for use in certain food processing applications. For the housing sector the number of suppliers is increasing and the application is feasible. With infrared heating panels the mass where it shines on is heated, comparable to the radiation from the sun. This is another sort of heating than conventional radiator systems which heat the air. Therefor the panels do not bring the air in motion which prevents air flows and the distribution of harmful particles. Seven percent is saved compared to conventional radiator heating for each degree a room is heated. Next to that, the panels can be placed anywhere in the room and are relatively small. (Centrale verwarming cv, 2015)

#### *4.2.9.3 Governmental regulations*

According to the authors of Claessens and Groenland (2014) there are hardly barriers from the government for housing associations to perform energy saving measures in social housing. New legislation has little or no influence on the effort to make the housing stock more sustainable. The knowledge of new laws and its estimations of the consequences is an aspect which is not sufficiently available. (Claessens & Groenland, 2014) Stated is that the regulations do not have a negative impact on the process of the sustainable transition. On the other hand, the regulations and subsidies can have a positive influence. For instance the “Herzieningswet voor woningcorporaties” (revision act for housing associations). This law requires performance agreements of the housing associations for the next five years. These performances concern sustainability and energy saving measures. To ensure that the plans will be executed, the agreements have to be defined SMART (specific, measurable, acceptable, realistic, time) to be able to control. (Noy, 2015) This measure can ensure that associations are obliged to consider what strategies are being adapted and therefor can accelerate the process towards energy neutral.

## 4.3. Results

In this chapter the results are discussed. First the outcomes of the applied renovation strategies on the housing stock of the selected database are described. The outcomes of VABI are adapted and inserted in an extensive Excel document in which the costs can be related to the applied measures. This Excel is developed by Atriensis and is adjusted for analyzing the data generated by the Vabi software.

In chapter 4.3.1 the effect on the energy-index is described. Chapter 4.3.2 shows the energy-consumption, -emissions and –costs followed by the costs of the renovation strategies. Final, in chapter 4.3.4 the influence of the external factors is discussed. Note, when is spoken about energy-indexes, then these are calculated according to the new method which is implemented in 2015.

### 4.3.1. Renovation scenarios; energy-index

The influence of the renovation strategies is shown in Figure 4.17.

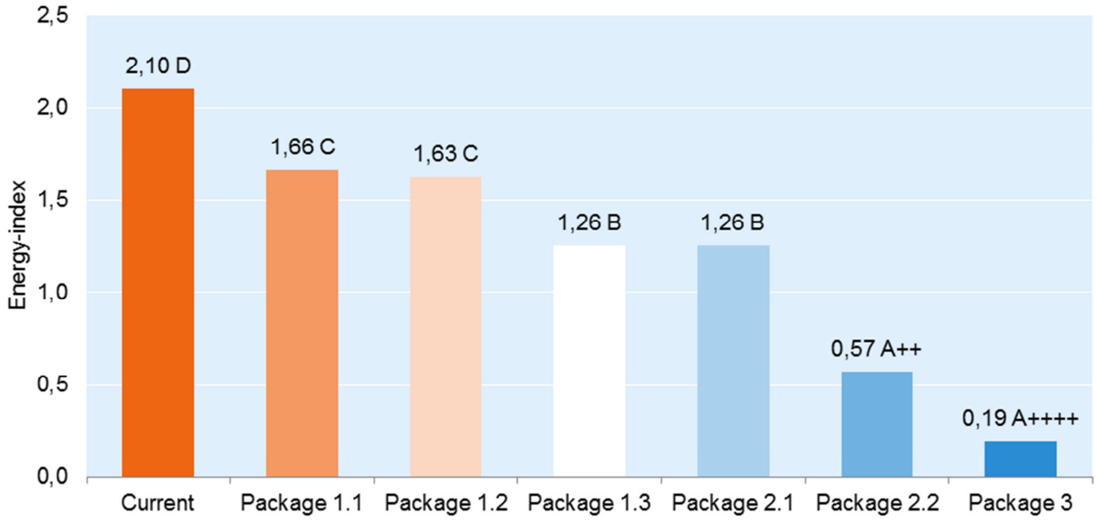


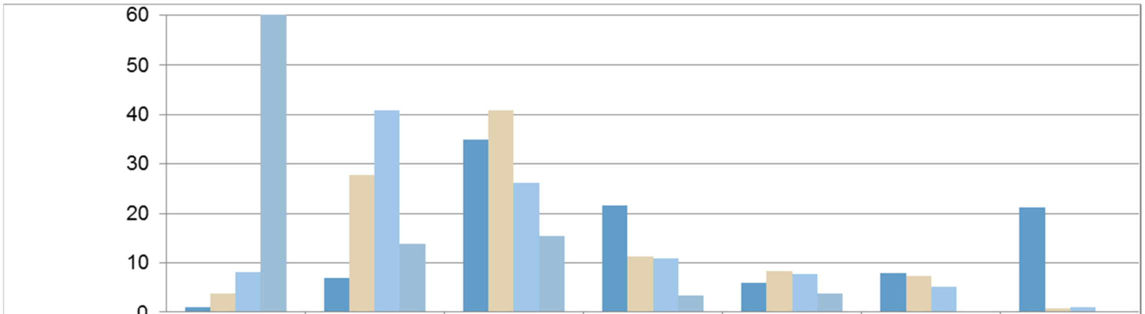

**Figure 4.17: Energy-indexes of renovation packages**

The current energy-index of the housing stock is 2,10 which corresponds with label D. Applying renovation strategy 1 with all its packages will eventually achieve an energy-index of 1,26 and will thus not be energy neutral because the energy-index is not below 0,6 as determined in chapter 4.1.3. Remarkable is that the difference of the energy-index between package 1.1 and 1.2 is not that significant. Those packages are executed in respectively 2020 and 2030. Package 1.3 is executed in 2040 and shows a decrease of the energy-index which is not enough to be energy neutral. Especially when for instance the methodology of the energy-index changes again and the conditions for an energy neutral house become stricter.

Renovation strategy 2 achieves an energy-index of 0,57 which complies the requirements for an energy neutral house. The package 2.1 which is executed in 2020 gives already an index of 1,26, enough to comply with the covenant Energiebesparing Huursector 2020. The result of package 2.1 is the same as the index of renovation strategy 1, this is because all measures applied in the packages of renovation strategy 1 are applied at once in package 2.1. Package 2.2 implies installations which are not applied in renovation strategy 1.

Renovation strategy 3 consists of one package and results in an energy-index of 0,19 which meets the requirements for an energy neutral house. This renovation strategy consists mostly of renovation measures that are also applied in strategy 1 and 2, but are in some cases stricter or more extensive. For example, the number of PV-panels is in renovation strategy much higher than in strategy 2, respectively 27 and 12.

Now the average energy-indexes are discussed, a more detailed approach is useful in order to see the effect of the renovation packages. An overview of the division of the houses over the energy labels in percentage is shown in Figure 7.1 in the Appendix. The division is shown for the current state and all the packages. A detailed view of the division of the packages of renovation strategy 1 is displayed in Figure 4.18.

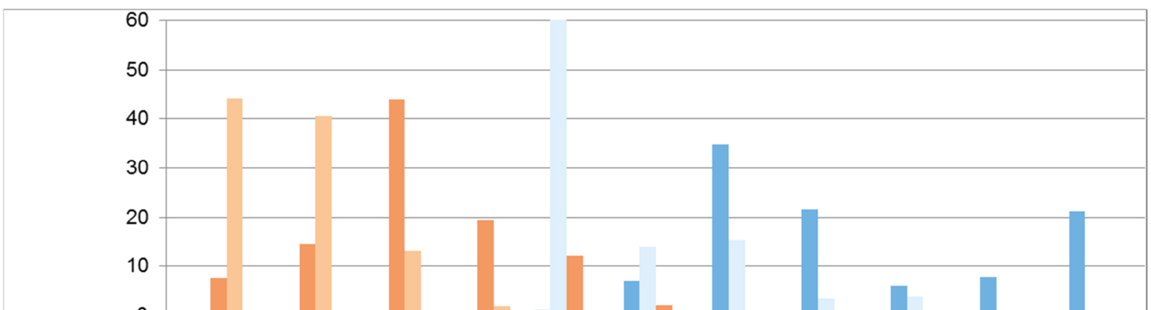


| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| Current | 1,2 | 7,1 | 34,9 | 21,7 | 6,0 | 7,9 | 21,3 |
| Package 1.1 | 3,8 | 27,7 | 40,7 | 11,4 | 8,4 | 7,3 | 0,8 |
| Package 1.2 | 8,1 | 40,8 | 26,1 | 10,9 | 7,8 | 5,2 | 1,1 |
| Package 1.3 | 63,4 | 13,9 | 15,3 | 3,5 | 3,9 | 0,0 | 0,0 |

**Figure 4.18: Division of energy labels in percentage renovation strategy 1**

In the current situation the majority of the houses have a C-label while the average energy-label is D as can be seen in the previous discussed Figure 4.17. Looking at renovation strategy 1 the majority of the houses shifts towards label A. More specific, in 2020 when package 1.1 is applied, the majority of the houses still has label C. Package 1.1 ensures that there are almost no houses left with label G. Applying package 1.2 in 2030 ensures that the majority shifts to label B and package 1.3 in 2040 will bring more than 60 percent of the houses towards label A. In that case there are no houses with label F and G and only a few with label D and E.

Figure 4.19 shows the division for renovation strategy 2 and 3.



| | A++++ | A+++ | A++ | A+ | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Current | 0,0 | 0,0 | 0,0 | 0,0 | 1,2 | 7,1 | 34,9 | 21,7 | 6,0 | 7,9 | 21,3 |
| Package 2.1 | 0,0 | 0,0 | 0,0 | 0,0 | 63,4 | 13,9 | 15,3 | 3,5 | 3,9 | 0,0 | 0,0 |
| Package 2.2 | 7,7 | 14,6 | 44,0 | 19,4 | 12,2 | 2,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Package 3 | 44,2 | 40,6 | 13,2 | 2,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

**Figure 4.19: Division of energy labels in percentage renovation strategy 2 and 3**

Renovation strategy 2 starts with an energy-index of 1,26 and a majority of the houses in label A. Package 2.1 creates a major shift towards lower energy-indexes and labels, there are no houses anymore with labels F and G and only a small percentage in D and E. Package 2.2 creates another major transition to more sustainable houses, the average energy-index is 0,57 (A++) and 44 percent of the houses has label A++. Nearly 8 percent has a label A++++ which is very energy efficient.

Renovation strategy 3 is the superlative of strategy 2, namely 44 percent of the housing stock receives a label A++++. Another 40 percent has label A+++, 13 percent A++ and a negligible 2 percent has label A. With this strategy the lowest energy label is better than the highest of the current situation.

### 4.3.2. Energy -consumption, -emissions and -costs

Table 4.11 gives more specific information about the effects of the renovation strategies and its packages. The labels and energy-indexes are listed, as well as the expected consumption of gas and electricity per house per year which are calculated by VABI.

For the energy consumption of the current situation assumptions have been made based on numbers determined by Atriensis. Assumed is that an average household consumes yearly 1.800 $m^3$ of gas and 3.000 kWh of energy. With use of VABI the savings are calculated. For determine the costs tariffs of four large energy companies are compared and averaged. This leads to the following costs which are shown in Table 4.10. (Maessen, 2015)

**Table 4.10: Energy prices (Maessen, 2015)**

| Energy prices | 2015 |
|---|---|
| **Gas fixed** | € 153 per $m^3$ |
| **Gas variable** | € 0,63 per year |
| **Electricity fixed** | - € 127 per kWh |
| **Electricity variable** | € 0,23 per year |

The fixed prices include the contract costs, which is negative for electricity. This is because the energy taxes for electricity that are eventually returned are already taken into account. The variable costs are related to the consumption of the household and therefor can differ.

The expected consumption includes only the usage that is related to the installations of the house, for example electricity for light, the boiler and gas for heating. The personal use of gas for cooking and electricity for all sorts of equipment is not taken into account in this assumption. Next to that, the CO2 emissions and energy costs and savings are listed. Note that the packages are not standing on its own, they complement each other. For example, applying package 1.3 implies that packages 1.1 and 1.2 are already executed.

**Table 4.11: Energy consumption, emissions and costs (installations, not personal use)**

| | Current | Package 1.1 2020 | Package 1.2 2030 | Package 1.3 2040 | Package 2.1 2020 | Package 2.2 2040 | Package 3 2020 |
|---|---|---|---|---|---|---|---|
| **Energy label** | D | C | C | B | B | A++ | A++++ |
| **Energy-index** | 2,10 | 1,66 | 1,63 | 1,26 | 1,26 | 0,57 | 0,19 |
| **Gas consumption ($m^3$ per house per year)** | 1.800 | 1.443 | 1.298 | 860 | 860 | 565 | 690 |
| **Electricity consumption (kWh per house per year)** | 3.000 | 2.984 | 2.984 | 2.982 | 2.982 | 1.350 | -2.732 |
| **$CO_2$-emmission (ton per house per year)** | 4,9 | 4,3 | 4,0 | 3,2 | 3,2 | 1,8 | -0,3 |
| **Energy costs (per house per year)** | € 1.850 | € 1.622 | € 1.530 | € 1.254 | € 1.254 | € 693 | - € 168 |
| **Energy costs (per house per month)** | € 154 | € 135 | € 128 | € 104 | € 104 | € 58 | - € 14 |
| **Energy savings per house per year compared to current situation** | | € 228 | € 320 | € 596 | € 596 | € 1.157 | € 2.018 |

The gas consumption is in all cases much decreased, which cannot be said about the electricity consumption. The electricity consumption does almost not decrease in renovation strategy 1 while strategy 2 and especially strategy 3 results in a large decrease. This difference can be assigned to the energy generating installations such as PV-panels in strategy 2 and 3. The decrease of the electricity usage can only be attributed to package 2.2. Namely, the effect of package 2.1 on the electricity consumption is negligible, although it results in a large reduction of gas usage compared to the current situation. The gas consumption by applying strategy 3 is not as low as strategy 2, but the decrease of the energy use is very large and even becomes negative which means that more energy is generated than used. The same effect plays a role for the CO2-emissions, in which the installations have much influence. The CO2-emmission reduces with every renovation strategy, but reduces significantly with strategy 2 and 3.

All the changes in consumption of gas and electricity lead to a change in the energy costs per house. In Table 4.11 the energy costs per house are listed per year, per month and the savings when the costs are compared to the current situation. Looking at the energy costs per year, renovation strategy 1 eventually saves 612 euros compared to the current situation. But before that result is achieved, in 2020 the savings are reduced with 225 euros and in 2030 to 321 euros.  Renovation strategy 2 starts with a reduction of 612 euros with package 2.1 which will be doubled to almost 1200 euros per year in 2040. Strategy 3 will realize in 2020 a total energy saving of 2000 euros per house per year.

### 4.3.3. Renovations scenarios: Costs

The costs of measures are based on benchmark numbers of Atriensis and can be found in Table 7.3 in the Appendix, in the same table is given to what extend each measure is applied when it is part of a renovation strategy.

Table 4.12 shows the costs of all packages individually and also cumulative so the total costs of a renovation strategy are given. The costs are shown for the housing stock as a whole and per house.

Table 4.12: Costs packages

| | Package 1.1 2020 | Package 1.2 2030 | Package 1.3 2040 | Package 2.1 2020 | Package 2.2 2040 | Package 3 2020 | *Package 3 (Elp & Hardeman, 2013)* |
|---|---|---|---|---|---|---|---|
| **Costs package (in Millions including VAT exclusion subsidies)** | € 15,2 | € 14,2 | € 42,8 | € 66,7 | € 42,3 | € 117,7 | *€ 183,7* |
| **Cumulative costs package (in millions)** | € 15,2 | € 29,3 | € 72,2 | € 66,7 | € 109,0 | € 116,7 | *€ 183,7* |
| **Costs per house per house (including VAT exclusion subsidies)** | € 4.951 | € 4.622 | € 13.993 | € 21.777 | € 13.806 | € 38.118 | *€ 60.000* |
| **Cumulative costs per house** | € 4.951 | € 9.573 | € 23.566 | € 21.777 | € 35.584 | € 38.118 | *€ 60.000* |
| **Saving on energy costs per house (including VAT)** | € 228 | € 320 | € 596 | € 596 | € 1.157 | € 2.018 | - |

Looking at the total costs of a renovation for the whole housing stock of the selected housing association, strategy 1 is most affordable with 72,2 million euros. But as discussed earlier this strategy does not achieve energy neutral, or in the last step a large investment has to be executed. Looking at the renovation strategies which achieve energy neutral, strategy 2 is slightly less expensive than strategy 3. However, in strategy 3 the investment has to be done immediately while the total investment of strategy 2 is spread over two moments. On the other hand, because the measures are applied at once in strategy 3, advantages of the benefits such as lower energy costs can be taken immediately.

The costs of package 3 are determined in two ways; according the measures applied in Vabi and according to the information available of the Stroomversnelling of the Energiesprong. The latter is displayed in the last column of

Table 4.12 and a large difference is notable. According to the information of the Energiesprong the average renovation price is 60.000 euros if the scale benefits are taken into account. This can be owed to the new techniques and way of working that is used in those cases and that it is only applied on single-family houses. Looking at package 3 according to this research, the costs are much lower. That can be the result of that the measures of strategy 3 are applied according to the boundaries that are defined in chapter 4.2.4.

### 4.3.4. Overall influence of external factors on the process towards an energy neutral housing association

In chapter 4.2.9 external influencing factors have been described. Trends of energy prices, costs and innovation of techniques and the governmental regulations have been discussed. In this chapter the effects of those factors on the renovation strategies are discussed whether it contributes or obstructs the chosen strategy.

First the energy consumption of gas which is slowly decreasing while the price is increasing. In the current situation almost 1800 $m^3$ gas is used. For renovation strategy 1 the increase in price is a problem because still much gas is used in the first two packages as shown in Table 4.11. Eventually in 2040 a usage of 860 $m^3$ will be achieved which is a reduction by half compared to the current situation but is still significant high compared to the other two strategies. Renovation strategy 2 achieves that halving already with package 2.1 in 2020 and reduces eventually to a gas consumption of 565 $m^3$. Strategy 3 results in a reduction to approximately 700 $m^3$, which is higher than strategy 3.

The electricity consumption seems to decrease but is fluctuating and is expected to grow because of the increasing number of energy consuming appliances. For electricity the costs are expected to increase as well. Looking at the results of strategy 1 compared to the current situation there is almost no difference in electricity consumption. The same can be concluded about package 2.1. Only when package 2.2 is applied a reduction is achieved to 1350 kWh per house per year as a result of the applied PV-panels. Looking at strategy 3, energy is generated by the many PV-panels, in this way that energy can be used for the personal consumption. This strategy is therefore not that dependent from the increasing energy price, unless the personal consumption is higher than the generated amount of energy.

The price of the PV-panels has decreased and seems to be stabilized and the efficiency is still being increased. Only in strategy 2 and 3 PV-panels are applied so strategy 1 cannot take advantage of that. In strategy 2 the panels are applied in package 2.2 in 2040; disadvantage is that from that moment the benefit of PV-panels can be used, on the other hand is it possible to choose more efficient and more affordable PV-panels when package 2.2 is executed.

The price of the heat pump used in strategy 2 and 3 is significant but the life expectancy is long and the maintenance cost very low. From that perspective that is a privilege for renovation strategy 3, it takes a high investment but gives immediately low maintenance costs. On the other hand, when applying strategy 2 in which the heat pump will be installed in 2040, the efficiency of heat pumps might be increased and the price might be decreased. Although the investment is much lower, the same aspects also apply for the solar water heater. This installation is only applied in strategy 2.

The other techniques that are discussed in chapter 4.2.9 are a heat and cold storage system and infrared heating. The first is very expensive and when it is adapted it will implies much adaptions to the existing house because groundwork needs to be done. This installation type is in this research considered to be too comprehensive and more appropriate for new houses to be constructed and therefor will have no impact on a chosen strategy. The interest in infrared heating panels is growing and might become a popular instrument to heat the house. The panels are easy to apply in existing housing and can be placed at someone's requirements. Question is whether tenants are willing to have such a heating system, though it might have many advantages it is another way of heating which requires another heating behavior.

Governmental regulations have little or no influence on housing associations in order to perform sustainable renovation. According to Claessens and Groenland (2014) there are hardly barriers. Nevertheless, the regulations can have a positive influence on the process as for instance the Revision Act for housing associations. As discussed in chapter 4.2.9 the obligation for housing associations to make performance agreements can work positive for the progress of the sustainable transformation towards energy neutral.

## 4.4. Conclusion, discussion and recommendations

In this section conclusions are given in response to the executed analyses and its results. The findings are placed in the context of the case study and can be used for other housing associations that are smaller or larger. In the discussion part striking aspects are discussed, as well as some aspects that need improvement in order to achieve a more appropriate result. At the end of this section some recommendations for further research are indicated.

### 4.4.1. Conclusion

The goal of this research is to provide insight in the consequences of a renovation strategy for the housing stock of a housing association towards energy neutral. To achieve an energy neutral housing stock of the housing association is only possible with renovation strategy 2 (stepwise) and 3 (at once). Applying renovation strategy 1 (regular maintenance) does not result in an energy neutral housing stock. The advantage of renovation strategy 2 is that there is room for innovation of the installations because these are integrated in 2040. As discussed in chapter 4.3.4 the price of techniques is expected to decrease and the efficiency increases. When these assumptions are taken into account, a better energy-index might be achieved with less investment. Renovation strategy 3 brings the housing stock immediately to an energy neutral level. The total costs do not differ much from strategy 2 but the investment has to be done immediately which might be hard to realize; on the contrary, the benefits of low energy costs will also start immediately. Another important factor is that within this strategy no advantage can be taken of the process of better efficiency and the decreasing prices of techniques. Looking at the data of the Energiesprong in

Table 4.12, it costs 20 thousand euros more than the one that is calculated in VABI. Assuming that the data of the Energiesprong is more accurate and reliable means that it is far more expensive than the other two strategies. This can also be the result of the calculation method of VABI and that used techniques and materials are used while the Energiesprong uses new or other methods and products. This implies that the Energiesprong is still too expensive, and upscaling is needed in order to increase the efficiency. Nevertheless the numbers from the Energiesprong are determined taken the scale benefits into account. So more innovation is needed in order to make the Stroomversnelling more efficient and affordable and thus a better option.

Looking at the influence of the external factors that are described in chapter 4.3.4, it can be concluded that renovation strategy 1 has much consequences of the increasing energy costs because the achieved savings are not that significant. Because the renovation strategy has no installations it will not benefit from the innovation of the installations. Renovation strategy 1 will suffer from the consequences of the Herziene Woningwet (Revised Act) in which a performance agreement has to be made. It might even be possible that such a strategy will not be approved and that another strategy is needed.

On the contrary, renovation strategy 2 consists of two packages; the first implies architectural adjustment and the second consist of installations such as PV-panels. Therefor advantage can be taken of the innovation of the installations and its price decrease. Point of attention is that the installations are applied in 2040 in package 2.2, but a large reduction of the energy consumption is already achieved with package 2.1 which is executed in 2020.

Because with this renovation strategy a long term goal is set and the packages are composed in order to achieve that goal, it can already fulfill the requirements that will be set by the governmental with the Herzieningswet.

The innovations on the long term for installations and techniques do not have any influence on renovation strategy 3 because all measures are applied at once in 2020. This means that the quality and efficiency depends on the products available at that moment what might be a limitation of the strategy. The question is whether this outweighs the advantage of a very long period of low energy costs and a sustainable house. That is a choice which has to be made by the organization of the housing association. Looking at the increasing price of the electricity, strategy 3 has a good position as it generates electricity. Gas is still used, and though it is halved in perspective of the current situation, still 690 $m^3$ per house per year is needed.

It can be concluded that strategy 2 is the most suitable strategy for the case study because of several reasons. First, the costs can be spread over two decision moments. In this way it is more affordable for housing associations, and also with package 2.1 is already a decrease on the energy costs achieved of almost 600 euro. Second, because the installations are applied in a later phase, the benefits of the innovation efficiency and the decrease of the price can be used, and as a result the total costs might become lower. Third, it fulfills the requirements of both the regulations from the government, the overall goal of the Energieakkoord and the Convenant Sociale Huursector. It might differ per housing association what strategy is most feasible and is dependent of their financial situation and what their policies are for integration innovative installations and techniques. Renovation strategy 1 is not possible at all because the eventual goal is not achieved. Renovation strategy 3 is possible, but still is too expensive to be an appropriate alternative.

Much needs to be done to obtain an energy neutral housing stock. In general can be concluded that applying installations such as PV-panels will give a large decrease of the energy-index and are essential, without it is impossible to achieve an energy neutral housing stock. There are some trends going on in which the efficiency of products is increasing. But one of the main issues with new products and installations is that users have to use it in the right way, so a changing user behavior has to be realized.

### 4.4.2. Discussion and recommendations for further research

This research uses a generic approach for the whole housing stock of a housing association. This means that no distinction is made between housing types, and whether houses are being demolished and rebuilt, it implies only renovation of existing houses. For further research it might be interesting to take into account that some houses are being demolished and rebuilt.

In this research is examined what the consequences are of a renovation strategy with current techniques. It might be useful to redo this research with new and innovative techniques in order to see which techniques might have a great influence on the process.

The measures are applied according the rules that are set in chapter 4.2.7, VABI combines all the characteristics of the houses with the measures and checks whether a measure is being applied. VABI does not in all cases examine whether a certain measure is possible; for example, it can assign a solar water heater to a multifamily house. This is possible, but when all houses in such a complex need to have an individual solar water heater on the collective roof, there might not be enough space. Therefor it is important to take into account that some measures cannot be applied on each house, or that other solutions have to be found. For instance the application of PV-panels on the roof of multi-family houses might be difficult because a single family house has more individual roof surface than a multi-family house. A solution can be to use another roof where is space left or to cover a piece of land with PV-panels, this is an example of an external approach to become energy neutral as discussed in chapter 4.1.1. These approaches are not examined in this research, but is recommended to do in further research.

The research is approached towards the housing associations and focuses and the house as a physical object. Therefor has been chosen to let the tenants out of discussion. So the changing rent prices are not taken into account which is also the result of the lacking data of the rent prices of the case study. Next to that, the behavior as well as the energy consumption of the tenant is not taken into account in this research. Recommended is to investigate how the tenant looks upon the different techniques and processes, and to integrate the personal energy consumption.

It is strange that renovation strategy 3 requires so much gas. A large reduction is achieved, but the gas consumption is even higher than the consumption after applying renovation strategy 2. This is the result of the fact that in renovation strategy a solar water heater is installed which is lacking in renovation strategy 3.

In this research the region of the housing association is not taken into account because this research focuses on a generic approach for an average housing association in the Netherlands. For further research it would be interesting to couple the renovation plans to different regions and complexes, regions with shrinkage or with a growing population. This is a link to strategic stock management which implies that there are different plans for different houses and complexes.

Questioned can be whether the regulations according the energy-indexes will change in the future, that it becomes stricter. In that case it must be taken into account that a lower energy-index has to be achieved in order to think ahead. In this research the energy-index is used for defining whether a house is energy neutral as a physical object. For future research it might be interesting to use the real in- and output of all energy flow in order to see whether a house is energy neutral.

A discussion point is whether VABI Assets is the most appropriate tool to use for this research because a few shortcomings have been experienced. VABI is not able to perform calculations towards in a long time span, the software makes no distinction whether it is renovated in 2020 or 2030 which has an influence on the energy-index. Another limitation is that there can only be chosen for a few previous set materials and products. This makes it impossible to model new innovative products or products with or without certain features. This was especially the case with renovation strategy 3 in which new preassembled facades are applied, which had to be modeled in VABI with commonly used products. Furthermore, in VABI the application of measures is related to Rc-values. For example, new insulation with a certain Rc-value is adapted when the current insulation is below a certain value. It might be more useful to be able to select certain products that have to be replaced by another product. These shortcomings do not lead to the results that are required, and therefore it is more important to interpret it in the right way.

# 5. Conclusion

In this section the overall conclusions of the research performed will be discussed and the research questions will be answered. Next to that the social, scientific and beneficiary relevance will be addressed. In general it can be concluded that energy neutral as a goal is difficult to describe, and that it is important for housing association to define for themselves what energy neutral is. All the described themes lead to the conclusion that the same overall goal is being achieved, a more sustainable built environment which is energy neutral in 2050. Nevertheless the thoughts on the road towards that goal are very diverse. Therefor different renovation strategies are applied what leads to inefficiency and indistinctness towards housing associations which can result in wrong strategic decisions on the long term. This research is executed in order to provide insight in the effects of a chosen renovation strategy.

The following sub questions were defined in order to answer the main question:

1. *What are the regulations, agreements for housing associations concerning sustainability; which actors are involved?*

The Energieakkoord (Energy Agreement) is undersigned by more than 40 organizations in September 2013, and is the base for a broad, robust and futureproof energy and climate policy. A part of the Energieakkoord is the "Convenant Energiebesparing Huursector" (covenant energy rental sector) which implies that housing associations have to achieve a certain average energy performance at the end of 2020. This covenant is prepared in 2008 and is adapted in 2012 as a part of the Energieakkoord and undersigned by the ministry of home affairs, national organization of housing associations Aedes, the Woonbond (organization for tenants) and Vastgoedbelang, the association of private investors in real estate. Another regulation that has influence on the sustainable transformation is the "Herzieningswet voor woningcorporaties" (revision Act for housing associations). This law requires performance agreements of the housing associations for the next five years and can enhance the awareness and process towards energy neutral.

2. *What is the trend of the average energy performance of housing associations; Which factors are responsible for this process, what barriers and potentials can be determined?*

The process is going too slow, the Convenant Energiebesparing Huursector seems not to be feasible. Barriers and potentials for this acceleration are found in different areas; the organization of housing associations, governmental regulations, technical barriers and the societal environment. The housing associations are seen as a barrier for the following reasons; some organizations are large and therefor it is difficult to realize major changes in the daily routine and management decisions; there is a lack of trust in partners and or techniques, therefor is always chosen for existing options; their scope is very short, this short-sighted approach result in short-term decisions which can be obstructive on the long term. Another barrier that is indicated is that some rules and regulations such as the Property Tax were made that housing association had to adapt their focus on the core tasks. Some indicate as a solution that the government has to make laws that condition instead of prescribing. Also the construction sector is blamed for the slow process, that there are not enough applicable and affordable products to make a house energy neutral. Because different barriers are experienced, the solutions are seen as well in different areas. Solutions are found in organization of housing associations, legislation of government, and the innovation of builders and the behavior of tenants. Different approaches are applied, one looks at the physical home and lets residents' behavior omitted while the other acts particularly from the interests of the resident. This division in potentials and also in the right renovation strategy might lead to inefficiency and indistinctness towards housing association. Insight is needed in which renovations strategy is most suitable for the housing stock of a housing association looking at the long term.

3. *What is the trend of the techniques used for sustainable renovation; is new knowledge expectable?*

Developments are expected in the installations, so it might be useful to focus on that. Therefor strategy 2 is the best strategy so the most efficient installations can be implemented. Trends are found in innovation of currently used systems. For example, PV-panels are becoming less expensive and more efficient which can accelerate the use of it and thereby the sustainable transformation. The Stroomversnelling of the Energiesprong implies a renovation at once with prefab elements that can be applied to the existing house. This process is still being developed so much can be expected of this project.

4. *Which strategies can be applied for sustainable renovation?*

According to the Trias Energetica these renovation strategies have been created and applied on the dataset of a housing stock of a carefully selected housing association that represents a general Dutch housing association. The following three strategies represent the approaches used nowadays and used in this research: regular maintenance (1), stepwise (2) and at once (3). Strategy 1 implies regular maintenance, strategy 2 achieves the predefined goal of energy neutral in two steps and strategy 3 achieves an energy neutral housing stock by implementing the renovation measures at once.

5. *What are the effects of the strategies for the average energy performance of housing associations?*

Applying renovation strategy 1 does not result in an energy neutral housing stock, strategy 2 and 3 do result in an energy neutral housing stock. Strategy 3 is more expensive than 2, but the advantage of strategy 3 is that it immediately can take the benefits of the energy savings. On the other hand strategy 2 can take advantage of the still developing installations which enhances the efficiency and decreases the costs. Therefor strategy 2 is the most suitable strategy for the case study. The investments can be spread and advantage can be taken of the increasing efficiency and the decreasing costs of installations. Next to that it fulfills all the requirements of the laws, the Convenant Energiebesparing Huursector as well as the Energieakkoord. Strategy 3, based on the plans of the Energiesprong is not yet a good alternative in a financial perspective. As already discussed, this research applies a generic approach; a housing association might chose for a multitrack strategy and can for example use different strategies for different houses.

## 5.1. Societal relevance

This research has indicated the barriers and potentials by conducting extensive literature review and interviews with experts. The context and its problems are made clear which can contribute to an improvement and acceleration of the process. The results of this research makes housing associations aware of the need of a proper renovation strategy for which a long term vision is required. The provided insight created with this research can therefore be used for housing associations in order to determine proper renovation strategies. This results eventually in a better environment in general. Houses are getting healthier, more comfortable and more affordable.

The results of this research concerning the case study can be applied on other housing associations in the Netherlands when the following aspects are taken into account. The research applies a generic strategy for all houses, therefor caution is needed for interpret and compare the results of the case study. Important is to have an overview of the housing types within a housing stock and the location, this might influence the possibilities of implementing installations. For instance, a housing association in a large city with many multifamily houses requires another renovation approach than an association with many single family houses on the countryside. Important as well are the demographic characteristics of the location, whether it is a shrinking region or that the population is increasing.

The application of this research to other countries is possible but might be difficult. Other weather circumstances are related to different renovation measures and other products. Next to that, the housing market in the Netherlands is quite different, 31 percent of the houses in the Netherlands belongs to the social housing sector; for example, in France this percentage is 17 (InfoNu, 2012).

It might be difficult to translate this research to the private housing market. The scale on which this research is adapted is too large and therefor to general in order to compare it with an individual house. Of course the defined renovation strategies are applicable and can be used for private housing.

## 5.2. Scientific relevance

The research uses another approach than previous researches. Previous researches were focused specific on techniques or specific housing types. This research is focused specific on the housing associations and will give them insight in a generic policy that can be applied. Therefor interviews have been conducted in order to obtain a general image of the problem, indicating its barriers and potentials using an Ishikawa-diagram. Based on that information renovations strategies for the long term have been defined, this long term approach is not common in the field and therefor added value. With use of VABI results have been generated which are discussed taking into account the external factors.

## 5.3. Beneficiary relevance

This research can be used by Atriensis for advising housing associations about renovation strategies for making the housing stock energy neutral. More and more the question raises within housing associations how to improve their housing stock energetically, some even have stated a goal to have an energy neutral housing stock somewhere in the future. Because this research has examined the consequences of a renovation strategy in a longer timespan than the scope that is commonly used, this research might help to determine what barriers have to be overtaken and which issues are important and require extra attention.

It can be concluded that the usability of Vabi is disputable; the software is not capable of calculating what an energy neutral house is and might be. It calculates with existing measures and techniques. Furthermore, it is not capable of calculating in a longer time spam towards energy neutral. Improved or new software is needed in order to be able to perform such a research in which energy neutral is the goal.

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# 7. Appendices

### Table 7.1: Overview of the interviews

| Interviewee | Strategy | Motivation | Energy neutral house |
|---|---|---|---|
| **Ministry of Home Affairs<br>Prisca Meesters<br>Niek Benschop** | Big steps | Depends on the step one wants to make. Big steps, achieve as much as possible. | Apply it when it is possible. If not, think about how eventually NOM can be achieved. |
| **RVO (Netherlands Enterprise Agency)<br>Constan Custers** | Multi track strategy | Be aware of the current situation and determine a goal so you can make the right investments towards 2050. | NOM is not the only solution. Important is to have flexible concepts. |
| **Aedes (national association of housing associations)<br>René van Genugten** | Big steps | Big steps, does not necessarily have to be NOM.<br>Calculate the current state of energy performance.<br>If the goal of the covenant 2020 is not achievable and if other strategies have a better result in 2030, is that even better. | 60% of 2,4 million houses still require a renovation before 2020, so NOM is not the only solution, than the innovation has to go very fast. |
| **Platform31 (knowledge and network association)<br>Jan Willem van de Groep** | One big step | If you renovate to label B and you know that it last 30 years before a house gets another renovation, then the step towards energy neutral has to be made between 2030 and 2040. That is not a smart strategy, so everything has to be done to come up with solutions to make everything energy neutral at this moment. | In the coming 35 years there is only one moment to decide something about what to do with a house. When you exclude possibilities by choosing for a renovation towards label B, then you will have to make disinvestments in order to make the large step, and that step has to be done at once. |
| **Woonbond (national association of tenants)<br>Jaap van Leeuwen** | Multi track strategy | Not everything is possible simultaneously, so a multitrack strategy has to be performed.<br>Check the maintenance planning at which moments energy saving measures can be applied.<br>Make an analysis of your tenants in order to know what is expected and what to do to achieve that. | Is not yet affordable. |
| **Bouwhulpgroep (advice and architecture)<br>Haico van Nunen** | Multi track strategy | In subparts a high level has to be achieved immediately because eventually energy neutral is the goal. Important is to know what you want to have in 20 years. It is about getting clear what the goal is for 2050, which is the same for the Stroomversnelling and the other strategies, but the road towards that goal is different. | There is a limited target group of houses which are suitable for an at once renovation, for instance the houses which have not had much maintenance in recent years. But for the vast majority of which in recent year maintenance has taken place, it is destruction of capital when you will make it energy neutral at once, then you will throw all the performed maintenance away, in those cases a stepwise strategy is needed. |
| **Woonbond (national association of tenants)<br>Onno van Rijsbergen** | Multi track strategy | Think carefully what has to be done when renovating a house. Do not only focus on a renovation towards label B, but think broad. | The question is whether NOM is the only solution. It is impossible to renovate all houses at once to energy neutral, it goes with different concepts and thus several strategies at the same time.<br>Another question is whether energy neutral is the goal. It is a part of the goal, the other part is a comfortable, healthy and pleasant house. Is an energy neutral house as well comfortable, healthy and pleasant? If not, than it is a waste of money. |
| ***Conclusion*** | | *Same goal, different routes: at once, in big steps or stepwise.* | *In general NOM is not seen as something negative. The majority agrees on that NOM has to be applied when possible. One group states that other strategies are also suitable as long as there is thought forward.* |

| Interviewee | Barriers | Solutions |
|---|---|---|
| **Ministry of Home Affairs Prisca Meesters Niek Benschop** | Energy savings are not integrated in the business process of housing associations. | Collaboration of parties.<br>Innovation of techniques. |
| **RVO (Netherlands Enterprise Agency) Constan Custers** | Housing associations want less company costs, reduce risks and concentrate on the core business.<br>There are more barriers than stated in the report of Companen (Claessens, 2014). | Individual agreements with housing associations.<br>Integrating energy saving into strategic stock management. |
| **Aedes (national association of housing associations) René van Genugten** | Directors.<br>(Financial) position.<br>Difficult housing types.<br>Property tax (Verhuurdersheffing).<br>Legal regulations ruin enthusiasm. | Integrate the energy performance in the strategic stock management.<br>Innovation of techniques.<br>Make the housing associations aware of the importance of energy saving. |
| **Platform31 (knowledge and network association) Jan Willem van de Groep** | People.<br>Organization.<br>Unconscious incompetence.<br>Housing associations think they have to come up with own solutions.<br>Existing solutions are being configured.<br>Sustainability is not integrated into policy.<br>Prescribing laws instead of conditioning. | Industrialization, challenge the construction sector to innovate and industrialize.<br>Model from the concept and check if the solutions or materials do exist or have to be developed.<br>Laws that condition and not prescribe. |
| **Woonbond (national association of tenants) Jaap van Leeuwen** | NOM is not yet affordable. | Long-term strategy for the housing stock.<br>Housing associations must comply with the following point: social moderate rent policy and the ability to continue to invest in sustainability. |
| **Bouwhulpgroep (advice and architecture) Haico van Nunen** | The scope a housing association has with a complex, looking beyond 20 years is difficult.<br>Technically there are many possibilities, but the conditions determine whether a house will be renovated in a sustainable way.<br>Laws have been adapted specific for NOM and not for the other strategies while the same goal is being strived. | We are not looking for how to make a house energy neutral because that is possible. The question is how it will be applied, and how can be ensured that what is promised will also be true. It is important how the tenant lives up to the consequences of the renovation, and how the housing association deals with that. |
| **Woonbond (national association of tenants) Onno van Rijsbergen** | Housing association combine easy measures in order to achieve label B.<br>There are many different departments within a housing association which makes it difficult to make energy saving an integral part.<br>Many associations do not communicate with their tenants.<br>The overview is difficult to control, sometimes previously set resources or subsidies by the government are rejected, which can cause troubles in a long term renovation strategy. | Techniques can be applied standardized but that is not possible with concepts. Therefor it should be approached from the location and the people.<br>Involve the people in the process, which measures fit with the experience of the tenant, how can that experience be improved and what else can be achieved.<br>The experience of the tenant must be taken seriously. A house that is not pleasant or comfortable is not sustainable. A tenant might move out which results in much mutation which gives extra expenses. |
| ***Conclusion*** | *There are different opinions about the barriers, certain factors are recognized by one as a barrier and rejected by others.*<br>*Factors are: operational process, company costs, directors, finance, housing types, property tax, regulations, unconscious competence, accountability, affordability NOM, scope, conditions, large organizations, communications tenants, overview.* | *Opinions about the solutions differ as a result of the different views on the barriers. Solutions are therefore directed to different parties; government, housing associations, construction sector and tenants.*<br>*Another difference in approach is that some parties focus on the physical home and omit tenants' behavior while other parties underline the importance of the tenants.* |

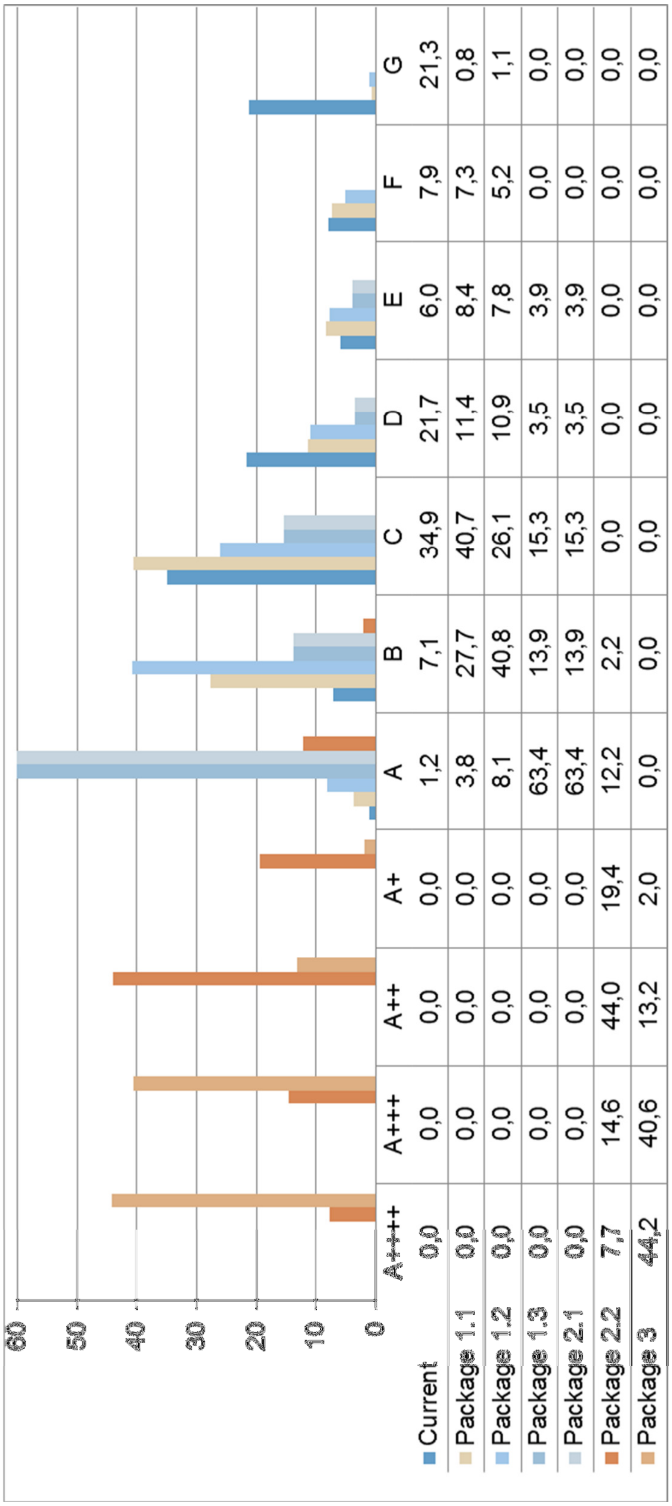
| Interviewee | Convenant Energiebesparing Huursector 2020 |
|---|---|
| **Ministry of Home Affairs**<br>**Prisca Meesters**<br>**Niek Benschop** | The signatories adhere to the covenant, but the real executive parties are not really integrated.<br>Research shows that not each housing association is really aware of covenant. |
| **RVO (Netherlands Enterprise Agency)**<br>**Constan Custers** | |
| **Aedes (national association of housing associations)**<br>**René van Genugten** | Important aspects of the covenant: awareness of support for sustainable renovation, dot on the horizon, obligation to do something about sustainability.<br>Covenant is outdated and requires recalibration. |
| **Platform31 (knowledge and network association)**<br>**Jan Willem van de Groep** | The covenant suggests a limitation that is only looking five years ahead, and that decisions are based on a goal which never should have been a goal, the goal should be energy neutral in 2050. |
| **Woonbond (national association of tenants)**<br>**Jaap van Leeuwen** | |
| **Bouwhulpgroep (advice and architecture)**<br>**Haico van Nunen** | |
| **Woonbond (national association of tenants)**<br>**Onno van Rijsbergen** | The covenant might be a reasonable goal in the perspective of the end goal, but that those goals are not linked to each other which is shortsighted.<br>Legislation is needed, but if the focus is only on regulations, it runs behind the developments and will act as a reactive rule. |
| ***Conclusion*** | *The covenant has made the housing associations aware of the energy saving, but might be considered as an outdated goal and may work obstructive for the overall goal of energy neutral in 2050.* |

**Table 7.2: Outcomes measures indivually**

| Measure | Description | Energy-index | Energy-index measure | Energy-index improvement | Number of Houses improved | Number of units | Unit |
|---|---|---|---|---|---|---|---|
| **M1** | Insulate floors with little or no insulation | 2,1 | 2,07 | 0,03 | 1790 | 88003 | $m^2$ |
| **M2** | Insulate flat roofs with little or no insulation | 2,1 | 2,09 | 0,01 | 166 | 10680 | $m^2$ |
| **M3** | Insulate pitched roofs with little or no insulation | 2,1 | 2,03 | 0,07 | 1362 | 74466 | $m^2$ |
| **M4** | Insulate walls with little or no insulation, indoor or outdoor | 2,1 | 1,93 | 0,17 | 2375 | 100255 | $m^2$ |
| **M5** | Insulate cavity walls with little or no insulation | 2,1 | 1,89 | 0,21 | 2553 | 113073 | $m^2$ |
| **M6** | Insulate panels | 2,1 | 2,1 | 0 | 52 | 218 | $m^2$ |
| **M7** | Insulate cavity wall panels | 2,1 | 2,09 | 0,01 | 736 | 3141 | $m^2$ |
| **M8** | HR++ glazing for single glazing or glazing with U>5 | 2,1 | 2,04 | 0,06 | 1202 | 21901 | $m^2$ |
| **M9** | Triple glazing for all other types of glazing or glazing with U>1,75. Replace all windows | 2,1 | 1,85 | 0,25 | 3062 | 52822 | $m^2$ |
| **M10** | HR107 boilers in individual and collective systems | 2,1 | 2,05 | 0,05 | 629 | 629 | house |
| **M11** | Heat pump electric in all individual systems, outside air, auxiliary gas HR107 | 2,1 | 2,05 | 0,05 | 466 | 466 | house |
| **M12** | Ventilation: Mechanical exhaust, CO2-controlled individual ventilation, DC (Direct Current) | 2,1 | 2,07 | 0,03 | 3062 | 3062 | house |
| **M13** | Sun boiler | 2,1 | 1,96 | 0,14 | 2594 | 2594 | house |
| **M14** | 12 PV-panels (19,2m2) | 2,1 | 1,64 | 0,46 | 3062 | 3062 | house |
| **M15** | Insulated door | 2,1 | 2,07 | 0,03 | 3062 | 4315 | house |
| **M16** | 27 PV-panels (43,2m2) (Stroomversnelling) | 2,1 | 1,12 | 0,98 | 3062 | 3062 | house |

**Table 7.3: Costs per measure**

| Measure | Description | Unit | Price per unit inclusive VAT | Number of units that are adapted | Number of units per house | Total costs (in million inclusive VAT) |
|---|---|---|---|---|---|---|
| **M1** | Insulate floors with little or no insulation | $m^2$ | € 35 | 88003 | 28,7 | € 3,1 |
| **M2** | Insulate flat roofs with little or no insulation | $m^2$ | € 70 | 10680 | 3,5 | € 0,7 |
| **M3** | Insulate pitched roofs with little or no insulation | $m^2$ | € 180 | 74466 | 24,3 | € 13,4 |
| **M4** | Insulate walls with little or no insulation, indoor or outdoor | $m^2$ | € 120 | 100255 | 32,7 | € 12,0 |
| **M5** | Insulate cavity walls with little or no insulation | $m^2$ | € 20 | 113073 | 36,9 | € 2,3 |
| **M6** | Insulate panels | $m^2$ | € 150 | 218 | 0,1 | € 0,0 |
| **M7** | Insulate cavity wall panels | $m^2$ | € 150 | 3141 | 1,0 | € 0,5 |
| **M8** | HR++ glazing for single glazing or glazing with U>5 | $m^2$ | € 250 | 21901 | 7,2 | € 5,5 |
| **M9** | Triple glazing for all other types of glazing or glazing with U>1,75. Replace all windows | $m^2$ | € 500 | 52822 | 17,3 | € 26,4 |
| **M10** | HR107 boilers in individual and collective systems | house | € 10.500 | 629 | 0,2 | € 6,6 |
| **M11** | Heat pump electric in all individual systems, outside air, auxiliary gas HR107 | house | € 23.500 | 466 | 0,2 | € 11,0 |
| **M12** | Ventilation: Mechanical exhaust, CO2-controlled individual ventilation, DC (Direct Current) | house | € 3.700 | 3062 | 1,0 | € 11,3 |
| **M13** | Solar water heater | house | € 2.750 | 2594 | 0,8 | € 7,1 |
| **M14** | 12 PV-panels (19,2m2) | house | € 4.200 | 3062 | 1,0 | € 12,9 |
| **M15** | Insulated door | house | € 380 | 4315 | 1,4 | € 1,6 |
| **M16** | 27 PV-panels (43,2m2) (Stroomversnelling) | house | € 9.600 | 3062 | 1,0 | € 29,4 |



| | A++++ | A+++ | A++ | A+ | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Current | 0,0 | 0,0 | 0,0 | 0,0 | 1,2 | 7,1 | 34,9 | 21,7 | 6,0 | 7,9 | 21,3 |
| Package 1.1 | 0,0 | 0,0 | 0,0 | 0,0 | 3,8 | 27,7 | 40,7 | 11,4 | 8,4 | 7,3 | 0,8 |
| Package 1.2 | 0,0 | 0,0 | 0,0 | 0,0 | 8,1 | 40,8 | 26,1 | 10,9 | 7,8 | 5,2 | 1,1 |
| Package 1.3 | 0,0 | 0,0 | 0,0 | 0,0 | 63,4 | 13,9 | 15,3 | 3,5 | 3,9 | 0,0 | 0,0 |
| Package 2.1 | 0,0 | 0,0 | 0,0 | 0,0 | 63,4 | 13,9 | 15,3 | 3,5 | 3,9 | 0,0 | 0,0 |
| Package 2.2 | 7,7 | 14,6 | 44,0 | 19,4 | 12,2 | 2,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Package 3 | 44,2 | 40,6 | 13,2 | 2,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

**Figure 7.1: Division of energy labels in percentage**