Dutch social housing associations' route towards 2050: establishing an assisting tool for the prioritization of dwelling complexes

"The factors influencing the pace of energy efficiency renovations and the prioritization and planning by Dutch social housing associations"

van der Hagen, Joost L.

Award date:
2022

Dutch social housing associations' route towards 2050: establishing an assisting tool for the prioritization of dwelling complexes

"The factors influencing the pace of energy efficiency renovations and the prioritization and planning by Dutch social housing associations"

Author: J.L. van der Hagen

Student number: 1497944

Graduation program: Urban Systems & Real Estate (7Z45M0)

Date: 28-08-2022

Graduation committee:

Prof. Dr. T.A. (Theo) Arentze	TU/e
Ir. S.J.E. (Stephan) Maussen MRE	TU/e
Ir. D.J. (Dyon) Noy	Atriensis b.v.

Colophon

Title: Dutch social housing associations' route towards 2050: establishing an assisting tool for the prioritization of dwelling complexes

Sub-title: The factors influencing the pace of energy efficiency renovations and the prioritization and planning by Dutch social housing associations

Key-words: *Dutch social housing associations, energy efficiency renovation pace, Multicriteria-Analysis, Analytical Hierarchy Process, interviews, determinants of interest, carbon-neutrality, The Standard, a prioritization model, Roadmap, prioritization, dwelling complexes*

Student

Author: Joost Leonardo van der Hagen

Student ID: 1497944

Mail: j.l.v.d.hagen@student.tue.nl / joostvdhagen@live.com

University

University: Eindhoven University of Technology

Address: 5612 AZ Eindhoven

Program

Department of the Built Environment

Master: Architecture, Building and Planning

Master Track: Urban Systems & Real Estate

Course code: 7ZW4M0

Study load: 45 ECTS

Period: Academic year 2021-2022

Graduation committee

First supervisor: Prof. Dr. T.A. (Theo) Arentze

The Built Environment

Real Estate and Urban Development

T.A.Arentze@tue.nl

Second supervisor: Ir. S.J.E. (Stephan) Maussen MRE

The Built Environment

Real Estate and Urban Development

S.J.E.Maussen@tue.nl

Company supervisor: Ir. D.J. (Dyon) Noy

Atriensis B.V.

Preface

The past nine months have flown by. Looking back on periods with visible results after a significant amount of work, are often great moments of satisfaction for me. And so too, is the end of my master thesis at TU/e. Prior to the research, I only knew the tip of the iceberg regarding the world of social housing associations within the Netherlands. I can proudly say that during my graduation project I have learned a great deal about one of the most important fields within Dutch real estate.

Although it sometimes felt as if I found myself in an ocean of constantly new and deeper information, I have managed to navigate my way through the forest of relevant research topics related to the Dutch social housing sector. It feels a bit like firstly diving into the deep-end and then learning how to inflate your floaties. I would like to offer my gratitude to the people who have helped me with this in the past period.

I would like to thank Dyon Noy, Atriensis' company supervisor, for his excellent guidance. Thanks to your help, I have managed to establish a concrete topic of research relevant to both real-life practice and the university. Further thanks for being a very helpful conversation partner. If Dyon doesn't know the answer to one of my questions, then probably not many other experts within his field do.

Furthermore, I would like to thank Theo Arentze for the consistent guidance throughout these months, the return of extensive and concrete feedback, and not to forget to mention the very fast response time. Additional thanks to Stephan Maussen for also accompanying my research and for providing feedback, functioning as the supervisor taking both the university's perspective as the real-life practice's perspective into consideration.

Finally, I would like to thank my father, brother, girlfriend, and all my closest friends for their continuous support. Not only during my graduation, but also during all the years before and in the years to come.

I am proud to offer my thesis for the reader's own amusement, inspiration and as additional knowledge on the complex and difficult transition that awaits the entire sector. The social housing sector will have to face an enormous task in the coming years, with limited strength. I hope that, like me, the reader wishes to make a positive contribution to this task so that in 100 years' time, we will still be able to enjoy the world as we know it.

I wish you much reading pleasure.

Kind regards,

Joost van der Hagen

Samenvatting

Introductie

De Nederlandse regering heeft het doel gesteld om in 2050 volledig CO_2-neutraal te zijn (De Nederlandse Coalitie, 2021). Vergeleken met het CO_2-uitstootniveau van 1990 moet 60% worden gereduceerd als een tussentijdse doelstelling voor 2030. De Nederlandse sociale woningsector, die ongeveer 29% van de woningvoorraad bezit en waarvan de helft van de woningen voor 1980 is gebouwd (Aedes, 2019), heeft een belangrijke verantwoordelijkheid in het bereiken van een CO_2-neutrale gebouwde omgeving.

Onderzoeksvragen

De sector staat voor een enorme opgave om hun bestaande woningvoorraad energie-efficiënt te maken. Onderzoek naar de factoren die van invloed zijn op de besluitvorming over energiezuinige investeringen door sociale woningcorporaties binnen Nederland en wereldwijd, ontbreekt en is niet meer van deze tijd. De mate waarin deze factoren van invloed zijn, gezien vanuit het perspectief van de sociale woningcorporaties en niet vanuit het perspectief van de huurders, is een onderzoek hiaat waar dit afstudeeronderzoek op inspeelt.

Dit onderzoek is gericht op het verklaren van de factoren die van invloed zijn op het tempo van energiezuinige renovaties, om te achterhalen wat Nederlandse sociale woningcorporaties drijft en belemmert in het bereiken van hun toekomstige doelstellingen. De vraagstelling van de scriptie ligt tevens in welke determinanten op dit moment worden meegewogen bij de prioritering van energiezuinig te maken wooncomplexen, en om de grootte van hun invloed te identificeren. De vastgestelde determinanten en de grootte van hun invloed kunnen dan gebruikt worden voor het opstellen van een prioriteringsmodel. Het model zou een theoretisch onderbouwde prioritering van woningen bieden en daarmee kunnen bijdragen aan een snellere actualisering van de woningportefeuilles van Nederlandse woningcorporaties.

De hoofdvraag van dit onderzoek luidt als volgt:

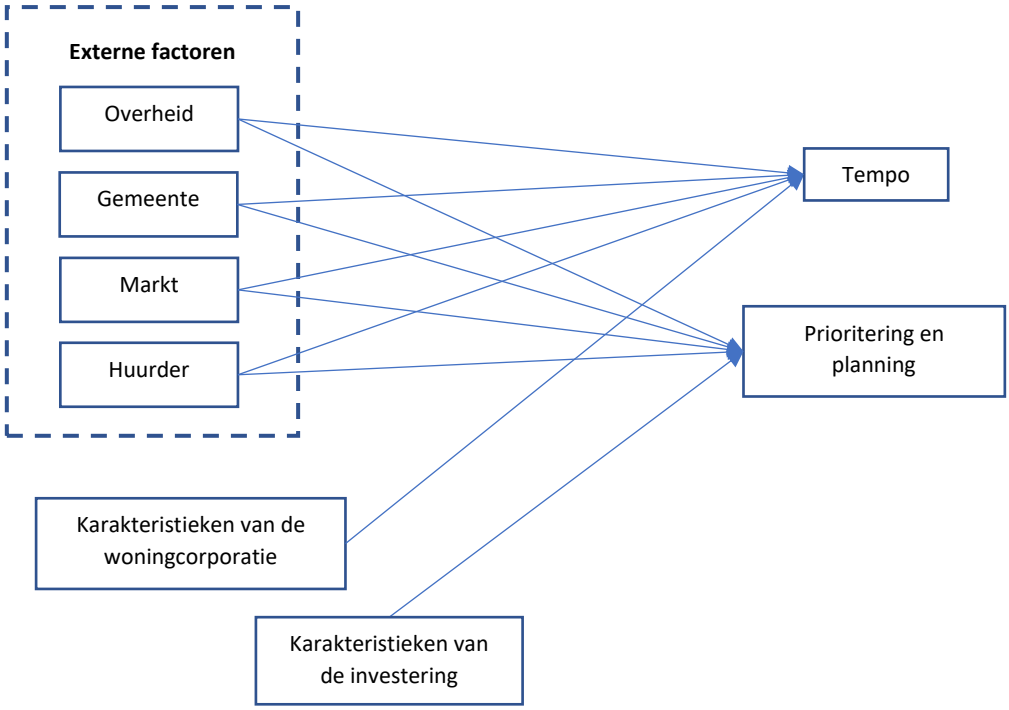
"Wat zijn de factoren die van invloed zijn op het tempo waarin woningcorporaties hun bestaande woningvoorraad energiezuinig maken en wat zijn de determinanten van invloed voor de prioritering van complexen door middel van een model?"

Daarnaast worden vijf bijbehorende deelvragen onderzocht om de hoofdvraag te helpen beantwoorden. De sub-vragen luiden als volgt:

1. Wat zijn de randvoorwaarden voor het energiezuinig maken van een bestaande woning?
2. Welke factoren zijn van invloed op het renovatietempo van woningcorporaties op het gebied van energiezuinigheid?
3. Wat zijn de determinanten die de prioritering en planning beïnvloeden?
4. Wat is de grootte van de invloed (gewicht) van de determinanten op de prioritering en planning?
5. In welke mate kan een model de planning en prioritering van energie-efficiënte renovaties door een woningcorporatie voorspellen?

De literatuur heeft een eerste basis geboden voor de determinanten die van belang zijn voor de prioritering van wooncomplexen die energie-efficiënt gemaakt dienen te worden. Daarnaast zijn toekomstige regelgevingseisen omtrent: *De Standaard*, de *Transitievisie Warmteplannen* van gemeenten en de afschaffing van slechte *Energielabels* ook meegenomen als belangrijke factoren van invloed. Verder maken Nederlandse sociale woningcorporaties gebruik van een *Routekaart* waarin

duurzaamheidsgerelateerde ingrepen in de tijd naar 2050 worden uitgezet, relevant voor veranderingen binnen hun woningportefeuilles. De determinanten van belang binnen *De Routekaart* bieden daarom aanvullend de determinanten die relevant zijn voor de prioritering en planning van woningen. De determinanten volgend uit de literatuurstudie, de toekomstige regelgevingen en De Routekaart, zijn gegroepeerd in overkoepelende onafhankelijke variabelen die van invloed zijn op beide afhankelijke variabelen: *Tempo* en de *Prioritering en planning*. De relaties tussen de onafhankelijke variabelen en de afhankelijke variabelen worden door middel van dit onderzoek onderzocht. De onafhankelijke en afhankelijke variabelen zijn weergegeven in het conceptuele model van de scriptie, weergegeven in figuur 1.



Figuur 1: Het conceptueel model van het onderzoek

De relatie tussen de factoren die van invloed zijn op het *Tempo* is onderzocht door middel van interviews, die kwalitatieve informatie opleveren. De criteria die van belang zijn voor de *Prioritering en planning* zijn ook vastgesteld door middel van interviews. De gewichten van de criteria worden vervolgens bepaald door middel van het *Analytisch Hiërarchie Proces,* met behulp van paarsgewijze vergelijkingen, als de toepasselijke Multicriteria-Analyse techniek. Aldus wordt kwantitatieve informatie verkregen die relevant is voor een prioriteringsmodel.

Voorbereiding van de interviews

Elf deskundigen van verschillende grootte van sociale woningcorporaties in Nederland zijn geïnterviewd. De interviews bestonden uit twee delen.

Tijdens deel I van het interview werd een gestructureerde lijst van vooraf gedefinieerde vragen gesteld om de variabelen te onderzoeken die relevant zijn voor het *Tempo* van de woningcorporaties. De deskundigen werd gevraagd naar de invloed van elk van de vooraf gedefinieerde factoren en om een onderbouwing van hun redenering te geven. De interviews hadden een open karakter, met open vragen en open antwoorden.

Deel II van het interview had als doel het bepalen van de vijf belangrijkste criteria voor het maken van een *Prioritering en planning*, te achterhalen uit een lijst van 20 vooraf vastgestelde criteria. De lijst met 20 criteria werd voorafgaand aan de interviews aan de deskundigen toegestuurd, waarbij hen werd gevraagd alvast hun vijf belangrijkste en hun vijf minst belangrijke criteria op te geven. Hun argumentatie en onderbouwing van de keuzes werden verder besproken tijdens de interviews. De meest gekozen criteria resulteerden in een lijst van de uiteindelijke belangrijkste en minst belangrijke criteria voor het maken van een prioritering en planning.

De deskundigen kregen een vervolgenquête toegestuurd om de gewichten (de belangrijkheid) van de vijf belangrijkste criteria vast te stellen en om bovendien de voorkeursscores van de categorische opties per criterium vast te stellen. Om de gewichten van de criteria te bepalen, werd de deskundigen gevraagd om elk van de vijf belangrijkste criteria paarsgewijs te vergelijken met de andere criteria, met betrekking tot hun belang voor de overkoepelende doelstelling: Het bereiken van een prioritering en planning naar CO_2-neutraliteit tegen 2050, in overeenstemming met De Standaard. De vraag die per paarsgewijze vergelijking werd gesteld was dan ook:

> *"Als u een routekaart zou moeten maken in overeenstemming met 'De Standaard' naar CO_2-neutraliteit in 2050, welk criterium zou u dan belangrijker vinden en hoeveel belangrijker?"*

Om de voorkeursscores voor elke categorische optie per criterium te bepalen, werd de deskundigen gevraagd 100 punten te verdelen over de categorische opties die bij het criterium hoorden, in verhouding tot hun voorkeur. Hoe hoger de score, hoe sterker de voorkeur. De gestelde vraag luidde dan als volgt:

> *"Hoe sterk is uw voorkeur voor elk van de categorische opties per criterium voor het energiezuinig te maken wooncomplex? U heeft 100 punten te verdelen over de categorische opties per criterium."*

De resultaten van deel II leveren kwantitatieve informatie op, die als input wordt gebruikt voor de opstelling van een prioriteringsmodel.

Resultaten & Conclusies

Interviews

Uit de resultaten van deel I van de interviews blijkt dat de *Overheid* als neutraal wordt ervaren. Dit betekent dat de meningen enigszins verdeeld zijn over de invloed van de overheid op het tempo van energie-efficiënte renovaties van woningcorporaties. De meest genoemde redenering van de deskundigen voor de perceptie dat de overheid geen invloed heeft, is dat woningcorporaties hun eigen koers varen. Zij zeggen te werken met de middelen en financiën die zij hebben. Of de overheid hen nu verplicht om meer te doen of niet, zij kunnen met hun beschikbare (financiële) middelen slechts een beperkte hoeveelheid werk verrichten. Anderzijds zegt de helft van de deskundigen sterk beïnvloed te worden door vertragende wet- en regelgeving en aangescherpte verplichtingen.

De *Gemeente* werd door meer deskundigen als van invloed beschouwd dan niet. Zij stellen dat een algemeen gebrek aan capaciteit bij de gemeenten leidt tot stroperige, langdurige en tijdrovende processen. Alle deskundigen waren het erover eens dat de *Markt* van invloed is op hun tempo. Voornamelijk door een gebrek aan capaciteit bij externe partijen, een gebrek aan materiaal, materieel en personeel en daarnaast door de stijgende kosten.

De *Huurder* wordt ervaren als een beïnvloedende factor op het tempo waarin de woningcorporaties hun bestaande woningvoorraad energie-efficiënt kunnen maken. Over het algemeen wordt gesteld dat de verplichting om de instemming van 70% van de huurders te verkrijgen voor de renovatie van wooncomplexen zeer tijdrovend is. Soms resulterend in langere processen dan gewenst.

Tenslotte werden de kenmerken van de woningcorporatie door alle deskundigen als een beïnvloedende factor beschouwd. Hun bestuur speelt een belangrijke rol wat betreft hun tempo. Zij bepalen waaraan elke euro wordt besteed. Aangezien elke euro maar één keer kan worden uitgegeven, bepalen zij het tempo waarin de woningcorporaties haar bestaande woningvoorraad energiezuinig gaat maken.

De resultaten van deel II van de interviews leverden de lijst op van de meest en ook minst belangrijke criteria, die relevant zijn voor de prioritering en planning van de energiezuinig te maken wooncomplexen. Vanwege het scoren van een gelijk aantal punten zijn uiteindelijk zeven criteria het belangrijkst, weergegeven in Tabel 1.

Categorieën	Criterium	Punten
Interne factoren	Strategie woningportefeuille	8
Staat van de woning	Trias energetica	8
Staat van de woning	Koppeling met planmatige renovatie	8
Staat van de woning	Energielabel	6
Staat van de woning	Koppeling met planmatig onderhoud (componenten niveau)	5
Externe factoren	Transitievisie warmte van gemeente	5
Interne factoren	Financiële mogelijkheden op korte/lange termijn in relatie tot opgave	5

Tabel 1: De meest belangrijke criteria voor het maken van een prioritering en planning

De zes minst belangrijke criteria voor de prioritering en planning van energie-efficiënt te maken wooncomplexen zijn weergegeven in Tabel 2.

Categorieën	Criterium	Punten
Interne factoren	Positionering in energietransitie	-9
Externe factoren	Subsidies op product	-7
Externe factoren	Marktinvloeden	-7
Interne factoren	Input belanghouders	-4
Staat van de woning	Bouw- of renovatiejaar	-4
Externe factoren	Ontwikkelstadium techniek	-4

Tabel 2: De minst belangrijke criteria voor het maken van een prioritering en planning

Vervolgvragenlijst

Wegens overlapping van criteria en om het aantal paarsgewijze vergelijkingen binnen proporties te houden, zijn sommige criteria samengevoegd, wat heeft geleid tot een definitieve lijst van de vijf belangrijkste criteria. Het criterium *Koppeling met planmatig onderhoud (componenten niveau)* is samengevoegd met *Koppeling met planmatige renovatie* tot *Het Proces waarbinnen de verduurzaming van het complex plaatsvindt*. Het criterium *Trias energetica* is samengevoegd met *Energielabel* tot *Gemiddelde bestaande energetische kwaliteit van het energiezuinig te maken complex*. Om het gewicht van de criteria te bepalen, worden zij door de deskundigen paarsgewijs vergeleken door middel van een follow-up-enquête. Vervolgens werd de deskundigen gevraagd hun voorkeur aan te geven voor de categorische opties die bij elk criterium hoorden. De gewichten van de criteria en de voorkeursscore per categorische optie is weergegeven in Tabel 3.

Gewichten (criteria) en voorkeursscores (categorische opties)	Criteria met bijbehorende categorische opties
47,9%	**Strategie woningportefeuille van te verduurzamen complex**
25	Vervangende nieuwbouw (sloop en nieuwbouw)
11	Verkoop bij mutaties
5	Complexgewijze verkoop
17	Doorexploitateren
42	Ingrijpend renoveren/ herstructureren
16,1%	**Gemiddeld bestaande energetische kwaliteit van te verduurzamen complex**
46	Slechte energetische kwaliteit (energielabels E, F en G)
33	Matige energetische kwaliteit (energielabels C en D)
19	Voldoende energetische kwaliteit (energielabels A, B)
3	Goede tot uitstekende energetishe kwaliteit (energielabels A+ en beter)
14,3%	**Proces waarbinnen de verduurzaming van het complex plaatsvindt**
20	Per afzonderlijke component verduurzaming op natuurlijk moment zoals planmatig onderhoud
17	Verduurzamingsingreep uitvoeren tijdens mutatie of op verzoek van klanten (per woning)
36	Alle afzonderlijke benodigde verduurzamingsmaatregelen in één ingreep voor een heel complex uiterlijk 2030, eventueel aangevuld met onderhoud en andere noodzakelijke zaken
29	Alle afzonderlijke benodigde verduurzamingsmaatregelen in één ingreep voor een heel complex na 2030, eventueel aangevuld met onderhoud en andere noodzakelijke zaken
13,1%	**Indicatief budget per te verduurzamen woning in euro's**
12	Indicatief verduurzamingsbudget per woning maximaal €10.000
26	Indicatief verduurzamingsbudget per woning €10.000 tot €30.000
47	Indicatief verduurzamingsbudget per woning €30.000 tot €50.000
16	Indicatief verduurzamingsbudget per woning meer dan €50.000
8,7%	**Transitievisie warmte van gemeente voor te verduurzamen complex**
18	Geen uitgesproken gebiedsvisie anders dan goed isoleren
12	Warmtenet uiterlijk 2030 (startwijk)
19	Warmtenet kansrijk na 2030
8	Elektrisch verwarmen uiterlijk 2030 (startwijk)
20	Elektrisch verwarmen kansrijk na 2030
15	Groen gas uiterlijk 2030 (startwijk)
8	Groen gas kansrijk na 2030

Tabel 3: Gewichten van criteria en de score van voorkeur voor de categorische opties

Prioriteringsmodel

De kwantitatieve resultaten van de vervolgvragenlijst met betrekking tot de paarsgewijze vergelijkingen en de voorkeursscores van categorische opties, worden gebruikt voor het opstellen van een prioriterings- en planningsmodel. Het model is in staat om wooncomplexen te prioriteren in overeenstemming met de vastgestelde gewichten van criteria en voorkeursscores van categorische opties en geeft daarmee een theoretisch onderbouwde prioritering van wooncomplexen. Een eerste prioritering is gemaakt met behulp van een Routekaart van een Nederlandse sociale woningcorporatie, die de vereiste kenmerken en informatie van 109 wooncomplexen bevat.

Vervolgens is een gevoeligheidsanalyse uitgevoerd om de gevoeligheid van de resultaten te beoordelen bij het aanbrengen van wijzigingen in de gewichten van de beoordelingen van de deskundigen. Vooralsnog heeft elke deskundige een gelijk gewicht van 1 gekregen en dus een gelijke bijdrage geleverd aan de weging van de criteria. Sommige deskundigen hadden echter minder kennis over het onderwerp van het onderzoek en de beoordeelde determinanten. Op basis van hun zelfperceptie van kennis, verkregen door het beantwoorden van een van de vooraf gedefinieerde vragen tijdens de interviews, zijn de gewichten van de beoordelingen van de deskundigen gewijzigd. Als de deskundige al een Routekaart gebruikte en De Standaard daarin verwerkte, werd zijn beoordelingsgewicht twee keer zo zwaar gewogen als dat van deskundigen die dat niet deden. In het geval dat slechts één van de twee van toepassing was, werd het oordeel van de expert 1,5 keer zo zwaar gewogen.

Een wijziging van de gewichten leidde tot een andere rangschikking, de resultaten zijn echter nauwelijks gevoelig voor een wijziging van de gewichten van de beoordelingen van de deskundigen. 33 van de 109 complexen veranderden niet van rangorde, 32 wooncomplexen veranderden met één prioriteitspositie en 17 complexen veranderden met twee prioriteitsposities. De overige 27 complexen veranderden met 3, 5, 6, 8, 9, 10, 13 of 14 posities.

Validatie van het model in de praktijk

Om te kunnen concluderen in hoeverre het prioriteringsmodel in staat is de planning en prioritering van energiezuinig te maken wooncomplexen te voorspellen, moet het model in de praktijk worden gevalideerd. Een eerste testronde is uitgevoerd middels het vergelijken van de prioriteitsrangschikking van het model met de prioriteitsrangschikking van een Routekaart. De Routekaart van de woningcorporatie waarvan ook de dataset is verkregen, wordt gebruikt ter vergelijking. Een vergelijking van de prioriteringen toonde aan dat het model de prioriteitsrangschikking van 7 van de 109 wooncomplexen correct heeft kunnen voorspellen en dus aanzienlijk verschilt van de prioriteitsrangschikking in de praktijk. Er moeten echter meer validaties worden uitgevoerd om conclusies te kunnen trekken over de logica en rationaliteit van de prioriteitsrangorde van het model, dan wel van de prioriteitsrangorde van De Routekaart.

Aanbevelingen

Aanbevelingen

De resultaten van de interviews boden hedendaagse inzichten met betrekking tot de factoren die van invloed zijn op het tempo, en de factoren die van invloed zijn op de prioritering en planning van Nederlandse sociale woningcorporaties. Het opgestelde model bevat de criteria en hun gewichten die op dit moment als belangrijk worden ervaren, het model is in staat gebleken een prioriteitsrangorde van wooncomplexen op te stellen en is bovendien methodologisch correct. De eerste aanbeveling is dan ook om het opgestelde prioriteringsmodel te gebruiken als een toevoeging op de huidige benadering van de prioritering en planning van wooncomplexen. Het model kan helpen bij het versnellen van de actualisatie van de woningportefeuille van een woningcorporatie.

De snelle ontwikkelingen binnen de Nederlandse sociale woningsector hebben echter geleid tot een aantal aanbevelingen met betrekking tot het gebruik van de resultaten van dit onderzoek.

De interviews zijn uitgevoerd in april en mei (2022) voorafgaand aan de publicatie van de Nationale Prestatieafspraken op 30 juni (2022). De Nationale Prestatieafspraken brengen belangrijke nieuwe verplichtingen met zich mee die tot andere resultaten van de interviews zouden kunnen leiden, als deze achteraf zouden zijn uitgevoerd. Uit deze opmerking vloeien twee aanbevelingen voort.

Ten eerste was de Transitievisie Warmte volgens de uitkomsten van dit onderzoek het minst belangrijke criterium van de vijf belangrijkste criteria (met een gewicht van slechts 8,7%). Gemeenten zijn volgens de Nationale Prestatieafspraken verplicht om in 2024 een duidelijke visie te hebben over wanneer, waar, welke ingreep gedaan gaat worden. Om zuinig en efficiënt met middelen om te gaan, is het aan te bevelen om de Transitievisie Warmteplannen van gemeenten sterker te heroverwegen binnen een prioriteitenstelling van wooncomplexen.

Ten tweede heeft de sector, in navolging van de Nationale Prestatieafspraken, de toezegging gedaan om in 2030 ongeveer een derde extra van de bestaande sociale woningvoorraad in overeenstemming te brengen met De Standaard. Uit de interviews bleek dat zeven van de elf deskundigen De Standaard niet hadden opgenomen, of beweerden geen ervaring te hebben met De Standaard. Het wordt ten zeerste aanbevolen om te beginnen met het leren over de gevolgen van, en te gaan werken met De Standaard, met betrekking tot veranderingen in de portefeuille, financiën, capaciteit etc.

Suggesties voor vervolgonderzoek

De eerste vervolgstap voor het vervolgonderzoek zou zijn om het model in de praktijk te valideren, door de prioriteringen van het model te vergelijken met reeds vastgestelde planningen en prioriteringen, zoals die van de Routekaarten. Op deze manier kunnen conclusies worden getrokken over de mate waarin het model in staat is om de planning en prioritering van wooncomplexen door Nederlandse sociale woningcorporaties te voorspellen. Verschillen in prioriteitsrangorde zouden ertoe kunnen bijdragen de logica van de prioriteitsrangorde van ofwel het model, ofwel die van de Routekaart onder de loep te nemen.

Verder zou toekomstig onderzoek een heroverweging van de criteria en hun gewichten moeten overwegen, als gevolg van de snelle ontwikkelingen binnen de sector, waaronder de Nationale Prestatieafspraken. Ten slotte wordt voorgesteld meer dan elf deskundigen te interviewen om de kracht van de resultaten te vergroten. Door meer experts te interviewen, na de publicatie van de Nationale Prestatieafspraken, kunnen nog actuelere gewichten van de criteria worden vastgesteld. Dit zal resulteren in een meer gevalideerd model en daarmee de rangschikking van prioriteiten van welke complexen als eerste in aanmerking komen om energie-efficiënt te worden gemaakt.

Discussie

Beperkingen

In de eerste plaats hebben de afzonderlijke wegingen van criteria door middel van paarsgewijze vergelijkingen soms de aanvaardbare drempelwaarde van 10% van de consistentieratio overschreden. Hoewel de algemene CR 3% bedroeg en dus aanvaardbaar was, kunnen sommige individuele wegingen toch nog onbetrouwbare resultaten opleveren.

Ten tweede ontbrak in de dataset, die als input voor het model werd gebruikt, specifieke informatie over het proces waarin het complex energie-efficiënt zal worden gemaakt, waardoor aannames moesten worden gemaakt. Dit resulteert in een minder betrouwbare prioriteitsrangschikking.

Ten derde geeft het model een rangschikking van prioriteiten waarbij alle maatregelen tijdens dezelfde interventie worden uitgevoerd. In werkelijkheid worden maatregelen echter niet altijd gelijktijdig uitgevoerd. Een prioritering van maatregelen zou ook het geval kunnen zijn. Het model dat uit dit onderzoek voortvloeit is dus een vereenvoudiging van de werkelijkheid, die een vereenvoudiging van de prioritering biedt.

Ten vierde worden in een Routekaart meerdere complexen binnen hetzelfde jaar gepland, maar wordt er geen specifieke rangorde van prioriteiten aangegeven. Dit betekent dat bijvoorbeeld de rangorde van 10 complexen in het jaar 2023 wordt gerangschikt van 1-10. Er wordt niet aangegeven of positie 1 een hogere prioriteit heeft dan positie 10. De vergelijking van de rangorde van prioriteiten in de Routekaart met de rangorde van prioriteiten in het model levert derhalve geen nauwkeurige resultaten op. De validatie van het model, door de planning en prioritering van een Routekaart in de praktijk te vergelijken, geeft dan ook geen exacte resultaten, eerder een indicatie.

Resultaten

Het is interessant om te zien dat de helft van de woningcorporaties zegt en ervaart dat de overheid geen invloed heeft op hun tempo. De overheid denkt daar anders over en verwacht het tempo en de weg naar CO_2-neutraliteit in 2050 te bepalen door middel van wet- en regelgeving en ondersteunende maatregelen. Toch is het begrijpelijk dat de experts van woningcorporaties stellen dat de overheid geen invloed heeft op hun tempo, omdat zij niet meer kunnen doen dan waartoe zij in staat zijn.

Bovendien houdt dit onderzoek slechts rekening met een beperkte set waargenomen criteria en laat het andere belangrijke factoren weg die relevant zijn voor het prioriteringsmodel. Het model geeft daarom geen alomvattend resultaat. In werkelijkheid zijn er veel meer meespelende factoren die van invloed zijn op de prioritering en planning van complexen. Bijvoorbeeld flankerende factoren, incidentele factoren, persoonlijke ervaringen etc.

Ten slotte bleek uit de vergelijking van de prioriteitsrangorde van het model met de prioriteitsrangorde van de Routekaart dat het *Proces waarin een woning energiezuinig wordt gemaakt*, door de Routekaart hoger werd gewaardeerd. Verder werden het *Budget* en de *Energielabels* minder gewaardeerd door de Routekaart. Wat betreft de woningcorporatie waarvan de Routekaart en de dataset is verkregen, zou het zo kunnen zijn dat zij de voorkeur geven aan natuurlijk geplande momenten, ongeacht het energielabel of het beschikbare budget. Ook hier geldt echter dat er meer validaties moeten worden uitgevoerd om tot een meer omvattende conclusie te komen.

Summary

Introduction

The Dutch government has set the target of becoming entirely carbon-neutral by 2050 (De Nederlandse Coalitie, 2021). Compared to the CO_2-emission levels of 1990, 60% needs to be reduced as an interim target by 2030. The Dutch social housing sector, who owns approximately 29% of the housing stock with half of their dwellings built before 1980 (Aedes, 2019), holds a significant responsibility in achieving a carbon-neutral built environment.

Research questions

The sector stands before an enormous task of making their existing housing stock energy efficient. Research towards the factors influencing the decision-making of energy efficiency investments by social housing associations within The Netherlands and around the globe, are lacking and not contemporary. The extent to which these factors are of influence, seen from the social housing associations' perspective rather than the tenants' perspective, is a research gap to which this thesis responds.

This research is aimed at explaining the factors influencing the pace of energy efficiency renovation rates, to find out what drives and hinders Dutch social housing associations in achieving their future goals. The question of this thesis furthermore lies in which determinants are currently taken into account for the prioritization of dwelling complexes to be made energy efficient, and to identify their sizes of influence. The identified determinants and their sizes of influence can then be used for the establishment of a priority ranking model. The model would offer a theoretical substantiated prioritization of dwellings and thereby, could help fasten the actualisation of Dutch social housing associations' dwelling portfolios.

The main research question of this research is as follows:

What are the factors influencing the pace in which housing associations are making their existing dwelling stock energy efficient and what are the determinants of influence for the prioritization of complexes by means of a model?

Additionally, five associated sub-questions are investigated to help answering the main research question. The sub-questions are as follows:

1. What are the preconditions for making an existing dwelling energy efficient?
2. Which factors are influencing the pace of housing associations' energy efficiency renovation rates?
3. What are the determinants influencing the prioritization and planning?
4. What is the size of influence (weight) of the determinants on the prioritization and planning?
5. To what extent can a model predict the planning and prioritization of energy efficiency renovations by a housing association?

The literature has offered a first base of the determinants of interest relevant to the prioritization of dwelling complexes to be made energy efficient. Additionally, future regulatory requirements regarding: *The Standard*, the *Transition Vision Heating* plans of municipalities and the abolishment of poor *Energy labels,* are also perceived as important factors of influence. Furthermore, Dutch social housing associations are using a *Roadmap* in which sustainability related interventions are set-out in time towards 2050, relevant to changes within their dwelling portfolios. The determinants of interest within *The Roadmap* therefore additionally offers the determinants relevant for the prioritization and planning of dwellings. The determinants of interest following from the literary study, future regulatory

requirements and The Roadmap, have been grouped into overarching independent variables of influence on both the dependent variables: *Pace* and the *Prioritization and planning*. The relationships between the independent variables and the dependent variables are investigated by means of this research. The independent and dependent variables are shown in the conceptual model of this thesis, shown in Figure 1.

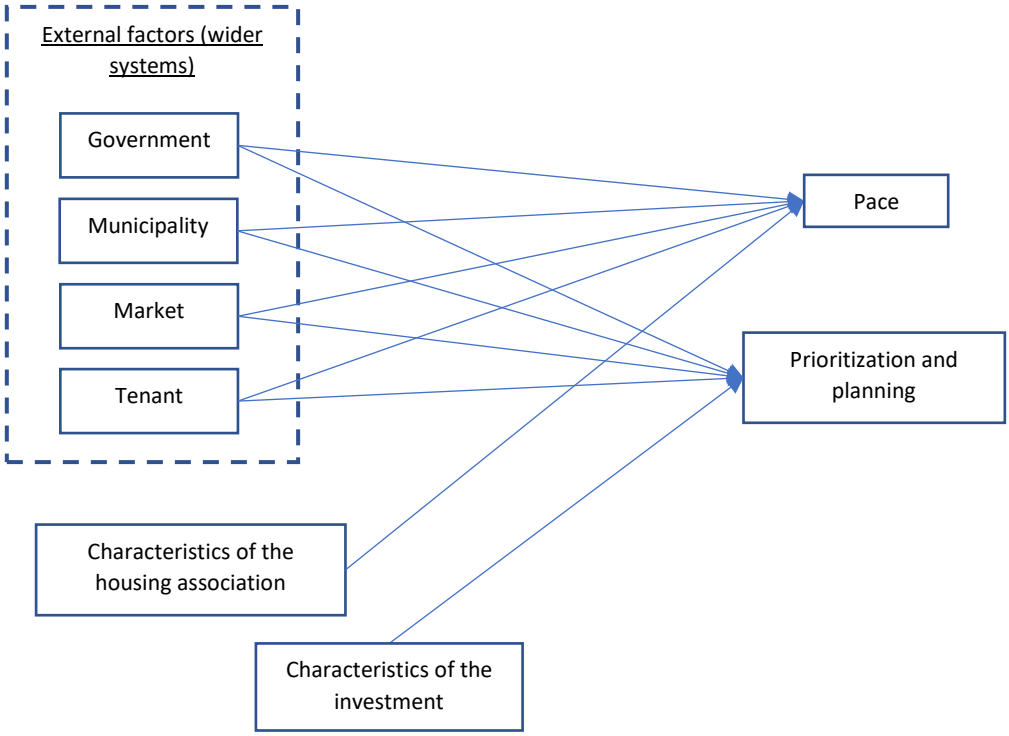


Figure 1: Conceptual model of the research

The relationship between the factors influencing the *Pace* have been investigated by means of performed interviews, offering qualitative information. The criteria of interest for the *Prioritization and planning* are also established through interviews. Subsequently, the weights of criteria are assessed by means of the Analytical Hierarchy Process as the applicable Multicriteria-Analysis, using pairwise comparisons. Thus providing quantitative information relevant for a prioritization model.

Preparation of interviews

Eleven experts at different sized social housing associations across The Netherlands have been interviewed. The interviews consisted of two parts.

During Part I of the interview, a structured list of predefined questions were asked to investigate the variables relevant to the *Pace* of housing associations. The experts were asked about the influence of each of the predefined factors and to give a substantiation of their reasoning. The interviews had an open character, with open questions and open answers.

Part II of the interview aimed to identify the five most important criteria for their *Prioritization and planning*, out of a list of 20 predefined criteria. The list of 20 criteria was sent to the experts before the interviews, in which they were asked to already provide their five most and their five least important criteria. Their reasoning and substantiation of choices were further discussed during the interviews. The most frequently chosen criteria resulted in a list of the final most and least important criteria for their prioritization and planning.

A follow-up survey was sent to the experts to establish the weights (importance) of the five most important criteria and additionally, to establish the preference scores of categoric options per criterion. For establishing the weights of criteria, the experts were asked to pairwise compare each of the five most important criteria with the other criteria, with regard to their importance for the overarching goal: Achieving a prioritization and planning towards carbon-neutrality by 2050, in compliance with The Standard. The question asked per pairwise comparison was then:

"If you had to make a Roadmap in compliance with 'The Standard' towards CO_2-neutrality by 2050, which criterion would you deem more important and how much more important?"

For deriving the preference scores for each categoric option per criterion, the experts were asked to distribute 100 points amongst the categoric options associated to the criterion, in accordance with their preferences. The higher the score, the stronger the preference. The question asked was then:

"How strong is your preference for each of the categoric options per criterion for the complex to be made energy efficient? You have 100 points to distribute over the categoric options per criterion."

The results of Part II provide quantitative information, used as input for the establishment of a prioritization model.

Results & Conclusions

Interviews

The results of Part I of the interview show that the *Government* is perceived to be of neutral influence. Meaning that opinions are somewhat divided regarding the influence of the government on the pace of the Dutch social housing associations' energy efficiency renovation rates. The most often mentioned reasoning by the experts for the government being of no influence, is due to housing associations following their own paths. They state to be working with the resources and financial means they have. Whether or not the government obliges them to do more, they can only perform a limited amount of work with their available (financial) resources. On the other hand, half of the experts claimed to be strongly influenced through delaying laws and regulations and tightened obligations.

The *Municipality* is perceived by more experts to be of influence than not. They argue that generally a lack of capacity at municipalities are resulting in viscous, lengthy and time-consuming processes.

All experts agreed that the *Market* is of influence on their pace. Mainly due to a lack of capacity at external parties, a lack of materials, equipment, personnel and additionally because of rising costs.

The *Tenant* is perceived to affect the pace of housing associations. Generally, the obligation of achieving the approval of 70% of the tenants for the renovation of dwelling complexes is stated to be very time-extensive. Sometimes resulting in longer processes than desired.

Finally, the *Characteristics of the housing association* were agreed by all experts as an influencing factor. Their board plays an important role regarding their pace. They determine to what every euro is spend on. Since every euro can only be spend once, they decide the pace in which the housing association is going to make their existing dwelling stock energy efficient.

The results of Part II of the interviews provided the list of the most, and also the least important criteria, relevant for the prioritization and planning of dwelling complexes to be made energy efficient. Due to a scoring of similar points the final most important criteria consist of seven criteria, shown in Table 1.

Categorization	Criterion	Points
Internal factors	Strategy housing portfolio	8
Housing conditions	Trias energetica	8
Housing conditions	Combination with planned renovation	8
Housing conditions	Energy label	6
Housing conditions	Combination with planned maintenance	5
External factors	Transition Vision Heating of municipalities	5
Internal factors	Financial possibilities	5

Table 1: The most important criteria for the prioritization and planning

Furthermore, the six least important criteria for the prioritization and planning of dwelling complexes to be made energy efficient are provided in Table 2.

Categorization	Criterion	Points
Internal factors	Positioning in energy transition	-9
External factors	Subsidizes on product	-7
External factors	Market influences	-7
Internal factors	Input from stakeholders	-4
Housing conditions	Construction or renovation year	-4
External factors	Stage of technologic development	-4

Table 2: The least important criteria for the prioritization and planning

Follow-up questionnaire

To establish the weights of the criteria, they are pairwise compared by the experts by means of a follow-up survey.

Due to overlap of criteria and to keep the amount of pairwise comparisons within proportions, some criteria have been merged, resulting in a final list of five most important criteria. The criterion *Combination with planned maintenance* has been merged with *Combination with planned renovation* into *Process in which the complex will be made energy efficient*. The criterion *Trias energetica* has been merged with *Energy label* into *Average existing energy quality of complex to be made energy efficient*. Subsequently, the experts were asked to rate their preferences for the categoric options associated per criterion. The weights of the criteria and the preference score per categoric option is shown in Table 3.

Weights (criteria) and preference scores (categoric options)	Criteria and associated categoric options
47.9%	**Strategy of housing portfolio for dwelling complex to be made energy efficient**
25	Replacement new construction (demolition and new construction)
11	Sell during mutation
5	Sale per complex
17	Continue to exploit
42	Major renovation/restructuring
16.1%	**Average existing energy quality of dwelling complex**
46	Poor energy quality (energy labels E, F and G)
33	Moderate energy quality (energy labels C and D)
19	Sufficient energy quality (energy labels A, B)
3	Good to excellent energy quality (energy labels A+ and better)
14.3%	**Process in which the dwelling complex will be made energy efficient**
20	Per individual component will be made energy efficient at natural time such as planned maintenance
17	Dwelling will be made energy efficient during mutation or at tenants' request (per dwelling)
36	All individual required sustainability measures in one intervention for an entire complex before 2030, possibly to include maintenance and other necessary items
29	All individual required sustainability measures in one intervention for an entire complex after 2030, possibly to include maintenance and other necessary items
13.1%	**Indicative budget per dwelling to be made energy efficient in euros**
12	Indicative sustainability budget per dwelling maximum €10,000
26	Indicative sustainability budget per dwelling €10,000 to €30,000
47	Indicative sustainability budget per dwelling €30,000 to €50,000
16	Indicative sustainability budget per dwelling more than €50,000
8.7%	**Transition vision heating of governments for dwelling complex**
18	No expressed area vision other than to insulate well
12	Heat grid by 2030 (pioneer district)
19	Heat grid potentially available after 2030
8	Electric heating by 2030 (pioneering district)
20	Electric heating potentially available after 2030
15	Green gas by 2030 (pioneering district)
8	Green gas potentially available after 2030

Table 3: Weights of criteria and preference scores for associated categoric options

Priority ranking model

The quantitative results of the follow-up questionnaire regarding the pairwise comparisons and the preference scores of categoric options, are used for the establishment of a prioritization and planning model. The model is able to prioritize dwelling complexes in accordance with the established weights of criteria and preference scores of categoric options and therefore, provides a theoretical substantiated prioritization of dwelling complexes. A first prioritization has been made with the use of a *Roadmap* of a Dutch social housing association, containing the required characteristics and information of 109 dwelling complexes.

Subsequently, a sensitivity analysis has been performed to assess the sensitiveness of results when making changes to the weights of the experts' assessments. As for now, each expert has had an equal weight of 1 and therefore, an equal contribution in the weighting of criteria. Some experts however, had less knowledge regarding the subject of the research and the determinants assessed. Based on their self-perceived knowledge, obtained by answering one of the predefined questions during the interviews, the weights of the experts' assessments have been changed. If the expert was already using a *Roadmap* and incorporated *The Standard*, their weight of assessment was weighted twice as much as experts who did not. In case only one of the two was applicable, the expert's opinion was weighted 1.5 as much.

A change in weights resulted in a different ranking, the results are however barely sensitive to a change in weights of the weights of the experts' assessments. 33 out of the 109 complexes did not change in ranking, 32 dwelling complexes changed by one priority position, and 17 complexes changed by two priority positions. The other 27 complexes changed by either 3, 5, 6, 8, 9, 10, 13 or 14 positions.

Validation of the model in practice

To conclude the extent to which the priority ranking model is able to predict the planning and prioritization of dwelling complexes to be made energy efficient, the model needs to be validated in practice. A first test-run has been performed. The priority ranking of the model has been compared with the priority ranking of a Roadmap, used by the same housing association of which the dataset has been acquired for the priority ranking of the model and therefore, a comparison of priority rankings could be made. A comparison of priority rankings showed that the model has been able to correctly predict the prioritization of 7 out of 109 dwelling complexes and therefore, significantly differs from the priority ranking in practice. More validations, however, need to be performed to draw conclusions regarding the logic and rationality of either the priority ranking of the model, or the priority ranking of The Roadmap.

Recommendations

Recommendations

The results of the interviews offered contemporary insights regarding the factors influencing the pace, and the factors influencing the prioritization and planning of Dutch social housing associations. The established model includes the criteria and their weights that are currently perceived to be important, the model has been able to make a priority ranking of dwelling complexes and additionally, is methodologically correct. The first recommendation is therefore to use the established priority ranking model as a different perspective on the prioritization and planning of dwelling complexes. The model could help in fastening the actualisation of a housing associations' dwelling portfolio.

Fast-moving developments within the Dutch social housing sector, however, have led to a number of recommendations with regard to the use of the results of this study.

The interviews have been performed in April and May (2022) prior to the publication of the National Performance Agreements on June the 30th (2022). The National Performance Agreements entail important new commitments which could give different results of the interviews, if they would had been performed afterwards. Two recommendations follow from this remark.

Firstly, according to the results of this research, the *Transition Vision Heating* was the least important criteria of the five most important criteria (weighing only 8.7%). By 2024, municipalities are obligated in accordance with the National Performance Agreements to have a clear vision regarding when, where, which intervention is going to be taken. To be economical and efficient with resources, it is recommended to stronger reconsider the Transition Vision Heating plans of municipalities within a prioritization of dwelling complexes.

Secondly, in accordance with the National Performance Agreements, the sector has made the commitment of making approximately a third of the existing social housing stock extra in compliance with *The Standard* by 2030. The interviews showed that seven out of eleven experts did not incorporate The Standard, or claimed to have no experience regarding The Standard. It is strongly recommended to start learning about the consequences of, and start working with The Standard, regarding changes in the portfolio, finances, capacity etc.

Suggestions for follow-up research

The first next step for follow-up research would be to validate the model in practice, by comparing the priority rankings of the model with already established plannings and prioritizations, such as Roadmaps. In this way, conclusions can be drawn regarding the extent to which the model is able to predict the planning and prioritization of dwelling complexes by Dutch social housing associations. Differences in priority rankings could help question or consider the logic of the priority ranking of either the model, or either the priority ranking of The Roadmap.

Furthermore, future research should consider a re-examination of the criteria and their weights, due to the fast-developments within the sector of amongst which has been the National Performance Agreements. Lastly, it is suggested to interview more than eleven experts to increase the power of the results. By interviewing more experts, after the publication of the National Performance Agreements, even more contemporary weights can be established of the criteria. Resulting in a more validated model and priority ranking of which complexes should be first in line for being made energy efficient.

Discussion

Limitations

Firstly, the individual weightings of criteria by means of pairwise comparisons have sometimes exceed the acceptable 10% threshold of Consistency Ratio. Although the overall CR was 3% and therefore acceptable, some individual weightings may however still provide unreliable results.

Secondly, the dataset, used as input for the model, lacked specific information regarding the *Process in which the complex will be made energy efficient* and therefore, assumptions had to be made. This results in less reliable priority rankings.

Thirdly, the model provides a ranking of priorities in which all measures are executed during the same intervention. In reality, however, measures are not always being executed simultaneously. A prioritization of measures could also be the case. The model following from this research is thus a simplification of the reality, offering a simplification of prioritizations.

Fourthly, a Roadmap plans multiple complexes within the same year but does however not indicate a specific priority ranking. Meaning, that for instance, the ranking of 10 complexes within year 2023 are ranked from 1-10. Not telling whether position 1 is more prioritized than position 10. The comparison of the priority ranking of The Roadmap, with the priority ranking of the model does therefore not give precise results. The validation of the model, by comparing the planning and prioritization of a Roadmap in practice, does therefore not give exact results, rather an indication.

Results

It is interesting to note that half of the housing associations state, and perceive, the government as no influencing factor regarding their pace. The government has a different opinion in this regard and expects to set the pace and path towards carbon-neutrality by 2050, through laws, regulations and supportive measures. Nevertheless, it is understandable that housing associations claim that the government does not affect their pace because they cannot do more than they are able to do.

Furthermore, this research does only take a limited set of perceived criteria into consideration and omits other important factors relevant for the priority ranking model. The model does therefore not provide an all-encompassing result. In reality, there are many more accompanying factors influencing the prioritization and planning of complexes. For instance, flanking factors, incidental factors, personal experiences etc.

Lastly, the comparison of priority rankings of the model with the priority rankings of The Roadmap showed that *The process in which a dwelling will be made energy efficient* was more valued by The Roadmap. Additionally, the *Budget* and the *Energy labels* were less valued by The Roadmap. Regarding the housing association of which The Roadmap and the dataset has been achieved, it might be the case that they prefer to make use of natural planned moments, no matter the energy label or the budget available. Again, however, more validations need to be performed to provide a more encompassing conclusions.

Table of contents

1. Introduction 23
1.1. Background and motivation 23
1.2. Problem analysis 25
1.3. Research questions 27
1.4. Conceptual model 28
1.5. Relevance 29
1.6. Research design 29
1.7. Reading guide 31
2. Literature study 32
2.1. State of research towards the determinants and their weightings for energy efficient dwelling investments 32
2.2. Future regulatory energy efficiency requirements as important determinants 35
2.3. Housing associations' pace towards CO_2-neutrality by 2050 39
2.4. The decision-making process and phases 41
2.5. The *Beleidsachtbaan* as a decision-making process tool for asset management 42
2.6. Multicriteria-analysis techniques 45
2.7. The Analytical Hierarchy Process for the execution of this research 52
2.8. Method as an addition to the AHP 55
2.9. Conclusion 56
3. Research methods 58
3.1. Interview set-up 58
3.2. Follow-up survey 62
3.3. The participating experts of Dutch social housing associations 63
3.4. Data validity and reliability 64
3.5. Conclusion 65
4. Results 66
4.1. Factors influencing housing associations' pace 66
4.2. Conclusion regarding the factors of influence on the pace 76
4.3. Criteria of interest for the prioritization and planning 77
4.4. Criteria weightings and preferences for categoric options 82
4.5. Establishing the model for planning and prioritization 86
4.6. Prioritization of dwelling complexes 88
4.7. Sensitivity analysis 89
4.8. Conclusion 92
5. Conclusions, recommendations and discussion 95

5.1. Conclusions 95
5.2. Recommendations 98
5.3. Discussion 99
Bibliography 101
Appendices 105
Appendix A – Follow-up questionnaire of pairwise comparisons 106
Appendix B – Individual sheets of AHP-results 107
Appendix C – Follow-up questionnaire for the preference scoring of options 117
Appendix D – Tabs of the planning and prioritization model 118
Appendix E – Full list of prioritization of complexes 123

List of figures, tables and equations

Figure 1: Conceptual model of the research 12
Figure 2: Conceptual model of the research 29
Figure 3: Research model of the thesis 31
Figure 4: The three phases of a decision-making process (Simon, 1960) 43
Figure 5: The Beleidsachtbaan (Van Os, De beleidsachtbaan in 8 episodes, 2021) 45
Figure 6: A decision hierarchy structure (Moutinho et al., 1994) 51
Figure 7: Goal - Criteria - Categoric options 65
Figure 8: Summary sheet of the AHP 85
Figure 9: Criteria and ranges of weights 85
Figure 10: Comparison matrix of criteria 86
Figure 11: Five most important criteria and associated categoric options 87
Figure 12: Prioritization of 109 dwelling complexes 90

Table 1: The most important criteria for the prioritization and planning 14
Table 2: The least important criteria for the prioritization and planning 14
Table 3: Weights of criteria and preference scores for associated categoric options 15
Table 4: Clustered determinants of interest 27
Table 5: Clustered determinants of interest according to Dieperink et al. (2004) 33
Table 6: Clustered determinants of interest according to Qin et al. (2022) 34
Table 7: Clustered determinants of interest towards a sustainable business model Lambrechts et al. (2021) 35
Table 8: Requirements according to The Standard (Aedes, 2021) 38
Table 9: Minimum requirement and Target values of The Standard (Aedes, 2021) 40
Table 10: Verbal scaling of relative importance; 1-3-5-7-9 (Saaty, 1987) 52
Table 11: Predefined list of questions Part I 60
Table 12: List of the 20 predefined criteria 61
Table 13: Categorization of the 20 predefined criteria 62
Table 14: Information of the housing associations 65
Table 15: Categories of sizes 66
Table 16: Summary of responses to the opening question 69
Table 17: Summary of argumentations for whether or not the government influences their pace 71
Table 18: Summary of argumentations for whether or not the municipality influences their pace 71
Table 19: Summary of argumentations for whether or not the market influences their pace 74
Table 20: Summary of argumentations for whether or not the tenant influences their pace 75
Table 21: Summary of argumentations for whether or not the characteristics of the Housing association influences their pace 76
Table 22: Summary of responses to the closing question 77
Table 23: Final scoring of influencing factors 78
Table 24: How many experts are already working with a Roadmap and The Standard? 79
Table 25: Categorization of criteria and their scores 79
Table 26: Total overview of point scoring per criterion 81
Table 27: The most important criteria for the prioritization and planning 82
Table 28: The least important criteria for the prioritization and planning 83
Table 29: Final five most important criteria 84
Table 30: Final overview of the weights of criteria and preference scores of categoric options 89
Table 31: Weighting of experts' opinions 93

Table 32: Changes in weights and preference scores due to a change in weight of experts' opinions 93
Table 33: Change in priority due to a change in weighing of experts' opinions 94

Equation 1: Obtaining the Subjective Expected Utility of a decision maker (Dodgson et al., 2000) 50
Equation 2: Obtaining the scores of options through weighted criteria (Dodgson et al., 2000) 51
Equation 3: Formula used for the prioritization model (adapted linear additive model) 90

1. Introduction

The first chapter of this thesis will provide background information and the motivation for the execution of the research. Then, the problem analysis will be outlined which is followed by the associated research questions. Afterwards, the conceptual model containing the variables to be investigated is discussed together with the relevance of this research. Finally, the research design is outlined and lastly, a reading guide is provided.

1.1. Background and motivation

This section will provide background information regarding the overarching problem; battling climate change. A demarcation is made to the Dutch social housing sector and the challenges they face.

1.1.1. Battling climate change

Last year, the Earth Overshoot Day occurred on July 29th 2021. It means that as of that day, the world has asked as much from the earth her capacities as the earth is able to regenerate in a single year (EarthOvershootDay, 2021). We are currently in need for 1.7 earths in order for the earth to regenerate the amount of natural resources and to absorb the amount of greenhouse gas emissions (Plan A Academy , 2022). A report by the Intergovernmental Panel on Climate Change (2022) in April has again stressed the severe impacts on our ecosystems resulting in, amongst others; flooding risks, depletion of bio-diversity, extreme heats and colds, failing crops and many more disastrous issues following from human-behaviour.

Mitigating the worldwide effects of climate change has established its first international agreement in 1992 during the United Nations Conference on Environment and Development (UNCED). Stabilizing the concentration of greenhouse gas emissions in the atmosphere to a level which would not harm the earth its climate-system to dangerous proportions was the concluding common goal (Klimaat.be, 2019). 154 countries and the European Economic Community (nowadays EU) had agreed to this shared goal. The climate convention of UNCED did however only offer a framework of actions to which subsequently in 1997, the Kyoto protocol was adopted. It offered clearer targets and an actual plan.

The Kyoto protocol entered into force in 2005 and was contributed by 192 parties of amongst which the European Union. Together, they aimed at reducing an average of 5% of the countries' greenhouse gas emissions compared to 1990 over a first commitment period of 2008-2012. During a second commitment period from 2012-2020 the goal was to reduce an average of 18% below the greenhouse gas emission levels of 1910 (United Nations, sd). In 2015, the Paris Agreement was signed three years after the first commitment period of the Kyoto protocol. Contributed by 194 parties and the European Union – representing 98% of the world's greenhouse gas emissions – another legally binding international treaty on climate change was agreed to. The contributing countries aimed at reducing global warming to well below 2 degrees Celsius.

The built environment has a significant responsibility in global warming with a share of 40% of the European Unions' energy consumption and a share of 36% in the greenhouse gas emissions (European Commission, 2020). The European Union suffers from a poor energy efficient housing stock. Roughly 75% of the buildings within the EU are not in compliance with contemporary energy efficiency standards whilst approximately 90% of all buildings of today will still be in use in 2050. In 2050, Europe wishes their built environment to be entirely CO_2-neutral according to the European Green Deal of 2021 (European Commission, 2021). The Dutchmen face a similar problem of old, non-energy efficient dwellings and have set even more ambitious plans than agreed within the Paris' Agreement. The Netherlands have set an interim target in which they aim to reduce 60% of The Netherlands' CO_2-emissions instead of 49% by 2030 (De Nederlandse Coalitie, 2021).

1.1.2. The Dutch social housing sector and their role in CO_2-neutrality

Throughout the years, housing associations within The Netherlands have shared an extra overarching goal and obligation in addition to their social function of being an affordable housing accommodator. They have an environmental role to fulfil as well, with respect to the amount of greenhouse gas emissions of their dwellings.

In 2020 The Netherlands accumulated for a total of 164 megaton CO_2-eq in which the built environment has had a share of 13.2% with 22 megaton CO_2-eq (CBS, 2021). Subsequently, households are the biggest greenhouse gas emitters within the built environment and are responsible for 71.2%. The biggest share of the housing stock within The Netherlands is owned by approximately 300 non-profit housing associations who function as a housing accommodator for the lower-income class. They own 29% of the Dutch housing stock which accumulates for 2.3 million dwellings. The social housing sector however, holds a legacy of old non-energy efficient buildings with more than half of their properties being built before 1980 (Aedes, 2019). They hold a significant responsibility regarding their total greenhouse gas emissions in achieving a CO_2-neutral built environment by 2050 and for reaching the interim goal of 60% CO_2-reduction by 2030, compared to 1990.

Tightened regulations, extra subsidies and an increased awareness of the need for energy efficient homes are driving and forcing the Dutch social housing sector towards an environmental-friendly built environment. The process in doing so is well-underway; however, it is not going fast enough in order to become CO_2-neutral by 2050 as aimed for by the Dutch government (Filippidou, 2018). A goal of which the overarching branch organisation Aedes (2021) has expressed their great worries about.

Good news for the sector is that on the 15th of December in 2021 an agreement has been made by the new Dutch governmental coalition. Within this agreement, they agreed to the abolishment of the landlord tax, resulting in an estimated €1.7 billion more to invest for the sector per year (De Nederlandse Coalitie, 2021). On the other hand, the sector will be expected to achieve a 60% carbon reduction by 2030, 70% by 2035, 80% by 2040 and finally, 100% by 2050 (Rijksoverheid, 2022). The interim target of 2030 is slightly more than the European goal of 55% by 2030. Also, the construction of new dwellings needs to scale to 100,000 dwellings per year.

On June the 30th in 2022 the National Performance Agreements between the overarching branch organisation of the Dutch social housing sector (Aedes), the Dutch association of municipalities (VNG), the Dutch association of tenants (Woonbond) and the Dutch government have been published as an expected return for abolishing the landlord tax. These agreements include making 450,000 additional existing homes gas-free by 2030 (Rijksoverheid, 2022). Municipalities will be obligated to establish a *Transition Vision Heating* plan by 2024. This plan shows when, and which neighbourhood will be detached from gas-supply and what the alternative heating source will be. The sector has furthermore agreed to the insulation of extra 675,000 existing dwellings (30% of the social housing stock) in compliance with *The Standard* by 2030. The Standard will be the new insulation requirement and expectably prohibited by 2050 according to the Climate Agreement (2019). Additionally, dwellings with an energy label E, F or G will be banned from 2030. Lastly, from 2023 onwards, hybrid heat pumps or other sustainable alternatives will be used to replace boilers.

1.2. Problem analysis

The following section provides brief information regarding the problem statement of this research. More regarding the literature and associated conclusions will be described in the following chapter. This section will furthermore offer input for the conceptual model which serves as a red thread throughout the execution of the research.

1.2.1. Problem statement

Social housing associations within The Netherlands own 29% of the dwellings and therefore, have a significant responsibility in achieving CO_2-neutrality by 2050. The Dutch state, however, has not made it easy for the sector to meet future challenges. Since 2013, the sector has been subject to the landlord tax to restore order to the Dutch state's finances. The landlord tax has generated billions of euros for the state but has however resulted in perverse incentives within the sector (Woonbond, 2017). Rents went up, affordability for tenants went down and the state subsequently had to invest more in rental concessions. Housing associations significantly reduced their investments in renovations and additionally, the number of new built houses was reduced by half from around 30,000 in 2013 to only 14,900 in 2015 and 15,200 in 2020 (Aedes, 2021).

The landlord tax will be abolished, starting from 2022 onwards the tax will gradually be reduced to 0 which will provide more financial space for the housing associations. In return for the abolishment of the landlord tax, the sector together with the government has agreed to National Performance Agreements (2022). The agreements following from the National Performance Agreements (2022), are expected to push the amount of energy efficient and affordable social rental dwellings towards the needed amount for achieving future goals (Rijksoverheid, 2022).

Finding what drives and hinders social housing associations regarding their energy efficiency renovation pace could help explain the differences in pace between housing associations. Well-informed and theoretically based decision-making could furthermore help their planning, in finding which dwelling complexes should be prioritized to be made energy efficient. To optimize their planning and prioritization, there is a need for understanding the importance of the factors influencing such policies (Dieperink et al., 2004; Qin et al., 2022; Lambrechts et al., 2021). Unfortunately, contemporary research regarding the determinants of interest and their extent of influence on the prioritization and planning, of specifically the Dutch social housing sector, is lacking.

1.2.2. Determinants of interest for the prioritization and planning

Lambrechts et al. (2021), Dieperink et al. (2004) and Hoppe (2012) have performed research towards the determinants for the decision-making of energy-saving measures for Dutch social housing associations. Furthermore, Qin et al. (2022) have performed a worldwide bibliometric analysis of determinants of interest for green energy adoption measures. The identified determinants of the aforementioned studies showed consensus, and offer input for the determinants of interest to be investigated throughout this research. Their determinants have therefore been aggregated and subsequently clustered into three overarching groups, namely: *External factors (wider systems); Characteristics of the housing association; Characteristics of the investment.* The overarching determinants consist of multiple sub-determinants, relevant to decision-making regarding energy efficiency investments. The corresponding sub-determinants also showed consensus, and have been combined and placed under the applicable associated group, shown in Table 4.

In addition to the determinants of interest as concluded by means of literature, a *Roadmap* additionally offers information regarding which determinants are currently taken into account. A Roadmap offers an insightful planning and prioritization tool of when each dwelling complex is planned and prioritized

to be made energy efficient, set-out in time towards 2050. Thankfully, Atriensies, the accompanying company of this thesis, can support in contemporary determinants of interest for the prioritization of dwelling complexes by means of a Roadmap. The determinants used for the prioritization and planning of dwelling complexes will be discussed in the following chapter.

Furthermore, future regulatory requirements are also perceived as crucial factors influencing Dutch social housing associations' prioritizations and plannings. These additional determinants of interest entail the obligation of The Standard, the Transition Vision Heating plans of municipalities, and the abolishment of poor Energy labels as discussed in §1.1.2.

The determinants of interest according to literature, The Roadmap and the future regulatory requirements, lead to a final overview of determinants of interest, as shown in Table 4. Table 4 functions as the input for the conceptual model for the execution of this research, to be discussed in §1.4. A further substantiation of the determinants of interest will be discussed in Chapter 2.

External factors (wider systems)				Characteristics of the housing association	Characteristics of the investment
Government	**Municipality**	**Market**	**Tenant**		
Policy and regulations	Transition Vision Heating plans	Collaboration (with the market and other housing associations)	Split-incentives (with the tenant)	Knowledge & experience	(In)feasibility
Incentive programs (subsidies etc.)		Demand & supply	Intrinsic motivations	Continuous innovation (through e.g. collaboration)	Technical complexity
Covenants		Level of R&D in branch	Support or resistance	Expected growth & economic prospects (financial health)	Fit in production process
Knowledge transfer		Development of prices			Competing options
					Technical performances
					Time to recover expenditure
					Locational characteristics

Table 4: Clustered determinants of interest

1.2.3. A need for contemporary research

Today's times are much different than a few years ago due to increased demand for energy efficient dwellings, sharpened ambitions and tightened upcoming regulations. Literature studies who have aimed to identify the factors influencing energy efficiency renovation rates can therefore be considered out-dated due to differences in time. The extent to which these factors have an influence is therefore also considered not contemporary. The aim of this research will thus be to provide contemporary research towards the determinants and additionally their importance for the prioritization of which dwelling complexes should be first in line for being made energy efficient and in compliance with The Standard.

1.3. Research questions

This section will discuss the main research question and the associated sub-questions for the execution of this research.

1.3.1. Main research question

The question of this research lies in what drives and hinders Dutch social housing associations into making their existing dwelling stock energy efficient and therefore, affect their pace in doing so. Additionally, the question lies in finding which determinants they take into account when prioritizing and planning which dwellings should be first in line and furthermore, what the actual size of influence is of these determinants. The main goal of this thesis is therefore, on the one hand to identify the factors influencing the pace in which they are making their existing dwelling stock energy efficient. On the other hand, to identify the determinants and their sizes of influence in order to establish a logical prioritization of dwelling complexes to be made energy efficient. The determinants, and their sizes of influence, can then be used for the establishment of a prioritization modelling-tool. The model would offer a theoretical substantiated prioritization of dwellings and thereby, help fasten the actualisation of Dutch social housing associations' dwelling portfolios.

This leads to the following main research question:

What are the factors influencing the pace in which housing associations are making their existing dwelling stock energy efficient and what are the determinants of influence for the prioritization of complexes by means of a model?

1.3.2. Sub-questions

With answering the main research question the thesis aims to explain the differences in pace between housing associations. Additionally, to support the decision makers in the prioritization and planning of their dwelling complexes to be made energy efficient. By means of a model, which will take the determinants and their weights into account, a more theoretical substantiated prioritization of dwelling complexes can be made. The model thus offers an assisting tool for establishing a logical prioritization and planning. The determinants will however first need to be identified, followed by an examination of the weights of these determinants.

With naturally a focus on the decision makers of Dutch social housing associations and their existing social rental dwellings to be made energy efficient, this leads to the following sub-questions:

1. What are the preconditions for making an existing dwelling energy efficient?
2. Which factors are influencing the pace of housing associations' energy efficiency renovation rates?
3. What are the determinants influencing the prioritization and planning?
4. What is the size of influence (weight) of the determinants on the prioritization and planning?

5. To what extent can a model predict the planning and prioritization of energy efficiency renovations by a housing association?

1.4. Conceptual model

A conceptual model has been established, consisting of independent and dependent variables. The dependent variables consist of the *Pace* in which housing associations are making their existing dwelling stock energy efficient, and the dependent variable *Prioritization and planning.* They are both influenced by a number of independent variables. The independent variables of the conceptual model are based on literature, The Roadmap and future regulatory requirements for the social housing sector. As briefly discussed in section §1.2. A further substantiation of these determinants of interest is provided in Chapter 2. Determinants of interest are thus factors of influence on either their *Pace*, their *Prioritization and planning*, or both. This research will examine the relationship between the independent variables and the dependent variables.

The *External factors (wider systems)* have a direct effect on both the *Pace* in which housing associations are moving towards 2050, as well as on their *Prioritization and planning.* Additionally, also the *Government* has a direct effect on both the Pace and *Prioritization and* planning due to their legal powers, just as the *Municipality* because of their Transition Vision Heating plans, the *Market* due to market effects such as demand and supply, and the *Tenant* due to intrinsic motivations and support or resistance. The *Characteristics of the housing association* are of direct influence only on their *Pace,* because of their knowledge, motives, attitudes and values, and expected financial health. Lastly, the *Characteristics of the investment* are of direct influence on which dwelling complex will be prioritized to be made energy efficient, and thus only on their *Prioritization and planning.* Specific investment characteristics such as (in)feasibility, technical complexity and performances, and whether or not the investment fits the production process can be of influence.

The beforementioned relationships between the independent and the dependent variables, based on Table 4, are put together in the conceptual model as shown in Figure 2. The conceptual model offers a base and a red thread for the execution of this research.

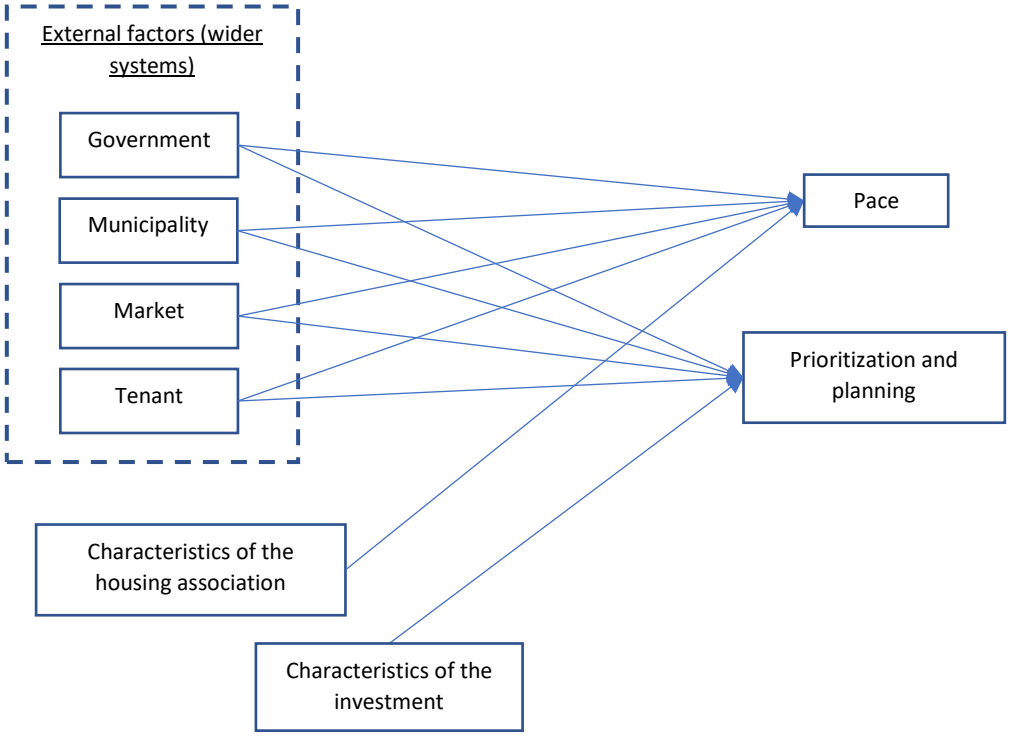


Figure 2: Conceptual model of the research

The relationship between the variables *External factors* and *Characteristics of the housing association* with the *Pace,* will be examined by means of qualitative information gathered through interviews. The determinants of interest related to the *Characteristics of the investment* will also be identified by means of interviews. The actual strength/weight of these determinants on the dependent variable *Prioritization and planning* shall further be examined through a follow-up questionnaire. By means of this questionnaire, housing associations will have to pairwise compare and rate the importance of the relevant determinants relative to each other. The gathered quantitative information regarding the weights of determinants will function as input for a model for the prioritization and planning of dwelling complexes to be made energy efficient.

1.5. Relevance

This section will discuss both the practical as well as the academic relevance of the thesis.

1.5.1. Practical relevance

The Dutch social housing sector stands before an enormous task, comprising existing and additional future regulations that are pushing the sector towards CO_2-neutrality by 2050, with an interim target of 60% reduction of CO_2 by 2030. The social housing sector holds a significant responsibility in achieving an energy efficient housing stock, due to their share of households. In return, they also offer great upwards potential if future targets will be met (Rijksoverheid, 2019). A model based on the weights of determinants of Dutch social housing associations' decision makers, could offer a different perspective to their prioritization and planning. It also offers insight into what they appear to find factors of influence and of importance. Subsequently, it could assist them by means of more theoretical substantiated decision-making based on contemporary research. Furthermore, the findings of the research are also expected to be of added value to the involved company of this thesis; Atriensis, who advice Dutch social housing associations on several sustainability challenges, of amongst which are making their existing dwelling stock energy efficient.

1.5.2. Academic relevance

There is need for a review and weighting of the determinants which influence decision makers, regarding energy efficiency investments (Dieperink et al., 2004; Lambrechts et al., 2021; Qin et al., 2022). A research regarding both the determinants and the size of their influences seen from a Dutch social housing associations' perspective, rather than a tenants' perspective, has not yet been performed; a problem to which this research responds.

1.6. Research design

The following section discusses the boundaries of this research, followed by a structured overview of the execution of the research by means of a research model.

1.6.1. Boundaries

The research has a number of research boundaries to limit the thesis in size and to keep it within appropriate boundaries. Firstly, the specified target group of the research will be limited to the social housing associations within The Netherlands. Secondly, the weighting of the determinants by means of a multicriteria-analysis through interviews will only regard the determinants of *Characteristics of the investment*. Since these determinants are measurable through dwelling-data and additionally considered a direct influence on the prioritization and planning. Subsequently, the weights of the determinants influencing the *Pace* of housing associations will not be investigated and will not be taken into account within a prioritization model, to be established by the execution of this research. The factors influencing the *Pace* will however be investigated by means of qualitative research questions during the interviews. Thirdly, and lastly, the determinants weighed through a multi-criteria analysis

by means of interviews are bound to the responses of a selected group of decision makers within the Dutch social housing sector. The results may thus not provide an all-encompassing conclusion for the entire sector.

1.6.2. Research approach & model

The execution of the thesis will comprise of three phases and will be based on both qualitative and quantitative research.

The first phase consists of a literature study to get acquainted with the problem statement and the associated determinants of interest.

The determinants will be further identified during the second phase of this research due to a lack of contemporary research regarding the specified target group and their determinants. Furthermore, experts at Dutch social housing associations' will be interviewed, of which qualitative information will be gathered regarding the relevant factors of influence on the pace from which conclusions can be drawn. They will additionally be asked to complete a follow-up survey in order to weigh the identified determinants through a multicriteria-analysis, relevant to the prioritization and planning. The results of the follow-up survey contain quantitative information, which will be used to set-up a model for the prioritization of dwelling complexes, in accordance with the identified determinants and their weightings.

During the third phase, a housing portfolio dataset will be used in order for the model to establish a planning and prioritization. Furthermore, a sensitivity analysis will be performed to check the sensitiveness of the results when changing the weights of variables. Finally, conclusions will be drawn of which recommendations shall follow.

A schematic overview of the research model is provided in Figure 3.

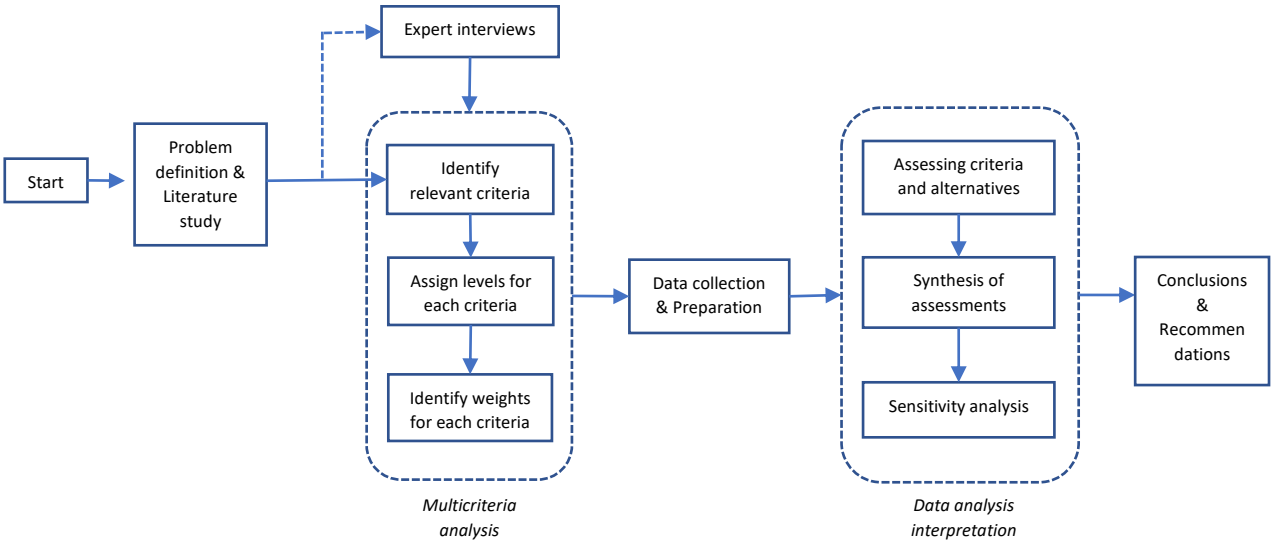


Figure 3: Research model of the thesis

1.7. Reading guide

Chapter 2 will provide a broader discussion of the problem statement by means of a literature study and additionally, discusses the current state of research towards the determinants of interest and their weightings. Furthermore, chapter 2 draws a conclusion regarding the method of research for the execution of the research. Chapter 3 provides the set-up and predefined questions for both the interviews and the follow-up survey. It additionally discusses how the interviews have been optimized regarding the validity and the reliability of results. Chapter 4 discusses the results of the interviews and the follow-up survey and additionally, provides the results of a prioritization of dwelling complexes by means of an established model. Furthermore, chapter 4 discusses a sensitivity analysis and ends with a conclusion. Chapter 5 provides the final conclusions of the thesis and answers the relations between the variables of the conceptual model. Subsequently, recommendations for the sector and suggestions for future follow-up research are provided. Lastly, chapter 5 ends with a discussion.

2. Literature study

This chapter starts by a further substantiation of the chosen determinants of interest by means of a literature study and future regulatory requirements. Then, the problem statement of this research will be outlined regarding the challenges faced by the Dutch social housing sector. Furthermore, the decision-making process and the associated tool for specifically the Dutch social housing sector will be described. Lastly, a variety of Multicriteria-analysis techniques shall be considered of which a conclusion is drawn regarding the appropriate MCA-method for the execution of this research.

2.1. State of research towards the determinants and their weightings for energy efficient dwelling investments

Existing literature stresses the need for making existing dwellings from all over the world energy efficient to meet climate goals and to tackle environmental issues. Housing associations with 29% of homeownership within The Netherlands have however been struggling to both built sufficient new dwellings and to make their existing dwelling stock energy efficient (Rijksoverheid, 2021). Well-informed and competent decision-making is needed by examining the determinants of interest and their weightings regarding energy efficiency investments by Dutch social housing associations' decision makers (Lambrechts et al., 2021). By means of literature, this section supports the importance of the determinants of interest used for the conceptual model. Furthermore, this section aims to strengthen the research questions through suggested follow-up research of the articles discussed in this section.

2.1.1. Determinants of interest for energy saving measures

By means of a secondary analysis of empirical studies, Dieperink et al. (2004) have integrated different partial explanations for the progress of energy-saving adoptions into a framework. The decision-making process of corporates' and individual decision makers within the Dutch built environment form the core. Their framework offers a starting point for the overarching determinants of interest towards energy efficiency decision-making within the Dutch built environment for the execution of this thesis. Dieperink et al. (2004) have clustered the factors of influence into three overarching clusters with further defined groups and associated sub-determinants, as provided in Table 5.

Company's context			**Technology**		**Macro developments**
Government	**Market and society**	**Company's characteristics**	**Economic aspects**	**Technical aspects**	
Policy and regulations	Level of co-operation	Knowledge / know-how	Efficiency	Complexity	Economic prospects of the branch
Incentive programs (subsidies etc.)	Branch association	Expected growth	Time to recover expenditure	Fit in production process	Environmental awareness in society at large
Covenants	Market demand	Willingness to innovate	Investment costs	Competing options	Development in energy supply
Support	Role of suppliers	Quality environmental management system			Prices
Knowledge transfer	Level of R&D in branch				

Table 5: Clustered determinants of interest according to Dieperink et al. (2004)

After identifying the explanatory variables for decision-making, Dieperink et al. (2004) additionally report that research is needed towards the weight and the actual effect of these variables, for instance through a questionnaire for the associated actors. Although their research dates from 2004, their findings regarding the determinants of interest and the suggested follow-up research towards the weightings is still of interest. The findings of Dieperink et al. (2004) show consensus with a more contemporary research performed by Qin et al. (2022), who have established a worldwide bibliometric analysis regarding the determinants for energy efficiency measures.

Green energy and energy efficient measures have received tremendous attention in the last century due to the important impact on battling climate change, and on achieving an environmental-friendly world (Qin et al., 2022). Battling climate change concerns every sector from all over the world and therefore, research towards which determinants influences decision makers on investing in energy efficient measures has gained attention as proven by Qin et al. (2022). By means of an extensive worldwide bibliometric analysis Qin et al. (2022) have identified and clustered the main determinants of interest for the adoption of energy efficiency measures into four themes with associated sub-determinants, as provided in Table 6.

Technical Matter	Adopter Level	Corporate Promotion	Environmental Challenge
Costs	Attitude	Green R&D	Governmental support
Performances	Income	Top management leadership	Community-based governance
Infrastructure	Education	Corporate social responsibility	Social norms (of external environment)
Technological capabilities	Environmental concerns	Competitive pressure	Regional economic conditions
Environmental regulations	Emotional issues	Customer demand	
	Personal norms	Financial benefits	

Table 6: Clustered determinants of interest according to Qin et al. (2022)

Qin et al. (2022) furthermore remark the importance of future research towards the determinants of interest for energy efficient measures for a specific level of actor. They suggest that research towards a specified level of actor is needed to develop better green energy promotion and investments plans, rather than generalized and combined determinants seen from different levels of actors.

Lambrechts et al. (2021) have established a conceptual model containing the factors of influence – either positive or negative – for a sustainable business model and an energy efficient dwelling stock. By means of investigated case studies and performed interviews focussed on the Dutch social housing sector, they have been able to provide specific information regarding their decision makers' determinants of interest. Six positively influencing critical success factors have been identified by Lambrechts et al. (2021) on the transition towards a sustainable business model for Dutch social housing associations, which are as follows: *(1) Collaboration (both with the market as well as other social housing associations); (2) clear narrative and vision; (3) continuous innovation (experimentation through collaboration); (4) foundation of sustainability (within the organization's culture); (5) profitability (or rather feasibility due to the nature of social housing associations); and (6) external events (society, government, market, tenant).*

In addition to the positive factors, Lambrechts et al. (2021) have also identified negatively influencing factors, which are: *(1) A lack of support from wider systems (society, government, market, tenant); (2) financial infeasibility; (3) the principal agent issue (split-incentives between the social housing association and the tenant).* The either positive or negative factors of influence for a transition towards an energy efficient housing stock can be either perceived as positive drivers or negative barriers, as identified by Lambrechts et al. (2021). Since these drivers and barriers can shift over time due to, for instance a change in legislations or changes in the market, they are clustered into determinants of interest for the decision-making towards a more energy efficient housing stock. The clustered determinants, either positive or negative, are shown in Table 7.

Characteristics of the housing association	Characteristics of the investment	External influencing factors
Sustainability organizational culture, narrative and vision	Financial (in)feasibility	Support from wider systems (government, market, tenant)
Collaborative (with the market and other social housing associations)		Split-incentives (with the tenant)

Table 7: Clustered determinants of interest towards a sustainable business model Lambrechts et al. (2021)

Although the research of Lambrechts et al. (2021) has a focus on the transition towards a sustainable business model and not particularly towards a sustainable housing stock, the identified explanatory variables on decision-making are still contemporary and therefore of added value to this research. Furthermore, Lambrechts et al. (2021) suggests follow-up research towards the actual weightings of the identified variables, similarly to the study from Dieperink et al. (2004) and is thereby of additional value to the problem statement of this thesis.

2.1.2. Similarity of determinants amongst different actors

The following sub-section discusses the similarity amongst different actors' determinants from different countries for the implementation of energy saving measures.

Seebauer (2021) has concluded the barriers and preferences amongst low-income tenants (welfare recipients) in Austria regarding energy efficient building renovations. Seebauer (2021) emphasizes the importance of a package solution comprising financial incentives, efficient dissemination of information, needed participation from the tenant and the need for policies in order to make energy efficient building renovations work. The identified determinants by Seebauer (2021) for social rental tenants in Austria show similarity with the determinants discussed in the previous sub-section, focussed on The Dutch built environment. Furthermore, the author suggests follow-up research towards the barriers and preferences for energy efficiency housing investments seen from the housing associations' perspective in order to make social building renovations work. His suggested follow-up research additionally shows consensus with the suggested follow-up researches by Dieperink et al. (2004), Qin et al. (2022) and Lambrechts et al. (2021).

Trotta (2018) has investigated the importance of determinants relevant to single-family homeowners in England on the potential of implementation of energy saving measures. The author has proven that technical building characteristics such as t*hermal quality, age of the house, past energy efficiency investments made* are better predictors than socio-economic characteristics, such as *income, education, age et cetera.* Although, the research is focussed on single-family homeowners in England, the findings of Trotta (2018) are still of added value to this thesis. By proving the importance of technical building characteristics as a direct influence on energy efficiency decision-making and socio-

economic characteristics as indirect influences, the author provides relevant determinants which show consensus with the aforementioned determinants as proven for the Dutch social housing sector. Additionally, Trotta (2018) emphasizes the need for a better understanding of the determinants of energy efficient renovation investments by specific target groups to achieve a higher level of implementation. The need for specified research towards a single target group for energy efficiency investments shows consensus with the suggested follow-up research of Qin et al. (2022).

Van Middelkoop et al. (2017) have established a behavioural model in which the factors of influence towards the implementation of energy saving measures have been identified for Dutch homeowners and tenants (both private and low-income tenants). By means of surveys and Dutch energy survey data, the authors conclude and emphasize the following determinants for homeowners and tenants' investment behaviour: *policies, the physical context (household and dwelling characteristics), the social context (behaviour/opinions of others), behavioural processes and knowledge, motives (preferences, convictions and values)'*. Although their research is focussed on the tenants instead of the social housing associations, the identified determinants for homeowners are proven to have consensus and overlap with the determinants identified by Qin et al. (2022), Dieperink et al. (2004) and Lambrechts et al. (2021). Van Middelkoop et al. (2017) are subsequently leaving a research gap for the determinants of energy efficiency investments seen from the housing associations' perspective rather than the tenants' (or homeowners) perspectives; thereby substantiating the need for a top-down review and weighting of the determinants.

To go into detail regarding the conceptual models and frameworks of the studies discussed in this sub-section will not be needed. Due to a difference in target groups and a difference in research methods as compared to this thesis, their models and frameworks will not be relevant. The identified determinants of interest for the implementation of energy saving measures however, do show consensus with earlier mentioned determinants and have therefore been taken into account for the conceptual model.

2.2. Future regulatory energy efficiency requirements as important determinants

This section will elaborate on future obligations regarding energy efficiency standards for the Dutch social housing sector. Reference is often made throughout the thesis towards Dutch social housing associations' obligation for making their existing dwelling stock *energy efficient*. This section will furthermore provide insight into the preconditions and minimum future regulatory requirements of *The Standard* and shall therewith explain what is meant with energy efficient.

2.2.1. National Performance Agreements for the social housing sector

The abolishment of the landlord tax gives back an estimated €1.7 billion per year to the Dutch social housing sector to invest (De Nederlandse Coalitie, 2021). In return for the abolishment of the landlord tax, the overarching branch organisation of the Dutch social housing sector (Aedes), the Dutch association of municipalities (VNG), the Dutch association of tenants (Woonbond) and the Dutch government have come to agreements to be achieved by 2030. The agreements have been published on June the 30th 2022 and entail the following topics (Rijksoverheid, 2022); the availability of social rental dwellings, a more sustainable housing stock, affordability, liveability (quality of life), and cooperation and execution (Rijksoverheid, 2022). The agreements by 2030 regarding sustainability can generally be outlined in four overarching commitments.

Firstly, municipalities are obligated to have established a clear vision by 2024, regarding when and which neighbourhoods will be detached from gas-supply. The plans on neighbourhood levels will be established in *Transition Vision Heating* plans, which will be further discussed in §2.2.4. Housing associations, as part of the municipal plans on neighbourhood levels, will make use of the Transition

Vision Heating plans to detach 450,000 extra dwellings of gas-supply by 2030 (approximately 20% of the Dutch social housing stock) (Rijksoverheid, 2022).

Secondly, a new minimum required insulation value will be obligated by 2030. The new insulation values are called *The Standard* and has been agreed upon to ensure energy efficient dwellings through a non-regret insulation measure. By 2030, 675,000 additional existing dwellings need to be insulated in compliance with The Standard (approximately 30% of the Dutch social housing stock).

Thirdly, social rental dwellings with a poor energy label will be banned. By 2030, dwellings with an energy label E, F or G will be prohibited.

Fourthly, from 2023 and onwards, boilers are obligated to be replaced by sustainable alternatives such as a hybrid heating pump, an electric heating pump or by the connection with a heating grid.

The beforementioned agreements will be obligated and are therefore considered as important determinants for the prioritization and planning, of which dwellings should be first in line for being made energy efficient. The following sub-sections will provide more information regarding Energy labels, The Standard and The Transition Vision Heating.

2.2.2. Energy labels

Since 2008, it is obligated to provide an energy label in The Netherlands for all dwellings to be delivered, sold or rented. An energy label is used to proof the amount of needed (fossil) energy use per m^2 per year for heating, cooling and hot water. The valuation method for energy labels entail solely the amount of needed (fossil) energy for the heating of the dwelling and has no other obligations regarding the insulation values. Because of this method of valuation, a dwelling with very bad insulation values but with additional solar panels can still be awarded a good energy label. If the dwelling meets a score and threshold of a certain amount of needed kWh fossil energy per m^2 per year. Whilst in reality, the dwelling just mentioned is very inefficient due to a loss of heating because of bad insulation values. The Dutch government obligates social housing associations to make their dwellings with a poor energy label sustainable through the abolishment of energy labels E, F and G by 2030 (Rijksoverheid, 2022). An important determinant for housing associations will thus be to prioritize dwellings with a poor energy label.

To ensure energy efficient dwellings, instead of poor insulated dwellings with sustainable generated energy through for instance solar panels, *The Standard* has come forth from the Climate Agreement (2019). The Standard offers a clear and no-regret measure regarding the insulation of dwellings (Rijksoverheid, 2019), and will be further discussed in the following sub-section.

2.2.3. The Standard

The Dutch law distinguishes between the following two types of constructional interventions in the case of an existing dwelling, other than solely maintenance: a major renovation and a reconstruction. In the case of a major renovation, more than 25% of the surface of the building shell is changed. This refers to the modification of the ground floor, the outer walls, the windows, the window frames, the doors and the roof (RVO, 2022). The associated minimum legal requirements for a major renovation are equal to the energy performance requirements of a new build dwelling: BENG (Nearly Energy Neutral Building).

In the case of a modification of less than 25% of the aforementioned surface area, the intervention is considered a reconstruction for which minimum requirements apply to the thermal insulation and technical installations; this will be the case for Dutch social housing associations for who *The Standard* will be used as a minimum requirement regarding energy efficiency. The sector has agreed to make

675,000 additional existing dwellings in compliance with The Standard by 2030, as discussed at the start of this section. Additionally, The Standard will expectably be obligated by 2050 for all social rental dwellings in accordance with the Climate Agreement (2019).

Formula for the Net heating demand in accordance with The Standard

The Standard demands a yearly maximum net energy demand per m^2 and includes a valuation method in which a total minimum required insulation value of the dwellings' roof, floor, façade, panels, windows & frames and front door is obligated. The requirements of The Standard obliges to first reduce the energy demand of the dwelling through insulation in order to make the dwelling future-proof. The Standard functions as a non-regret investment for dwellings in which the required insulation value will set the foundation for heating without gas and without losing energy due to poor insulation. Instead, these dwellings will be heated by alternative sustainable heating generators such as hybrid systems, all-electric, heating grids et cetera. The formula for the calculation of the maximum net heating demand is shown in Table 8.

Formula of *The Standard*		
Dwelling type	**Proposed Standard Compactness (A_{ls}/A_g)**	**Net heating demand (kWh/m^2)**
Single family dwelling < 1945	< 1.00	= 60
	≥ 1.00	= 60 + 105 * (A_{ls}/A_g – 1.0)
Single family dwelling > 1945	< 1.00	= 43
	≥ 1.00	= 43 + 40 * (A_{ls}/A_g – 1.0)
Multi-family dwelling < 1945	< 1.00	= 95
	≥ 1.00	= 95 + 70 * (A_{ls}/A_g – 1.0)
Multi-family dwelling > 1945	< 1.00	= 45
	≥ 1.00	= 45 + 45 * (A_{ls}/A_g – 1.0)

Table 8: Requirements according to The Standard (Aedes, 2021)

The compactness of a dwelling is calculated by dividing the total amount of 'lost' surface within the energetic shell of the dwelling by the total amount of surface within the energetic shell of the dwelling.

A_{ls} = Surfaces considered as a loss within the energetic shell of the dwelling entail the floor, roof, windows and the façades.

A_g = The total amount of surface within the energetic shell of the dwelling, including the considered lost surfaces.

Note that the difference between Energy labels and The Standard is that Energy label scores are judged by calculating the amount of fossil energy use per m^2 per year. A good energy label can be achieved by having more sustainable and green installations, such as solar panels, whilst having bad insulation values. As opposed to The Standard, which obligates a minimum required insulation value in line with energy efficiency standards. For this reason, within the next few years The Standard will replace Energy labels as a guideline for energy efficiency standards (Atriensis, 2021).

Insulation values of The Standard compared to the Target values

The level of The Standard can differ per dwelling since it depends on the dwellings' type, size, construction year and compactness. The housing association is free to tackle the insulation value per building element (roof insulation, double glass, ventilation, air gap-sealing etc.) as long as the total insulation value is in accordance with The Standard. There are additional insulation target values per building element which, if met, offers even more guarantee for a future-proof dwelling. The target values exceed the required values of The Standard and are equal to a Net Zero Energy dwelling (Atriensis, 2021). These insulation values are advised for dwellings which plan to tackle/renovate

particular building elements and want to be sure that additional future insulation is not needed when the heating generation system of the dwelling will be changed to an alternative (sustainable) generating system. Nevertheless, a housing association can comply with The Standard if the net maximum heating demand is met, according to the sum of the total minimum required insulation values per building element. The minimum insulation values which lead to the required Standard compared with the more ambitious Target values are shown in Table 9, in which additionally the comparison is made for the required ventilation systems and gap-sealing.

	Minimum values which lead to The Standard when add up	Target values
Roof	R_c = 3.5 m^2K/W (dependent on insulation material 8-15 cm insulation)	R_c = 8 m^2K/W (approx. 35cm insulation)
Floor	R_c = 3.5 m^2K/W (dependent on insulation material- and floor type 7-14cm insulation underneath the floor)	R_c = 3.5 m^2K/W (approx. 14cm insulation)
Façade	R_c = 1.7 m^2K/W (pearls, flakes or foam in the cavity wall) NB *Only for post-war dwellings*	R_c = 6 m^2K/W (approx. 26cm insulation)
Panels	If present: insulation value R_c = 1 m^2K/W (40mm sandwich panel)	1.4 W/m^2K (insulated)
Windows & Frames	U-value window = 1.4 m^2K/W (HR^{++} glass)	U_w = 1.0 W/m^2K (Triple glass in new frames)
Front door	1,4 W/m^2K (insulated)	1,4 W/m^2K (insulated)
Ventilation	Natural inflow and mechanical extraction in toilet, kitchen and bathroom or balanced ventilation with sensor control in living room and master bedroom	Balanced ventilation with heat recovery, control of supply or exhaust through CO_2-measurement
Gap-sealing	$Q_{v;10}$ = 0.7 dm^3/sm^2 (improved gap-sealing of windows and doors and connection façade with rood	$Q_{v;10}$ = 0.4 dm^3/sm^2 (further improved gap-sealing of windows and doors and connection façade with roof by professionals)
Explanatory note	The sum of all these measures will lead to The Standard. These measures are realizable within the existing structure.	The sum of all these measures lead to a further reduction of the heating demand, compared to The Standard. With these values, the exterior of the dwelling is usually provided with an insulating shell.

Table 9: Minimum requirement and Target values of The Standard (Aedes, 2021)

Aedes (2021) have concluded that 88% of the existing social housing stock does not meet the requirements of The Standard. It will however be obligated to make approximately 30% of the existing Dutch social housing stock in compliance with The Standard by 2030 (Rijksoverheid, 2022). The requirements of The Standard entail specific technical characteristics, they are therefore considered important determinants of interest for housing associations' planning and prioritization.

2.2.4. Transition Vision Heating

The Dutch built environment needs to have reduced 60% of their emissions by 2030 as compared to 1990 and needs to become entirely CO_2-neutral by 2050 (Rijksoverheid, 2021). Following from the Climate Agreement (2019), a vision regarding the transition of poor-environmental heating sources towards sustainable alternatives had been obligated to be established by the end of 2021 for every Dutch municipality. In accordance with the new National Performance Agreements (2022), it has now been obligated by 2024.

Within the *Transition vision heating* the municipalities indicate on a neighbourhood scale, when and which amount of dwellings are planned to be detached from gas supply and will undergo an insulation uptake aimed to reduce CO_2-emissions. Furthermore, the vision needs to indicate which affordable, reliable and sustainable heating alternatives and infrastructures offer potential for implementation accompanied with the lowest social costs.

As of medio September 2021, an intermediate report had shown that 39% of the 352 municipalities had already established a Transition vision heating and that 57% was still working on it, and subsequently 4% had not started yet or had not responded to the report (PAW, 2021). The municipalities have been advised to start the prioritization and planning together with the most important stakeholders of amongst which are social housing associations, due to their many dwellings throughout the neighbourhoods.

Housing associations are however not obligated to follow the visions of the municipalities, but are nevertheless strongly influenced by governmental and municipal decisions. The municipality thus has a strong influence on the housing associations' prioritization and planning through the Transition Vision Heating and therefore, considered as an important determinant of interest.

2.3. Housing associations' pace towards CO_2-neutrality by 2050

This section offers a further substantiation of the problem statement.

2.3.1. A struggling Dutch social housing sector

Dutch social housing associations own 29% of the housing stock and therefore have a significant responsibility in achieving a CO_2-neutral built environment by 2050 according to the Rijksoverheid as stated in the Climate Agreement (2019). Unfortunately, the social housing sector has been struggling with energy efficiency renovation rates due to a lack of financial space because of the landlord tax since 2013 (Woonbond, 2017). The sector failed to achieve an earlier target, of accomplishing an average energy label B by 2020 as agreed to in The Covenant of energy saving in the rental sector (2012). Instead, they achieved an average energy label B for all social rental dwellings by the end of 2021.

Besides being subject to the landlord tax which has cost the sector billions of euros, the reason for housing associations being a year later than planned can partly be explained due to over-time changed regulatory requirements and a change in energy efficiency-measurements. The changes in measurements by the government has made it harder for the housing associations to keep up with new demanded standards and energy labels. However, on the other hand, the achievement of an average energy label B can also be partly explained thanks to new build dwellings rather than energy efficiency renovations of the existing housing stock.

The achievement of an average energy label B throughout the sector provides a contradictory view of the pace in which they are actually making their existing housing stock energy efficient. Housing associations however state themselves to not make their existing dwelling stock energy efficient as fast as they would want to, in order to become carbon-neutral by 2050 (Aedes, 2021). A note following from the Climate agreement (2019) expresses the need for scaling far-reaching energy efficiency renovations within the built environment:

> The number of extensive energy renovations is far too low, the costs remain too high and investments in innovations are not forthcoming. This creates an impasse from which a breakthrough is needed quickly. The current pace of a few thousand homes per year must be increased. A market volume that does not yet exist must be created. (Background note 'The Renovation Accelerator' for the sector table Built Environment, 2019, p. 2)

Major renovations aimed at energy-efficiency and -reduction of social rental dwellings are lacking behind and the costs for doing so remain too high. Dutch social housing associations need to fasten their pace in making their housing stock energy efficient to achieve the interim reduction of 60% emissions by 2030 (compared to 1990), and to subsequently become entirely CO_2-neutral by 2050 (Rijksoverheid, 2021).

An analysis performed by Filippidou (2018) regards the energy performance progress and renovation rates of Dutch social housing associations, and has concluded beforehand that the sector would not be able to achieve an average energy label B in 2020. Filippidou (2018) additionally concludes in her research that, based on the prognosed yearly renovation rates aimed at making existing dwellings energy efficient, the social housing sector will additionally not be able to achieve a CO_2-neutral housing stock by 2050.

The author has emphasized in particular, that the rate of major renovations aimed at saving energy will remain as they are and therefore, the pace in which housing associations will make their existing dwelling stock energy efficient will remain too slow. The used data within the research of Filippidou (2018) can however be considered out-dated because of severe changes in ambitions, subsidies and plans throughout the years. For example, due to the abolishment of the landlord tax by 2023 as agreed upon in the new coalition agreement by the Dutch government (2021), Dutch social housing associations will have an estimated of €1.7 billion more to invest per year, from 2023 onwards. This money can be spend on both the construction of new energy efficient dwellings and on making their existing dwelling stock energy efficient, with which an acceleration of the renovation rates can be achieved (Aedes, 2021).

2.3.2. A roadmap towards carbon-neutrality by 2050

Aedes has established a Roadmap (2017) which offers insights into the impacts following from sustainability-related needed investments within their housing stock. The Roadmap assists and informs housing associations regarding changes within their sustainability and housing strategies in order to achieve a CO_2-neutral housing portfolio by 2050. The Roadmap of 2017 has however been outdated due to further refinement of future regulations and ambitions of the Climate Agreement (2019); like *The Standard* as a future obligated energy efficiency requirement and the *Transition Vision Heating* of local governments. The Roadmap of 2017 has been upgraded at the start of July in 2022, in accordance with new agreements and the execution of The Performance Agreements of June the 30th in 2022 (Aedes, 2022).

The revised Roadmap plays a very important role for the housing associations' decision makers in order to plan and prioritize as economical and adequate as possible towards 2050. Atriensis, who offers consultancy to housing associations on matters related to sustainability, has established a Roadmap as well. The Roadmap of Atriensis offers contemporary insights regarding which factors are currently taken into account for the establishment of a planning and prioritization towards 2050, hence determinants of interest. The determinants of interest taken into account are; planned maintenance, the transition vision heating, energy labels, indicative budget in euro's per dwelling, strategy per dwelling complex (to demolish, to sell, to continue exploitation et cetera), and the year of construction or renovation.

2.4. The decision-making process and phases

This section will provide background information regarding the decision-making process and the importance of its structuring.

2.4.1. The three phases of a decision-making process

Decisions are often made on intuition with many influencing factors. Generally, the decision-making process starts with finding an occasion for making a decision during the *Intelligence phase* (Simon, 1960). Secondly, possible courses of actions are found during the *Design phase*. Thirdly, and finally, a course of action is chosen during the *Choice phase*. Figure 4 provides an overview of the three decision-making process phases according to Simon (1960).

Without the structuring of a decision-making process, it can sometimes be perceived chaotic. Important considerations can be easily overlooked due to a lack of structure and overview. The structuring of decision problems is important to offer a better understanding and clarification of the actual decisions made, subsequently resulting in the decision maker being less likely to overlook crucial aspects which could lead to the choice of different alternatives. A decision-making overview offers structure, clarification and provides the opportunity to easier defend or explain decisions made afterwards.

Intelligence phase

During the first proposed phase of decision-making by Simon (1960), a problem is identified which remains vague during its initial phase. A further, more specified problem formulation is required together with the collection of associated data. Both the specification of the problem formulation and the collection of data needs to be done properly to ensure that the following two phases operate on the right problem. In essence, the intelligence phase is used for the formulation of the found problem and additionally for explaining and predicting possible outcomes of the choices to be made.

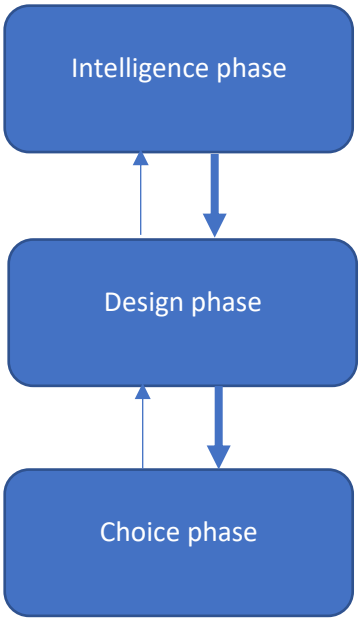


Figure 4: The three phases of a decision-making process (Simon, 1960)

Design phase

There is often not one single solution to a problem, otherwise the choice would be fairly easy. Instead, there are often many different solutions to a problem which however, are not always equally satisfying due to a difference in preference for certain alternatives used to solve the problem. Within the design phase, they aim to identify those relevant alternatives which could be used to solve the problem as formulated in the intelligence phase. Specified and concrete information is required so that a decision maker can identify relevant alternatives for their problem. The identification of alternatives can be established, for example, by means of his own past experience, by copying others' experiences or by generating alternatives through a creative process.

Choice phase

In the final phase of the decision-making process of Simon (1960), a choice is made after finding the most satisfying or acceptable alternative for solving the problem. The alternatives generated in the design phase are limited to the ones that meet the minimum requirements of the decision maker. In order to be economical with time and resources, the alternatives which meet the minimum requirements will be further evaluated. The evaluation of alternatives are based on a number of criteria which are considered important for finding the right solution. To find the most satisfying

solution, both tangible and intangible factors need to be considered. Finally, the most satisfying alternative for solving the identified problem is chosen, based on the objectives of the decision maker.

This research is interested in determining which direction should be the best possible course of action for the decision maker according to their criteria. The phase of the decision process considered in this research entails the *Choice phase* and has surpassed the *Intelligence phase* and the *Design phase*. The alternatives are already known and the decision maker needs to choose the best possible course of action.

2.5. The *Beleidsachtbaan* as a decision-making process tool for asset management

This section will explain one of the most applied decision-making processing tools within the Dutch social housing sector: *De Beleidsachtbaan.*

2.5.1. Structuring an organizational decision-making process

The *Beleidsachtbaan* is one of the most widely used models for structuring the processes associated to asset management within the Dutch social housing sector (RIGO, 2021). The method has been introduced by Van Os (2007) to insightfully integrate the housing associations' overarching strategy level, with their tactical and operational level. The method offers a process in which the building blocks of asset management by housing associations are interlinked with each other, and therefore helps the set-up and assessment of real estate portfolio policies and strategies.

In general, the *Beleidsachtbaan* integrates three fundamental aspects for structuring the decision-making of social housing associations; the management triad, a policy cycle, and a top-down management perspective (Van Os, Vastgoedbeleid bij woningcorporaties; een procesbenadering, 2007).

The management triad

The management triad offers a layered management structure for the decision-making process for organizational policies and strategies. The triad consists of a strategic layer on top, followed by a tactical layer in the middle and an operational layer below, with each their own control mechanisms (Van Os, 2007). The top layer (the strategic layer) is the smallest of size and provides the strategic frameworks and policy guidelines for the lower two layers.

Policy cycle

A policy cycle makes sure that the execution, evaluation and the adaptions of policies in each of the three layers of the management triad is performed. This cycle consists of four straightforward elements; plan, do, check, act (Van Os, 2007). The policy cycle is time-dependent and follows a certain cycle, for instance, per quartile, per six months or per year. Feedback obtained from the evaluation of processes can be used for the next cycle at the start of a new policy cycle.

Top-down approach

A top-down perspective means that the decision-making follows from the top layer to the bottom layer. For the establishment of sharp and achievable goals, the layers need to be linked to each other. The top layer (strategical layer) offers a framework for the down layer (operational layer) to follow. Simultaneously, the down layer provides the top layer with their output of the execution of the policies and frameworks, the top layer uses this info to assess and refine their policies and strategies. The mid-layer (the tactical layer) is essential for the interaction between the top and the down layer through the translation of policies to below, and the evaluation of outcomes of the lower layer to the upper layer. If the three layers are not managed correctly by the middle layer, vague and unachievable goals and policies may exist and may not be correctly executed (Van Os, Vastgoedbeleid bij woningcorporaties; een procesbenadering, 2007).

2.5.2. The steps concerning the *Beleidsachtbaan*

The aforementioned fundamental aspects of structuring organizational decision-making processes have been integrated by Van Os (2007) into the *Beleidsachtbaan*. It is essential to note that people (the tenants), bricks (the dwellings) and money (capital to serve the tenants and the market) are related to each other and centralized in the property management of housing associations. The main goal for housing associations is to serve the market, herewith the Dutch social housing market, their financial positions are preconditions rather than a goal on itself since they are non-profit organizations.

The following steps involved in the *Beleidsachtbaan* function as an integral process model for specifically the Dutch social housing sector. The model consists of eleven steps to follow with eight building blocks, spread across two different cycles throughout the three management layers of the management triad. Figure 5 provides an overview of the steps of the *Beleidsachtbaan* as established by Van Os (2007).

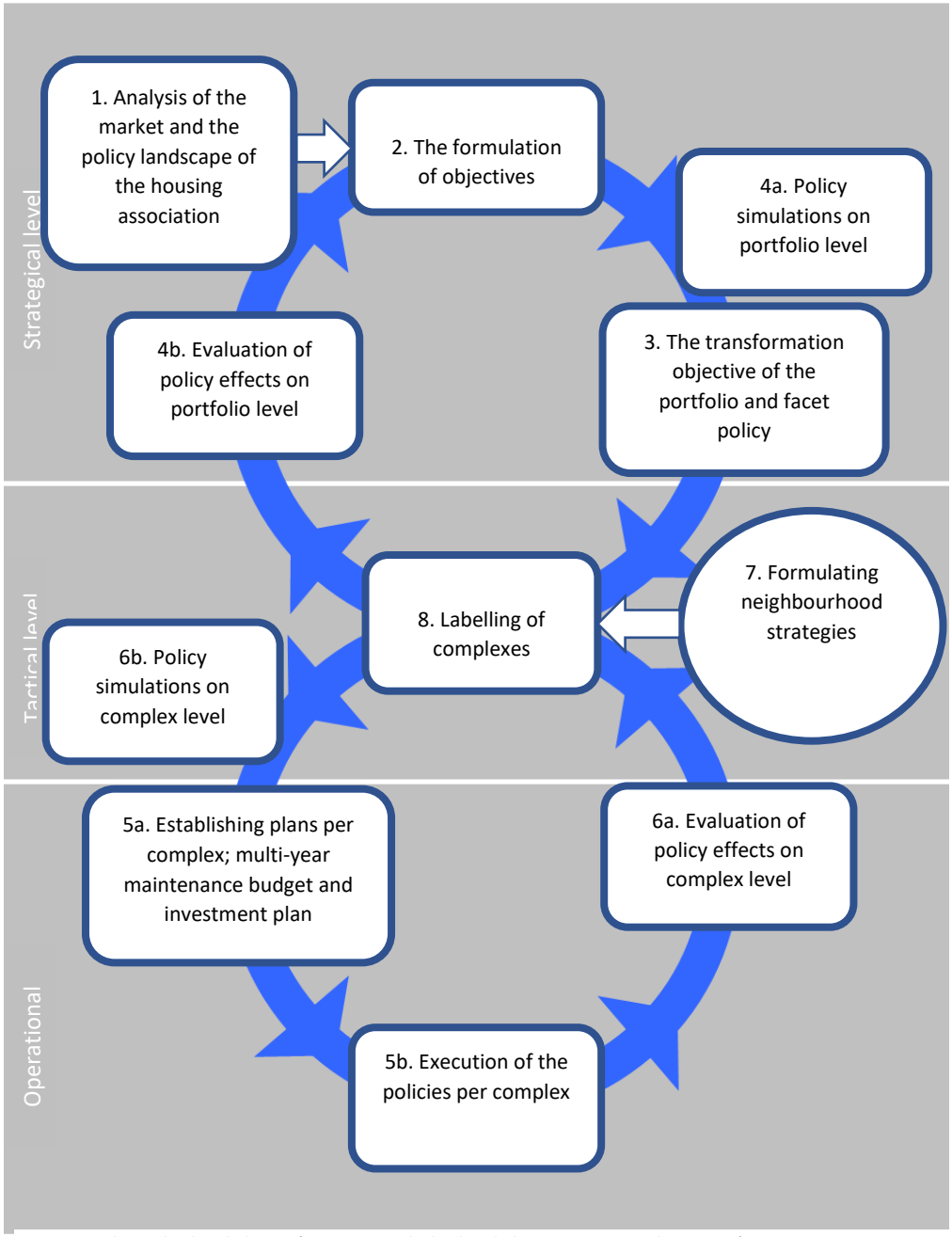


Figure 5: The Beleidsachtbaan (Van Os, De beleidsachtbaan in 8 episodes, 2021)

1. Analysis of the market and the policy landscape of the housing association

During the first step, the housing association will perform a market analysis containing for instance future expectations regarding demand and supply. Furthermore, an additional research regarding other exogenous factors of influence on their particular market will be executed. Exogenous factors such as demographic, political, cultural, financial and social developments (DeCorporatieStrateeg, 2017).

2. The formulation of objectives

Step 2 entails the execution of an internal analysis, focussed on the people and organization of the housing association. Specified objectives are formulated based on the external analysis of step 1 and the internal analysis of step 2. The objectives mainly entail their social goals related to their housing stock, related to for instance affordability, amount of dwellings and quality (DeCorporatieStrateeg, 2017). The formulated goals are used for their business plan and performance agreements with municipalities.

3. The transformation objective of the portfolio and facet policy

Based on the analyses of step 1 together with the formulated objectives of step 2, a desired target portfolio is established in step 3. The established target portfolio is compared with the contemporary housing portfolio of which the difference provides the transformation objective. Furthermore, potential changes by governmental laws and regulations or within corporation policies will be evaluated with regard to the facet policy (DeCorporatieStrateeg, 2017). Facet policy entails the policy regarding one particular aspect of their asset management, such as rental pricing, sustainability or housing quality.

4a. Policy simulations on portfolio level

Step 4a runs a simulation regarding the effects of the policy needed to achieve the desired target portfolio. The simulation provides both social insights regarding the future dwelling stock as well as financial insights.

4b. Evaluation of policy effects on portfolio level

Step 4b uses the input from the bottom layer to evaluate on the policy effects on the entire portfolio level. The outcomes of the evaluation can be used at the start of a new policy cycle through adaptations in the overarching policy and strategy.

5a. Establishing plans per complex; multi-year maintenance budget (MYMB) and investment plan

The needed transformations for achieving the target portfolio must be translated to the neighbourhoods and subsequently to each of the complexes. Based on the outcomes of a performance measurement of the dwelling complexes and multi-year maintenance budgets, a MYMB for the entire portfolio is established together with an investment plan for the entire portfolio.

5b. Execution of the policies per complex

After the MYMB and the investment plan have been established, the policies per complex will be executed. If needed, policies can be changed and adapted along the way.

6a. Evaluation of policy effects on complex level

Step 6a evaluates the MYMB-policy and the investment plan per complex as established in the previous step. Similar to step 4b, the outcomes of the evaluation can be used at the start of a new policy cycle.

6b. Policy simulations on complex level

Step 6b, just as step 4a, provides a simulation regarding the effects of the policy, however in contrary to step 4a, this step focuses on the complex level rather than the entire portfolio.

7. Formulating neighbourhood strategies

The transformation objective of step 3 needs to be translated to neighbourhood and dwelling complex levels for the lower layer. A SWOT-Analysis will be performed in which the strengths, weaknesses, opportunities and threats of the neighbourhoods are investigated (DeCorporatieStrateeg, 2017).

8. Labelling of complexes

Lastly, step 8 involves a final labelling of the dwelling complexes. Step 3 and 7 have offered frameworks for the execution of policies on complex and neighbourhood level. Step 6a has evaluated the effects of the policies per complex. The results of the previous steps results in a final labelling of complexes which are for instance, to sell, to reconstruct, to continue exploitation or to demolish (DeCorporatieStrateeg, 2017). The cycle then repeats itself through the evaluation of the policy effects on portfolio level for the upper lower, using the input of the lower layer whilst being translated by the middle layer.

The *Beleidsachtbaan* of Van Os (2007) is nowadays still an important tool for Dutch social housing associations to structure the building blocks for the decision-making processes of their asset management (Van Os, 2021). Looking at the three decision-making process phases by Simon (1960), both the intelligence phase, as the design phase, and the choice phase are integrated throughout the model of Van Os (2007). The *Beleidsachtbaan* offers a clear modeling of all three decision-making phases by Simon (1960) and analyzes, formulates, executes, and evaluates the courses of action, specified for the Dutch social housing sector. As described at the end of §2.4, this research is however only interested in finding the course of action which should be chosen during the *Choice Phase,* and has surpassed the intelligence and the design phase. The research methods associated to the *Choice phase* entail *Multicriteria-analyses (MCA)* methods and shall be further discussed in the following section.

2.6. Multicriteria-analysis techniques

This section discusses the *Multi-attribute utility theory, Linear additive models, the Analytical Hierarchy Process and Outranking methods* as relevant Multicriteria-analysis techniques.

2.6.1. Making choices based on various criteria

During the choice phase the goal is to find the most optimal course of action for established and limited discrete alternatives, based on various and mixed criteria of the decision maker. It can be hard to make the most rational choice when the criteria are both tangible and intangible due to their difference in units. For example, comparing an alternative based on euro's is fairly easy and straightforward due to the same unit of analysis. Comparing an alternative based on both euro's, the ease of accessibility, and crime rates on the other hand, can be rather hard since there are additional qualitative measures into play.

The multicriteria-analysis (MCA) method makes it possible to evaluate alternatives based on mixed criteria with large and different information. It involves a systematic stepwise approach in which the alternatives will be assessed by means of identified criteria to provide an overall valued scoring. The MCA can additionally help to establish weights for all criteria according to their relative importance. By assessing the alternatives by means of criteria and their weights, the decision maker can make a more formally and numerical judgement of alternatives (Raiffa & Keeney, 1975).

Generally, decision-making research can be divided into the following three lines of research:

- *"Descriptive research* examines how decision makers actually undertake their decision-making in real practice, and;

- *Normative research* tries to establish how individuals should choose between competing alternatives under rationality, and;
- *Prescriptive research* tries to find procedures and aims to bring actual decision-making, with the weaknesses of human decision-making identified through *descriptive research*, closer to the decision-making in practice according to *normative* ideals."
  (Dodgson et al., 2000, p. 103)

There are a variety of multicriteria-analysis (MCA) techniques based on both normative and prescriptive research. The amount of MCA-techniques keeps growing due to the existence of many different decision-making problems, varying in time, available data, resources, and because of varying analytical skills of those who support de decision (Dodgson et al., 2000). It is therefore not of interest to this research to outline and elaborate each of these methods. Based normative and prescriptive research, logic and easiness of understanding, transparency and easiness of use and the availability of needed software, this section will further outline and elaborate on the following techniques: *Multi-attribute utility theory; Linear additive models; The Analytical Hierarchy Process; Outranking methods.*

2.6.2. Multi-attribute utility theory

The Multi-attribute utility theory (MAUT) has first found its theoretical introduction in the 1940s by work of von Neumann and Morgenstern, followed by work of Savage in the 1950s. These works are generally seen as the starting point of MCA-methods. Following the line of normative research, their method provides insight of how rational individuals should choose between competing alternatives, based on their Subjective Expected Utility (SEU) and based on subjective expected uncertainty (Raiffa & Keeney, 1975).

Keeney and Raiffa (1975) further developed a set of procedures based on the theoretical foundation of MAUT by von Neumann and Morgenstern. They have been able to put the earlier principles and theory of MAUT into practical decision-making problems. These set of procedures consist of three mathematical steps for deriving the SEU:

1. Identify all future states of the world that could reasonably be viewed as relevant to this decision (uncertainty factors);
2. Calculating the utility U_{ij} (degree of attractiveness) which the decision maker associates with the outcome that follows from the combination of choosing option i and it later turning out that future state of the world j actually occurs, and;
3. Creating the probability weighted average of all the outcome utilities, where the probabilities are the individual's subjective estimates of the probability of each of the outcomes actually occurring. (Dodgson et al., 2000, p. 103)

Equation 1 is used for the calculation of the overall utility (preference score):

$$U_i = p_1 u_{i1} + p_2 u_{i2} + \cdots + p_n u_{in} = \sum_{j=1}^{n} p_j u_{ij}$$

Equation 1: Obtaining the Subjective Expected Utility of a decision maker (Dodgson et al., 2000)

- *"*U_i is the overall utility (preference score) of option i;
- p_j is the decision maker's best judgement of the probability that future state of the world j will occur;
- u_{ij} is the subjective expected utility of option i if, having chosen option i, it subsequently results in that state of the world j occurs." (Dodgson et al., 2000, p. 104)

The Multi-attribute utility theory (MAUT) method is used as a supportive decision-making tool in which the decision maker faces a choice between limited available alternatives. The choice to be made is based on a variety of attributes, which are hereafter referred to as criteria.

Limitations

Firstly, although the Multi-attribute utility model is generally a well-regarded and effective model, the model is however in its most general form still a relatively complex method. It seeks to simultaneously take into account both subjective uncertainty and subjective evaluation in terms of many allowed criteria (Shanmuganathan et al., 2018).

Secondly, the model does not account for mutual independence between preferences of criteria, it allows interaction between criteria instead of simple additive fashion. Meaning, that the calculation of the Subjective Expected Utility (SEU) can become more difficult because criteria are related to each other. When criteria are allowed to be related to each other, the SEU-calculation can sometimes result in being too complex for quick, practical non-specialist decision-making (Dodgson et al., 2000). Generally, decision-making problems in which the interaction between criteria are used, based on subjective expected utility and uncertainty, are often used for problems in which high risks on either or both financial and human consequences occur (Dodgson et al., 2000). For example in the decision-making for nuclear generation or waste.

Thirdly and finally, a general limitation of the theory is that it assumes that human decision makers make rational decisions based on the summation of scores of specific attributes of products. In reality, on the other hand, human choices are also made on intuition and emotion rather than the summation of preferences of a product's attributes (Jansen, 2011).

2.6.3. Linear additive models

Linear additive models are a primary foundational base for MCA-modelling which incorporate the idea that criteria are independent of each other and additionally, they do not formally built-in uncertainty – as opposed to the Multi-attribute utility theory (MAUT) of the previous sub-section. Linear additive models support decision makers in multicriteria-decisions through a straightforward, easy to understand and transparent way by summating the scores of all criteria relative to their weightings into a total score per option.

In a letter of Benjamin Franklin (1772), the first linear additive MCA-method of prudential calculus can be traced. Mr. Franklin established a method in which he encourages the decision maker to carefully think about identifying and choosing key criteria; although not yet scoring alternatives or weighting the criteria, the line of thinking is similar to the base of multicriteria-decision analysis.

The linear additive model often provides a very good return for the analytical effort consumed (Dodgson et al., 2000). The formula used for such decision-making problems is quite similar to equation 1, used for the SEU-model of the Multi-attribute utility theory following from the work of Keeney and Raiffa (1975). Keeney and Raiffa (1975) offered a good perspective on linear additive models, however they incorporated uncertainty and dependency of criteria, which is not the case in linear additive modelling. Equation 2 is used for the calculation of scores per option according to the weights of criteria.

$$S_i = w_1 s_{i1} + w_2 s_{i2} + \cdots + w_n s_{in} = \sum_{j=1}^{n} w_j s_{ij}$$

Equation 2: Obtaining the scores of options through criteria and their weights (Dodgson et al., 2000)

- S_i is the total weighted summation of scores of option i on all criteria
- w_n is the estimated weight of criterion n
- s_{in} is the score of option i on criterion n

Another important perspective on linear additive modelling is from the work of Edwards (1971). He independently developed a Simple Multi-Attribute Rating Technique (SMART) as a model for understanding how psychologically-oriented decision makers came to their decisions. SMART was originally a seven-step procedure model and has later been extended by the 'Swings' of weights. The Swings of weights is used to find how the swing from 0 to 100 on one preference scale is compared to the swing of 0 to 100 on another preference scale; therewith called SMARTS instead of SMART.

The SMARTS-model has later been extended by work of Edwards & Barron (1994) to SMARTER (SMART Exploiting Ranks). The goal of their extension was to lessen the demand of required information from the decision maker, so that the model could be constructed quicker and therefore be applied quicker. Less demand of required information on itself brings a weakness of less precise input, ultimately resulting in less precise output and recommendations. Less precise outcomes has however been refuted by the extension of SMARTER itself, by proving that it performs about 98% as well as SMARTS does (Edwards & Hutton, 1994). Nevertheless, a trade-off can still be made regarding the amount of time saved compared to the slightly less accurate results.

In principle, decision makers can surely be uncertain about the accuracy of their weights or scores, or both. Since the weights of the criteria are subjectively established by the decision makers. Often, not always, decision makers' weightings rather than their scoring are uncertain. For instance, due to similar judgement because of similar experiences and shared background of evidence regarding the criteria at hand (Dodgson et al., 2000). If the weightings instead of the scores are uncertain, two approaches are useful for the optimal result and the recommendation of alternatives according to Edwards & Barron (1994).

One approach is to concentrate on the maximum and minimum values which the weighted average S_i can take, look for dominance in criteria and rank out the ones who offer both the highest potential maximum weighted value, and simultaneously avoid the potentially lowest weighted value. This approach is likely to be worth pursuing in the case that the estimate of the alternatives' score is uncertain, rather than the weighting.

The second approach would be to seek out a centroid point; a representative single set of weights for all the possible acceptable weight combinations. The decision maker would only have to evaluate each option with this centroid point, followed by ranking the alternatives in terms of the weighted average score regarding the centroid point.

It could also be the case that both the weighting as the scoring are perceived uncertain, to examine the actual consequences of these uncertainties is however much more complex. The uncertainty of the inputs would most likely lead to an output of S_i (performance ranges for alternatives) that are widely and uninformative, leading it to be unlikely worthwhile to pursue this line of enquiry.

Limitations

A limitation of linear additive modelling is that there is uncertainty about either the subjective weightings or either about the scoring by the decision maker. In addition to this uncertainty, the less demanded requirements as input could give less precise and informative results (Dodgson et al., 2000).

2.6.4. Analytical Hierarchy Process (AHP)

Another MCA-method is the Analytical Hierarchy Process (AHP), developed by Saaty in the 1970s and refined since. The AHP is a technique which also develops a linear additive model and assumes mutual independence between criteria, as opposed to the Multi-Attribute Utility Theory which does not.

In its standard form, the AHP supports multicriteria-analysis decision problems by scoring alternatives based on subjectively weights of criteria through pairwise comparisons. Each criterion will be pairwise compared with another criterion, regarding its importance for achieving the overall objective. By means of the pairwise comparisons, weights can be derived per criterion to which each alternative can be scored. The AHP therefore entails a method in which the relative importance of each individual criterion results to an overall weighted scoring of alternatives.

The AHP-method provides a structural overview of multicriteria decision analysis problems through a hierarchical decision-making model. The decision hierarchy structure consists of at least three levels; (1) An overarching goal, (2) criteria functioning as means to achieve the goal, which are possibly subsequently followed by sub-criteria needed to achieve the criteria and therewith the goal, (3) alternatives from which information will be analysed relative to each criterion and associated sub-criteria. Figure 6 provides an example of a decision hierarchy structure.

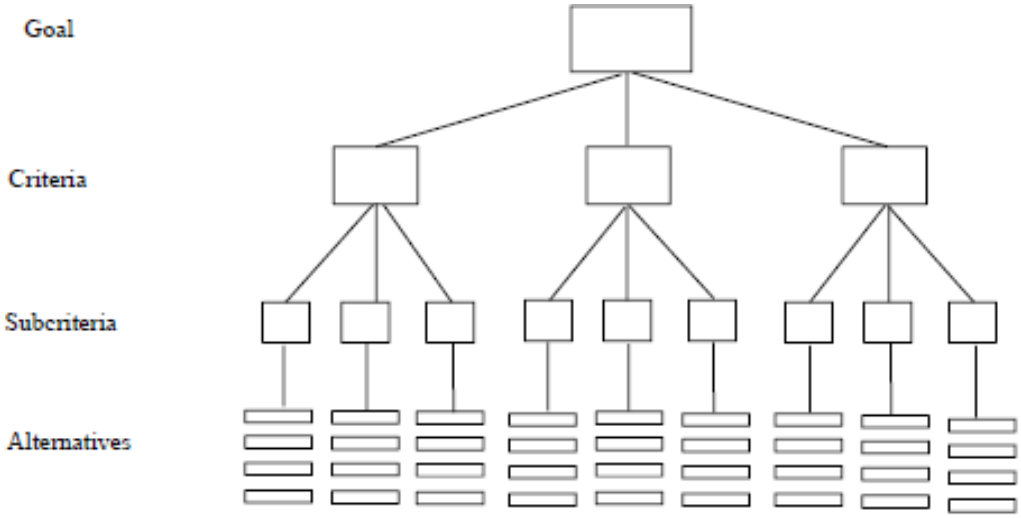


Figure 6: A decision hierarchy structure (Moutinho et al., 1994)

Calculating the weight of criteria through pairwise comparisons

Pairwise comparisons are made horizontally between the criteria of the same level with respect to their parent element within the decision hierarchy. The method is used to establish the importance of the criteria for achieving the overall goal; thereby converting subjective assessments of importance to relative weights of criteria to calculate the final scores of alternatives (Saaty, 1987). The general question asked for pairwise comparing criteria to derive the weights is: *"How important is criterion A relative to criterion B for achieving the objective?"*. The responses are gathered in a verbal form and are subsequently codified on an intensity scale of 1 to 9 as shown in Table 10.

How important is criterion A relative to criterion B?	Scale point
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9

Table 10: Verbal scaling of relative importance; 1-3-5-7-9 (Saaty, 1987)

After the weights have been identified through pairwise comparisons and after the alternatives have been scored, the alternatives are then evaluated using the earlier described simple linear additive model (Equation 2). The total weighted summation of scores of option i (S_i) will range somewhere between 0 and 1. With 1 being the most preferred alternative and 0 being the least preferred alternative, subject as always to sensitivity testing.

The required steps for an Analytical Hierarchy Process structure, the data entry of the weights and the scoring of alternatives are generally perceived as easy to undertake. Due to its easiness of use, AHP is an attractive method of MCA, making it one of the most widely applied MCA-methods (Dodgson et al., 2000).

Limitations

Even though the Analytical Hierarchy Process is widely accepted and considered a useful tool, critical questions have been raised regarding the underlying theoretical basis of the technique.

Firstly, Belton and Gear (1983) argue that a ranking made by means of the AHP can change and even reverse by the introduction of a new alternative. Even though that the same criteria and weightings apply to the new alternative to be assessed, an issue being broadly discussed as *The rank reversal problem* could still be the case (Whitaker, Saaty, & Vargas, 2009). Since alternatives are evaluated independently, it is reasonable to expect that the overall preference order (ranking) would remain unchanged by introducing a new alternative. There is however a chance that the relative importance of a criterion is dependent on the alternatives to be evaluated, meaning that a change in ranking can be the case (Belton & Gear, 1983). Introducing a new alternative to the decision-making problem could thus result in a reversal in ranking which on itself is not the actual failing, but rather whether or not independency applies. An assumption that most of the multi-criteria methods use.

Secondly, the assessment of criteria is subject to the empirical interpretation of the expert and the comparisons made. Because of a possible different interpretation of the comparisons and the vocabulary of the point scale, the results can be internally inconsistent. Logically, in the case of three criteria A, B and C; if A is considered more important than B and B is considered more important than C, then it follows that A must be more important than C. However, with the point scale of 1-3-5-7-9 and the associated vocabular descriptions (1 = equal importance; 3 = slightly more important; 5 = more important; 7 = much more important; 9 = extremely more important), a chance arises for potentially inconsistent choices of importance in which, as from the example just given, C can potentially indirectly be stated to be more important than A. Subsequent to the potential of internal inconsistency, a largely discussed criticism exists concerning the lacking theoretical foundation of the 1-9 point scale (Whitaker, Saaty, & Vargas, 2009).

Thirdly and lastly discussed, decision analysts are debating about the correctness of the underlying fundamentals and basic principles of the Analytical Hierarchy Process. Decision analysts are debating the relevance and the meaning of pairwise comparisons. They question whether the pairwise comparisons can be perceived as behavioural and spontaneous in nature and argue that there is not sufficient clarification for the method to be empirically tested (Whitaker, Saaty, & Vargas, 2009).

2.6.5. Outranking methods

The Outranking Methods are seen as another perspective on MCA and have originated from France in the mid-1960s following from the work of Roy – as opposed to the previous methods which have been originated from the US and the UK. Both MCA-methods as Outranking methods share the same purpose of providing support to multicriteria decision-making problems. The data needed for the Outranking methods is additionally quite similar to the data needed for MCA-models. Namely, they

both need a specification of the alternatives known. The performances of alternatives will furthermore also be assessed by means of weights of criteria expressing their relative importance.

Nevertheless, the Outranking Methods has substantial differences compared to MCA-methods. The fundamentals of Outranking follows from the general idea of comparing two alternatives, and the idea of one option dominating another option on predefined relevant criteria. One option appears to dominate the other if it scores at least as good on all criteria and better on at least one criterion, as compared to another option (Roy, 1991). A set of procedures have been developed in order to operationalise Outranking as a way to support the decision-making of decision-making problems. For example, through Electre I (one) which has been developed by Roy (1991), involving two steps.

Step 1: Defining concordance and discordance

The concordance and discordance indices are used as matrices to identify the dominant alternatives by means of thresholds. The concordance index represents the relation of dominance between alternatives and expresses the degree to which an alternative is better than another alternative. The discordance index looks the other way around as opposed to the concordance index, it represents the relation of dominance between alternatives by the degree to which an alternative is worse than another alternative.

Step 2: Combining concordance and discordance

During the second step, thresholds are established for both the concordance threshold and the discordance threshold. The larger the concordance threshold and the lower the discordance threshold, the more alternatives will be sought for dominating other alternatives. The thresholds result in a short-list of which option outranks another option.

Although both Outranking methods and MCA-methods aim for the same outcome as a supportive decision-making tool, the two are quite different in underlying assumptions. MCA delivers a final ranking by means of a more formula based calculation, which then need to be checked again to make sure that important criteria have not been forgotten in the model. Outranking methods, as opposed to MCA, leaves more of the final ranking to the decision maker (Dodgson et al., 2000). The decision maker in return is able to finetune his or her preferences in terms of the concordance and discordance thresholds. Outranking additionally has built-in that some alternatives will be left out if they do not meet certain minimum thresholds, which is quite similar to decision-making in real life practice. In practice, if alternatives do not meet a minimum threshold, they are likely not to be acceptable at all and therefore, Outranking stimulates a more interactive process between the decision maker and the model (Dodgson et al., 2000).

Another interesting feature of Outranking is that two alternatives, under certain conditions, can be classified '*incomparable'* or in other words, difficult to compare (Dodgson et al., 2000). For instance, due to a lack of information at hand which results in '*incomparability'* of two alternatives. This built-in function results in the formal assessment of alternatives to continue, without omitting these two incomparable alternatives because of, for instance, a lack of substantiative information to remove both from consideration. It simply notes the problem of two alternatives being hard to compare with each other.

Limitations

Outranking Methods appear to focus less on the actual process of decision-making and leaves more of its ranking to the actual decision maker (Dodgson et al., 2000). On the one hand, this is a strength on its own, since it encourages more interaction between the decision maker and the model. On the other hand, it could take up more time and effort for the decision maker. Furthermore, the limitation of Outranking lies in the dependency of arbitrary definitions for outranking, and additionally the

parameters of the thresholds. Both the definitions of outranking and the threshold parameters can subsequently be subjectively manipulated by the decision maker.

2.7. The Analytical Hierarchy Process for the execution of this research

This section will substantiate the choice for the AHP-method as the appropriate method of this research. Furthermore, this section will outline the stages of the AHP. Lastly, a different research method will be discussed as an addition to the AHP which will also be used for this research.

2.7.1. Choosing the Analytical Hierarchy as the appropriate method of research

The *Multi-attribute utility theory; Linear additive models; The Analytical Hierarchy Process and Outranking methods* have been discussed in the previous sub-sections as being well-regarded MCA-methods. These methods contain slight differences in their line of thinking and in ways of establishing a final score and ranking of alternatives. The assumptions and easiness of use of The Analytical Hierarchy Process are closest in line to this research, and is therefore used as the MCA-method for the execution of this thesis.

The Analytical Hierarchy Process further develops a linear additive model and also follows the assumption of mutial independence between criteria. Because of the mutual independency between criteria, the calculation of ranked alternatives are not as complicated as the Multi-attribute utility theory, which does not assume such independency. The AHP is generally regarded as easy to use and furthermore, offers a transparant method through documentation and structuring of the decision-making problem (Dodgson et al., 2000). By means of a subjective assessment of the weights of criteria through pairwise comparisons, the relative importance of each criterion relative to the others can be established. The method of pairwise comparisons are also easy to use and therefore used for the execution of this thesis; which aims to find the importance (weights) of the determinants of interest for the prioritization and planning of dwelling complexes.

The Multi-attribute utility theory is nevertheless a well-regarded method as well and a useful tool for decision makers to rationalize their choices. Just as the AHP, the MAUT also weights the criteria through subjective assessments by the decision maker but however, MAUT has built-in subjective uncertainty. Because of simultaneously taking both subjective expected utility and subjective uncertainty into consideration, the method is generally regarded as complex (Shanmuganathan et al., 2018; Dodgson et al., 2000). Additionally, MAUT does not account for mutual independence, meaning that the criteria affect each other and therefore the final scores and ranking of alternatives, also resulting in a much more complex calculation.

Due to the nature of Outranking methods, enabling the decision maker to change the thresholds in order to change the rankings rather than to use the weights of criteria, the AHP is preferred over the Outranking methods. Although the encouraged interaction between the decision maker and the decision-making problem through Outranking methods is beneficial for being more in line with real-life decision-making, it can be of inconvenience to this research. It could take extra time and effort for the decision maker, asking them to change their thresholds and to think of new alternative rankings. Furthermore, the results are subjective to the threshold parameters which in return can be subjectively manipulated by each of the decision makers. The AHP uses weights of criteria instead of thresholds and can therefore result in a faster process of ranking, using less time and effort for the decision makers than with the use of Outranking methods.

2.7.2. An eight-step process of the Analytical Hierarchy Process

The steps of AHP are not as dry-cut as with the following eight steps which will be discussed. In practice, these steps are used as guided explorations of a problem rather than a step-by-step to follow process. The three steps of the decision-making phases by Simon (1960) as provided in §2.4 can be extended into an eight-step procedure of the Analytical Hierarchy Process (Moutinho et al., 1994; Dodgson et al., 2000), entailing the following:

Step 1) Establishing the decision context

The Analytical Hierarchy Process starts with finding the objective at hand, it is crucial for the rest of the process to have a clear view of the objective and the associated criteria for achieving the objective. Additionally, the administrative, political or historical context are subject to the specified objective to be achieved and therefore, clearly describing the context of the problem and objective needs to be done accordingly (Dodgson et al., 2000). A clear overview of the objective, the criteria and associated sub-criteria needed for achieving the objective, and the yet to be investigated alternatives may be designed in a hierarchical-structured value tree as shown in Figure 6.

Step 2) Identifying alternatives

Often, decision makers may already have an idea about potential alternatives suited and alternatives definitely not suited for achieving the objective (Dodgson et al., 2000). The second step within the AHP-process regards finding those alternatives and making a short-list of alternatives based on basic data and quick procedures. Meaning, to be economical with the alternatives assessed and therefore, already eliminating the alternatives which do not meet the minimum requirements of the criteria (Moutinho et al., 1994). Later on in the process, the decision makers might go back to step 2 in order to find new and more satisfying alternatives needed to achieve the objective.

Step 3) Identifying criteria and sub-criteria

During the third step of the process, the criteria are identified to which each alternative will be judged and therefore, the criteria serve as a performance measure for each alternative. The criteria are needed for achieving the overarching objective, the sub-criteria are in return needed for achieving the mother criterion to which the sub-criteria are associated as shown in Figure 6. A way of identifying criteria relevant to the task is by, for example, uncritically brainstorming in groups, perhaps with different stakeholders and seen from different perspectives, or by examining policy statements to derive criteria which reflect their concerns (Dodgson et al., 2000). Choosing criteria must however be economical, meaning that redundant or several criteria with the same meanings must be eliminated. They must also be logical, as each alternative must and can be judged against each criterion.

Step 4) Assigning weights to all criteria

Weights are needed to reflect the relative importance of each criterion with respect to the overarching objective. The decision maker will be asked to verbally pairwise compare one criterion with another criterion relevant to its importance for achieving the objective. The verbal scaling is shown in Table 10 and the process for eliciting the weights of the criteria have been described in §2.6.4.

Step 5) Combining weights and scores to derive an overall value

In step 5, the weights derived from the pairwise comparisons of the criteria are now synthesised (put together) to find the alternatives with the highest priorities. The assessor can either use the *Distributive method* if the purpose is to rank alternatives or the *Ideal method*, if the purpose is to select the best alternative (Moutinho et al., 1994). With respect to the goal of this thesis, the *Distributive method* will be used to rank the alternatives (dwelling complexes) considering the assessed importance of the criteria.

A very crucial aspect for deriving overall scores of the alternatives is that all the criteria must be *mutually preference independent* (Dodgson et al., 2000). Meaning, that assessing the preference of a criteria must possibly be done without having to know another criterion, so that the preference of both criteria are independently given. The choice of preference must not affect each other. If the decision maker cannot rate his preference for a certain criterion without knowing another criterion, step 3 must be done again. Two criteria may be merged if they are directly related to each other and might mean the same.

Step 6) Examine the results

Based on the final weighted average of the preference scores of all alternatives, a final examination of the results can be made. Check whether the 'best' possible answer is achieved by examining the ranked alternatives based on intuition and perceived logic. If the best ranked alternative is not fit to be the best possible answer, the decision model, the criteria, and their weightings are likely needed to be changed.

Step 7) Sensitivity analysis

The weightings of decision makers has been very important in the overall weighted scores of alternatives. A sensitivity analysis is performed to assess the sensitivity of the chosen alternatives when making slight adjustments to the weights of the criteria.

Step 8) Documenting the decision

All the decisions made throughout the entire decision-making process need to be documented to explain and defend following conclusions. Documenting contains the processes in which the criteria have been established and additionally weighted in accordance with their relative importance for achieving the overarching goal. Documenting furthermore entails the ranking of alternatives based on the weights of criteria.

2.7.3. An Excel-tool for deriving weights

A free Excel template-tool developed by Goepel (2013) will be used as the Analytical Hierarchy Process tool for deriving the final weightings of the criteria. The tool consists of multiple tab sheets:

- A summary sheet to display the final results of the weightings, based on the Eigen Value Method (EVM);
- Multiple sheets in which the pairwise comparisons are filed per individual expert, showing the inconsistency ratio of their responses and the assessment of the results based on the Geometric Mean Method (GMM);
- A sheet showing the consolidated results per criterion relative to the other criteria and additionally, showing summarizing tables of each expert;
- A sheet with reference tables (random index, limits for geometric consistency index, judgement scales)

The Eigenvalue Method (EVM). There are many ways to calculate the priority vector, showing the relative weights of the criteria compared, however the AHP uses the EVM as proposed by Saaty (1987). The EVM calculates the total amount of variance which can be explained by a certain component (Dallas, 2019). It represents the importance of a component. The bigger the Eigenvalue, the more it correlates with more important directions, and thus the better. In case of five participants, the Eigenvalue must exceed five for the factors to be considered. The final calculation of priorities as shown in the summary sheet is according to the EVM.

Row Geometric Mean Method (RGMM). The RGMM is used in the individual sheets for the calculation of weights, and involves another method, other than the EVM used to calculate priority weights. The

RGMM and the EVM give approximately the same results (SpiceLogicInc, 2022), however involve different mathematical steps.

Absolute Errors. The absolute error indicates the difference between the observed value and the expected value.

Mean Relative Error (MRE). A Relative Error is calculated by dividing the absolute error by the measured value. The MRE takes the average of all the absolute errors and indicates how well the measurement is of an object.

Consistency Ratio (CR). The Consistency Ratio determines the consistency of the pairwise comparisons made by the decision maker. It provides a measure of judgements between the judgements being totally random, and being totally consistent. For example, in the case of three criteria, A, B and C; if A is considered more important than B and B is considered more important than C, then it follows that A must be more important than C. This may however not always be the case. If not, the consistency ratio goes up and increases randomness. According to Saaty (1987), a CR may not exceed 10% or the results may otherwise have to be reconsidered.

2.8. Method as an addition to the AHP

This section discusses an additional, straightforward method to the AHP, relevant for the execution of this research.

2.8.1. Preference scoring of categoric options

The weights of criteria will be established through pairwise comparisons and will be used for the establishment of a planning and prioritization model. Based on the known characteristics of the dwelling complexes, a decision maker is able to make a prioritization according to his/her criteria and the associated weights (importance) per criterion. However, to make a decision based on the weights of criteria will not be sufficient. The criteria associated with prioritizing dwelling complexes consist of particular *Categoric options*. These categoric options will be fundamental for the decision maker to prioritize a dwelling complex over another.

For example, a decision maker has to make a prioritization of dwelling complexes with respect to the criterion *Energy labels*, between complexes X, Y and Z. The prioritization to be made by the decision maker is then dependent on the energy labels of the complexes. The energy labels can for example be grouped into; Poor energy labels (E, F and G), moderate (C and D), sufficient (A, B) and good to excellent (A+ and better). The grouped energy labels are considered *Categoric options*, of which a decision maker holds a certain preference for.

To investigate the preferences of each categoric option associated with each individual criterion, the decision maker will be asked to distribute 100 points according to his/her preference with respect to the overarching goal. Logically, the decision maker, with respect to prioritizing which dwelling complex should be first in line for being made energy efficient, would hold a greater preference for complexes with a poor energy label. A division of points could then be; 70 points to a dwelling complex with energy label E, F or G, 20 points to C or D, and 10 points to A or B. The preference of the decision maker for each categoric option, relevant to the associated criterion (in this example; Energy labels) will thus be investigated by the division of the 100 points.

The score of preference for the categoric option relevant to the dwelling complex to be prioritized, times the weight of the criterion associated with the categoric option, results in a weighted score of alternatives (dwelling complexes) of which a ranking can then be established.

2.9. Conclusion

This section will conclude the determinants of interest relevant to the prioritization and planning of dwelling complexes by Dutch social housing association. Furthermore, a conclusion is drawn regarding the AHP as the method used for the execution of this research.

Determinants of interest

By means of a secondary analysis of empirical studies, Dieperink et al., (2004) has provided a starting point for the determinants of interest within the Dutch built environment regarding energy efficiency investments. They have proven the importance of many explanatory variables, entailing; Government, market and society, the company's context, economic aspects, technical aspects, macro developments. Their findings have been substantiated by Qin et al., (2022), who have identified and clustered the main determinants of interest for the adoption of energy efficiency measures through a worldwide bibliometric analysis into; Technical matters, adopter level, corporate promotion, environmental challenges.

With a particular focus on the Dutch social housing sector, Lambrechts et al., (2021) established a conceptual model containing both positive as well as negative factors influencing the transition towards an energy efficient housing stock. Their research, based on investigated case studies and performed interviews, substantiated the importance of; Characteristics of the housing association, characteristics of the investment, and external influencing factors.

The suggested follow-up researches of the aforementioned articles all show consensus. There is a need for a top-down review of the determinants for energy efficiency investments, seen from the housing associations' perspective rather than the tenants' perspective (Dieperink et al., 2004; Qin et al., 2022; Lambrechts et al., 2021; Seebauer, 2022; Trotta, 2018; Van Middelkoop, 2017).

Further important determinants of interest will be the prioritization of dwelling complexes with a poor energy label due to the abolishment of labels E, F and G by 2030 (Rijksoverheid, 2022). The Dutch social housing sector, together with the Dutch government, have furthermore agreed to insulate 675,000 additional dwellings in compliance with *The Standard* by 2030 (Rijksoverheid, 2022). The Standard entails minimum required insulation values of the dwelling to enhance energy efficiency, and will therefore be an important determinant of interest. Following from the Climate Agreement (2019), municipalities are obligated to establish a *Transition Vision Heating* in which they indicate when and which dwellings are planned to be detached from gas supply. The Transition Vision Heating is of strong influence on the planning and prioritization of housing associations because of the great amount of owned dwellings in certain neighbourhoods. Thus, the Transition Vision Heating is also considered an important determinant of interest.

By 2050 the Dutch social housing sector needs to be CO_2-neutral and by 2030, they need to have reduced their CO_2-emissions with 60% compared to the levels of 1990 (Rijksoverheid 2021). The sector is not going as fast as they want to be in order to meet the future goals (Aedes, 2021). Thankfully, the abolishment of the landlord tax by 2023 will provide the sector an estimated of €1.7 billion more to invest per year, from 2023 onwards (De Nederlandse Coalitie, 2021). To provide insight in the changes within their housing portfolios related to (sustainability) investments made, and to help establish a strategy towards 2050, Aedes has established a Roadmap (2022). The Roadmap contains contemporary determinants of interest regarding which factors are currently taken into account for establishing a planning and prioritization towards 2050. The determinants concluded and used are;

planned maintenance, the Transition Vision Heating, energy labels, indicative budget in euro's per dwelling, strategy per dwelling complex (to demolish, to sell, to continue exploitation et cetera), and year of construction or renovation.

The Analytical Hierarchy Process

The *Multi-attribute utility theory; Linear additive models; The Analytical Hierarchy Process and Outranking methods* have been discussed in the previous sections as being well-regarded MCA-methods (Dodgson et al., 2000). Each method contain slight differences in their line of thinking and in ways of establishing a final score and ranking of alternatives. The Analytical Hierarchy Process will be used for the execution of this research. Generally, the AHP-method uses a structural overview of the decision-making problem, is considered transparent, and the method of deriving weights of criteria through pairwise comparisons is perceived as easy-to-use and straightforward (Dodgson et al., 2000).

The AHP furthermore assumes mutual independence of criteria, which as opposed to the Multi-Attribute Utility Theory, makes the calculation and ranking of alternatives less complex (Shanmuganathan et al., 2018). Instead of a more formualic calculation of a final ranking as with the AHP-method, the Outranking method on the other hand leaves more of the final ranking to the decision maker. The Outranking approach offers benefits through more interaction between the actual decision maker and the decision-making problem, which however might be inconvenient to this research due to limitations in time. The AHP enables a faster process of ranking alternatives whilst not being too much dependent on the decision makers' time and effort.

3. Research methods

This chapter will discuss the set-up of the interviews and the follow-up survey relevant for investigating the relationships between the variables of the conceptual model. Furthermore, the participating experts of the housing associations will be anonymously described. Lastly, the data validity and reliability will be discussed.

3.1. Interview set-up

Interviews with experts of Dutch social housing associations have been prepared to investigate the relationships between the independent variables and the dependent variables within the conceptual model (Figure 2). The interviews consist of two separate parts. Part I aims at finding which factors are influencing the pace of Dutch social housing associations towards CO_2-neutrality in compliance with The Standard by 2050 and Part II aims to conclude the criteria of interest for their prioritization and planning. This section will describe the set-up of both parts of the interviews and shall further elaborate on the questions asked during the interviews.

3.1.1. Part I – Factors influencing the pace of renovations

Part I aims to find the factors of influence on the pace in which housing associations are making their existing dwelling stock energy efficient. Within the conceptual model, the influences of the *Government, Municipality, Market, Tenant, and the Characteristics of the housing association* on their *Pace* will be investigated.

The first part of the interview consist of open interview questions which have been structured to provide guidelines to steer the interview towards the desired course. The interview questions start with an introductory question to elicit the influence of the aforementioned factors on their *Pace* or to elicit possible other factors of influence. After the opening questions, sub-questions will follow associated to each factor of influence (government, market, tenant, characteristics of the housing association). Lastly, three final closing questions will be asked and marks the end of Part I. The list of the open interview questions of part I is provided in Table 11.

Opening question	
1	What barriers do you experience regarding the pace at which your housing association is making its existing housing stock energy efficient?
Influence *government and municipality* on the *pace?*	
2	How do you feel about the current policy at the central government level with regard to the pace at which your housing association is making its existing housing stock energy efficient?
	a. And on municipal level?
3	What are your thoughts regarding *The Standard* to be achieved by 2050, is it achievable or too ambitious?
	a. And why?
4	Where would you like more support from the municipality and national government, for example in the process, finances, laws and regulations, etc.?
	a. And why?
Influence *market* on the *pace*?	
5	What market influences do you experience that affect the pace at which you make your current housing stock energy efficient? (e.g. cooperation, manpower, price developments, Research & Development, supply and demand, etc.)
6	How do you experience the cooperation between housing associations and market parties with respect to achieving a CO2-neutral sector by 2050?
	a. And with housing associations?

7	How strong do you think the influence of price developments (e.g. construction or energy prices) affects the pace of making existing dwellings energy efficient?
Influence *tenant* on the pace?	
8	How strongly do you feel tenants influence the pace at which you can make your existing housing stock more sustainable?
9	Do you find support or resistance from residents more often?
10	If required, how do you persuade tenants to agree to energy efficiency renovations/interventions?
Influence *characteristics of the housing association* on the *pace?*	
11	What characteristics of a housing association do you consider important for the pace of energy efficient renovation rates? (e.g. manpower, finances, management, corporate culture, etc.)
	a. And why?
12	How do you feel about the level of knowledge and experience within your housing association with regard to 'The Standard' to be achieved by 2050?
Closing questions	
13	If you could advise the Minister of Housing and Spatial Planning (Hugo de Jonge), what specifically would you like to see changed tomorrow or in the near future in view of the 2050 goal?
14	As opposed to what is not (yet) going well, what do you think is going well in the run-up to a CO2-neutral social housing stock?
15	Do you expect to achieve a fully carbon-neutral housing portfolio by 2050?

Table 11: Predefined list of questions Part I

Clarification of results

The factors related to the *Pace* of housing associations is investigated by means of qualitative research, as described in Chapter 1. To be able to provide and outline an impression of the influences of the factors, a scoring will be established. A score of +1 will be awarded if the expert states that the particular factor is of influence on their pace, and a score of -1 will be awarded if the factor is stated to be of no influence on their pace. If, for instance, 10 experts are interviewed, a scoring of +10 means that the factor is of very strong influence and a -10 means that the applicable factors is of no influence on their pace. A zero would mean that the opinions are divided and that the applicable factor is nor of influence, nor of no influence.

3.1.2. Part II – Criteria of interest for the prioritization and planning

Part II aims to find the five most important criteria for prioritizing and planning which dwellings should be first in line for being made energy efficient. Preceding the interviews, 20 criteria have been established by means of both the list of determinants of interest according to literature as concluded in Chapter 2, and the help of experts from Atriensis. The list of the 20 predefined criteria are shown in Table 12.

List of the 20 predefined criteria	
1	Combination with planned maintenance
	Sustainability interventions together with the replacement of a façade, floor or glass
2	Combination with interventions in the direct surroundings
	Sustainability interventions together with the sanitation of sewers or the gas- and electricity network
3	Combination with planned renovation
	Sustainability interventions together with naturally planned renovations

4	Because residents may or may not be interested
	Whether or not to make the dwelling sustainable at the request or resistance of the resident
5	Energy label
	Dwellings with energy label E, F and G are given priority
6	Transition Vision Heating of municipalities
	Creating the Route Map on the basis of municipal force through the Transition Vision Heating at neighbourhood level
7	Liveability in the neighbourhood
	Dwellings in a neighbourhood with poorer liveability are given priority
8	Trias energetica
	Creating The Roadmap according to the Trias energetica: 1) reduce energy demand 2) use sustainable/renewable energy 3) use remaining fossil energy as efficiently and cleanly as possible
9	Stage of technologic development
	Postponing sustainability investments because of the expectation that, for example, heat pumps will be cheaper in 10 years' time
10	Subsidizes on products
	To start or to wait with sustainability investments due to potential availability of subsidies
11	Financial possibilities in the short/long term in relation to the objective
	Postponing sustainability in year x because of insufficient budget
12	Strategy housing portfolio
	Whether or not to make a dwelling sustainable due to planned demolition, sale or continued exploitation
13	Government
	The measures to be taken plotted in time in the Route Map are, for example, dependent on 'The Standard'
14	Construction or renovation year
	Dwellings with the oldest year of construction are given priority, in contrary to dwellings that have already been renovated
15	Amount of energy bill/energy poverty
	Dwellings suffering from energy poverty are given priority
16	Combinations with indoor climate quality/noise pollution
	Dwellings with low (reported) comfort are given priority
17	Input from stakeholders
	Performance agreements with municipalities determine which dwellings will be tackled first
18	Market influences
	Postponing sustainability investments due to a shortage of supply or increased prices
19	Profitability for the housing association on (partial) intervention
	Influence of profitability on when which home is made sustainable
20	Positioning in energy transition
	Whether or not to speed up the process of making the housing portfolio sustainable, for example by taking the lead in energy transition

Table 12: List of the 20 predefined criteria

The list of criteria have additionally been categorized into three different overarching categories from which conclusions will be drawn. Firstly, the criteria concerning the physical and energetic state of the dwelling are related to *Housing conditions*. Secondly, the criteria concerning the market, tenant, government, municipalities or the direct surroundings of the dwelling have been categorized into *External factors.* Thirdly and finally, the criteria concerning characteristics of the housing association, such as finances and strategies are related to *Internal factors.* The categorization is shown is Table 13.

Categorization of the 20 predefined criteria		
Housing conditions	5	Energy label
	8	Trias energetica
	14	Construction or renovation year
	1	Combination with planned maintenance
	3	Combination with planned renovation
	16	Combinations with indoor climate quality/noise pollution
External factors	2	Combination with interventions in the direct surroundings
	9	Stage of technologic development
	18	Market influences
	4	Because residents may or may not be interested
	15	Amount of energy bill/energy poverty
	7	Liveability in the neighbourhood
	6	Transition Vision Heating of municipalities
	13	Government
	10	Subsidizes on products
Internal factors	19	Profitability for the housing association on (partial) intervention
	11	Financial possibilities in the short/long term in relation to the task
	12	Strategy housing portfolio
	17	Input from stakeholders
	20	Positioning in energy transition

Table 13: Categorization of the 20 predefined criteria

Before performing the interview, the expert was asked to choose the five most important criteria and the five least important criteria out of the list of 20 predefined criteria. During the interview, their choices will be discussed by means of open interview questions to find the reasoning and logic behind their choices. The experts will however not get insight into the categorizations of criteria but are solely asked to choose between the 20 predefined criteria.

The final five most important criteria gathered from the responses of all the experts will be further assessed regarding their weightings. The assessment of weights will be established by means of pairwise comparisons of criteria through a follow-up survey, which will be further described in the following section. The five least important criteria function solely as extra obtained information from which conclusions will be drawn. They will however not be incorporated for the establishment of a planning and prioritization model.

Clarification of results

The results provide insight into which factors Dutch social housing associations' experts deem the most, and also least, important for planning and prioritizing. To provide a conclusion and final list of most and least important criteria, a point system will be used. A score of +1 is assigned to a criterion which the expert deems one of the five most important criteria. A score of -1 is awarded in case a criterion is chosen as one of the five least important criteria. In this way, criteria are assigned points of which a final list and conclusions can be drawn.

3.2. Follow-up survey

This section will provide further information regarding the set-up and content of the follow-up survey. The survey consists of two parts. In the first part, pairwise comparisons are made between the five most important criteria to derive the weights. In the second part, the experts are asked to give their preferences regarding each of the categoric option per individual associated criterion.

3.2.1. Deriving the weights of criteria

Following from the interview as described in the previous section, a follow-up survey will be send to the experts a few weeks after their interviews. The conclusions drawn regarding the five most important criteria – following from Part II of the interview – function as input. By means of the follow-up survey, the expert is asked to rate the importance of each criterion compared to another criterion relative to the overarching goal; to establish a prioritization and planning towards carbon-neutrality in accordance with The Standard by 2050.

The associated method for establishing the weights of criteria is through pairwise comparisons according to the *Analytical Hierarchy Process (AHP)* as concluded in Chapter 2. To derive the importance (weighting) of each criterion for achieving the overall goal, the expert is asked the following question by each pairwise comparison of criteria:

"If you had to make a Roadmap in compliance with 'The Standard' towards CO_2-neutrality by 2050, which criterion would you deem more important and how much more important?"

The expert is then asked to rate the importance on a 1-9 scale as shown in Table 10.

3.2.2. Deriving the preference scores for categoric options

In addition to deriving the relative importance of each criterion, the preference scores for each categoric option per criterion is also assessed, as described in §2.8.1. The expert is asked to distribute a total of 100 points amongst the categoric options associated to the criterion, in accordance with his preference. The question asked is then:

"How strong is your preference for each of the categoric options per criterion for the complex to be made energy efficient? You have 100 points to distribute over the categoric options per criterion."

With knowing the preference score of each categoric option relative to its weighted mother criterion, a dwelling complex can be scored of which a ranking can be established. Generally, an overview of the overarching goal, the five yet to be defined most important criteria and their associated categoric options, is shown in Figure 7.

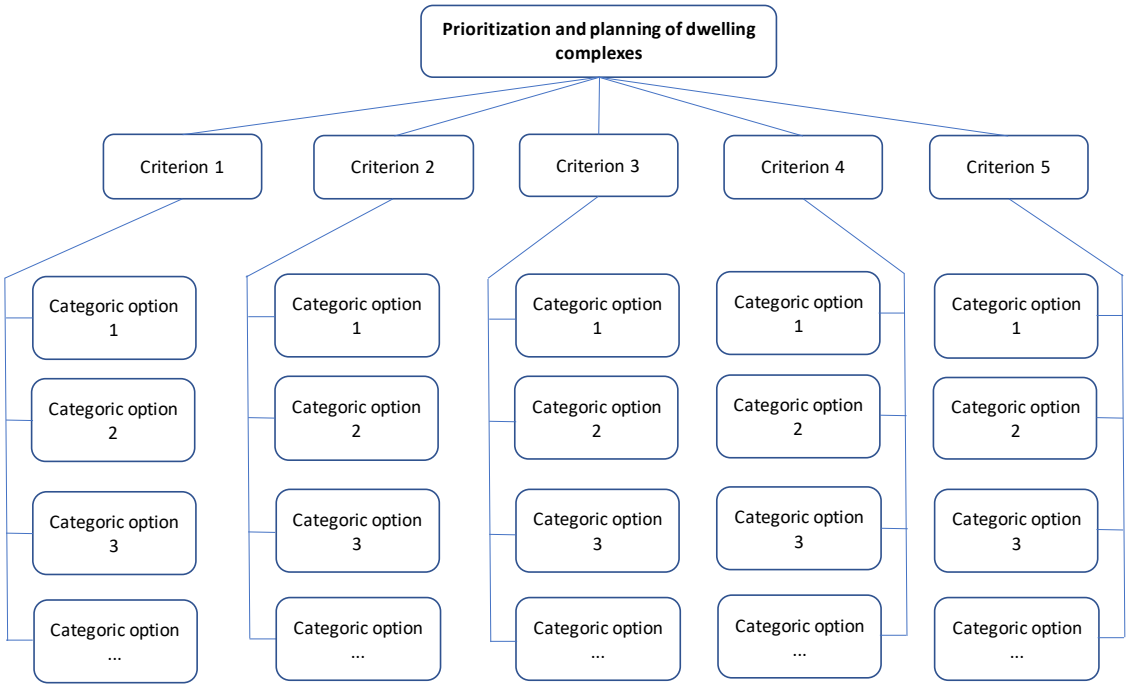


Figure 7: Goal - Criteria - Categoric options

3.3. The participating experts of Dutch social housing associations

To ensure that people with comparable perspectives are interviewed, for the purposes of the study, experts with similar positions at a variety of social housing associations spread across The Netherlands were contacted. Eleven out of the twelve people who were contacted are willing to participate in the research of this thesis. General data regarding the function of the expert, the city of the housing associations' office, their amount of dwellings and the associated size of their association is organized and shown in Table 14.

Function expert	City	#Dwellings (2020)	Size
Portfolio manager	Rotterdam	60,451	Large
Program manager sustainability	Utrecht	51,188	Large
Senior policy advisor	Roermond	13,610	Medium
Program manager sustainability	Nijmegen	11,000	Medium
Policy advisor real estate	Zwijndrecht	10,913	Medium
Advisor sustainability & innovation	Emmen	10,188	Medium
Group manager real estate	Den Helder	9,072	Medium
Manager real estate	Gorinchem	6,525	Small
Policy advisor	Goeree-Overflakkee	6,043	Small
Real estate & project coordinator	Apeldoorn	5,200	Small
Advisor real estate	Zevenaar	3,706	Small

Table 14: Information of the housing associations

In total, there are approximately 300 social housing associations in The Netherlands owning 2,300,000 dwellings. On average, every housing association would then own 7,667 dwellings (= 2,300,000/300). This would however not provide a realistic expectation of the amount of dwellings owned per housing association, since the three largest housing associations own slightly less than 10% (192,000 dwellings) of the entire social housing stock (Woonbond, 2019).

Without taking the amount of dwellings of the largest housing associations into consideration, a housing association would own 7,097 dwellings on average ((2,300,00 – 192,000) / 297 housing associations). Since the median is expectably slightly lower than the average, the amount of dwellings per housing association is rounded off to 7,000 dwellings. The sizes of the housing associations have been organized by small, medium or large, based on the amount of owned rental dwellings as shown in Table 15.

Size	# Dwellings
Large	> 15,000
Medium	7,000 – 15,000
Small	< 7,000

Table 15: Categories of sizes

3.4. Data validity and reliability

Validity is an important indicator for ensuring that the measurements of the interviews and the follow-up questionnaires have provided the desired answers. Subsequently, the reliability of the answers, through consistent and correct interpretation of the questions asked, is in return an important indicator for the validity of the measurements (Scribbr, 2019). Hence, the validity regards whether or not the desired outcomes of the research have been accurately measured. The reliability regards whether or not the experts consistently and correctly understood the questions asked, to ensure a more valid measurement.

3.4.1. Data validity

Experts at housing associations arguably have their own professional jargon and therefore, it is important to understand their jargon. To prevent a misunderstanding during the interviews due to a mismatch in vocabulary, the list of questions will firstly be checked with a consultant of Atriensis. By means of having the questionnaire checked by an Atriensis consultant, potential misconceptions are identified and thus, validity is optimised.

The eleven experts have been chosen according to their functions at Dutch social housing associations. A prerequisite for the experts was to work at a strategic position associated with policies, strategies, housing portfolios or plannings. If experts in different positions would have been interviewed, with different involvements regarding the subject of this thesis, expectably lots of different answers seen from different perspectives would have been obtained. By interviewing experts at similar functions relevant to this research, the accuracy of the desired outcomes will be optimized.

At the start of the interview, the experts will be asked whether or not they are known with the future obligation of The Standard. Additionally, whether or not they are already using a Roadmap, in which they aim for carbon-neutrality in accordance with The Standard by 2050. By asking these two questions, a better understanding will be achieved regarding the knowledge of the experts on both these matters. In case the experts do not already have some knowledge regarding at least one of the two subjects, questions can be raised regarding the validity of their answers.

3.4.2. Data reliability

The interviews entail open questions with open answers and therefore, the interviews offer some space for further substantiating the questions asked in case the questions are misinterpreted. Doing so, the reliability of the answers is being optimized since the expert will be steered towards the desired direction whilst ensuring open and honest answers.

Because the follow-up surveys will be completed by the expert alone and send back per e-mail after completion, the e-mail shall contain a substantiation of the questionnaire to limit the risks of misinterpretation. Furthermore, examples of potential answers will be provided per mail and within the questionnaire file as well. If still a misunderstanding occurs by noticing odd or illogical answers given, the expert will be contacted and asked for clarification.

3.4.3. Risks

Performing interviews do not go without any risks. Answers and therewith results can be sensitive to personal circumstances and can additionally be very time dependent. Difference in past experiences can also result in differences in answers and may therefore weaken the validity of the research. There could also be a potential bias in answers. It might be, for instance, that an expert would feel bad about commenting on certain characteristics of their own housing association, or talking bad about their municipality. The risk of this bias will however be limited through anonymisation of the experts and their responses. That way, the answers cannot be traced back to one of the experts which might encourage honest answers.

3.5. Conclusion

This chapter has outlined the content and information regarding the questions prepared for the interviews to be conducted. It has furthermore offered a clarification regarding the set-up of the interview, the follow-up survey and their main goals with respect to this research. The following chapter shall discuss the results of the performed interviews, and draw a conclusion regarding the factors of influence related to the pace in which housing associations are making their existing dwelling stock energy efficient. Subsequently, chapter 4 will discuss the conclusions regarding the most important criteria, their weightings and associated preference scores of the categoric options. Finally, a model for the prioritization and planning of dwelling complexes can be established of which a first test-run of priority ranking will be established.

4. Results

This chapter provides the results of Part I and Part II of the interviews and additionally the results of the follow-up survey. The first section will clarify and outline the factors influencing housing associations' pace towards 2050, followed by a conclusion in the second section regarding the latter. The third section will provide and further discuss the results of the most and least important criteria of interest for the prioritization and planning. The fourth section discusses the weights of the criteria assessed and the preference scores of categoric options. The fifth section offers a model for prioritizing and planning which dwellings should be first in line for being made energy efficient. The sixth section discusses a first test-run of the model, offering a prioritization of dwelling complexes by means of the model. The seventh section offers a sensitivity analysis of the results of the model. The eighth and final section of this chapter offers a final conclusion regarding the results of the research.

4.1. Factors influencing housing associations' pace

This section will provide the answers of the experts regarding Part I. The section is structured in accordance with the structure of the interview. The interview and therefore this section, starts with an opening question. Then, the answers to each of the four themes in accordance with the conceptual model will be discussed in the following sub-sections (Government, Municipality, Market, Tenants, Housing associations' characteristics). Lastly, the section ends with the responses to the closing questions.

Each sub-section finishes with a table. The table provides an overview of the investigated influence of that particular factor regarding the pace of energy efficiency renovations. Based on scorings of -1 (no influence) or +1 (influences), as described in §3.1.1.

4.1.1. Opening question

The responses to the opening question show great similarity with each other and have therefore been categorized into the following themes: *Governmental and municipal barriers, Market deficits, Characteristics of the housing association*. The themes are similar to the predefined overarching themes from the conceptual model. This shows that the predefined overarching themes, by means of literature and future regulatory requirements, have been useful as concluded in Chapter 2. The opening question entails the following:

1) *Which barriers do you experience regarding the pace at which your housing association is making its existing housing stock energy-efficient/sustainable?*

Governmental and municipal barriers

A very important factor of influence, mentioned by every housing association to be a delaying factor, is that the government has imposed restrictive laws and regulations that are no longer in line with the task that lies ahead for their sector. Examples which will be further discussed in the following sub-sections entail the 70% rule of tenants' approvement for renovating a complex, and the *Nature protection law* resulting in delaying projects. Furthermore, lengthy and viscous processes of the municipality have also been mentioned to be a great barrier. On the one hand, due to the impeding regulations just mentioned, and on the other hand, as a consequence of a lack of capacity at municipalities.

Market deficits

As a response to the opening question, influences from the market have also been mentioned to be a key delaying factor for most of the housing associations. The lack of capacity at contractors in particular played an important role. Due to the tightness of the labour market it is more difficult for contractors to attract qualified personnel, resulting in plannings of projects being stretched out for a longer amount of time than previously needed. Additionally, the growing price levels of materials are said to be pressuring the amount of renovations and new constructions that housing associations can perform. Less available money to spend ultimately results in a delay over the longer period of time. Furthermore, some housing associations implied a lack of innovation within the sector, a lack of capacity at nuts-companies, and a lack of financial gains for commercial parties resulting in that the entire sector – besides the social housing sector alone – is not accelerating as much as it should be.

Characteristics of the housing associations and tenants

In contrary to governmental, municipal and market factors, which are rather factors from external influences, many housing associations also mentioned a few internal factors to be of influence on their pace of sustainability renovations. Since, with more money, more dwellings can be renovated and more dwellings can be constructed than with less money could be done, and vice versa, a lack of financial budgets was often mentioned to be an important constraint. Furthermore, the tenant and the associated process of achieving a 70% vote was also often mentioned to be a delaying factor which sometimes resulted in very time consuming processes. Lastly, a lack of internal capacity, a lack of internal contemporary knowledge, a fragmented housing stock, and delaying internal decision-making processes were also mentioned to be delaying factors.

The responses to the opening question gave immediate insight into which factors the housing associations perceive to be of strongest importance as factors of influence on their pace. This offered a very good first understanding and image of the housing associations' problems and delaying factors. These factors have been further explored by means of the predefined categorised sub-questions. Table 16 provides a categorized overview of the responses.

	Opening question	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11
external	**Governmental and municipal**											
	Impeding laws and regulations	■		■	■	■	■	■		■		
	Lacking capacity at governments/municipalities	■	■		■	■	■	■	■			
	Viscous, lengthy external processes			■	■	■	■					
	Market											
	Lacking capacity at contractors	■	■		■	■	■	■				■
	Price increases	■	■			■	■	■	■			■
	Lack of innovations	■	■									
	No direct gains for commercial companies	■										
	Grid operators' capacity		■									
internal	**Housing association characteristics**											
	Financial budget/availability	■		■			■			■	■	
	Delaying decision-making			■						■		■
	Resistance of tenant / Lengthy tenant processes			■	■		■				■	
	Lacking internal knowledge			■								
	Fragmented home-ownership						■					
	Lacking internal capacity			■		■						■

Table 16: Summary of responses to the opening question

4.1.2. The government

2) *How do you feel about the current policy at the central government level with regard to the pace at which your housing association is making its existing housing stock energy efficient…?*

All housing associations have mentioned the importance of the central government regarding the energy transition towards a carbon neutral sector in 2050, due to their strong influences through laws and regulations. Their influence on the actual pace in which housing associations are making their existing dwelling stock energy efficient, is however not as strong as expected. Typically, there prevails a large distrust towards the central government due to many regulatory changes in the past few years. These changes have resulted in housing associations to follow their own paths, with carbon-neutrality in 2050 as a common and centred goal. Meaning, that the central government has a strong influence on their tasks and obligations but however, as perceived by half of the experts, does not influence the pace in which housing associations are working towards the set goals by the government. As stated by one of the experts:

> *"It has no influence on our pace. We are a little more cautious in the transition because of a distrust towards the government and its changes in recent years. We sail our own routes (follow our own path) with CO2-neutrality as a dot on the horizon and we will make adjustments along the way where necessary."*

One might argue that housing associations in some way are obligated to fasten their pace, due to obligatory demands within a short range of time – such as a 60% reduction of carbon by 2030 as compared to 1990 throughout the entire sector (Rijksoverheid, 2021). The experts however have a simple explanation to refute this statement. In some way they are affected because they may need to fasten their pace in order to meet future requirements. They are however working with the tools and finances they have and are limited in their capacity to both realize new homes, and to make old dwellings energy efficient. Even if they wanted to accelerate they are still bound to every euro that can only be spend once.

Whilst six experts stated that their pace is not influenced by the central government, five experts did mention that their pace is significantly affected by the government through restraining and contradictory laws and regulations. Consensus has been concluded regarding the specific regulation which is delaying the housing associations, whom have stated that the central government affects their pace. The regulation in question regards the *Nature protection* regulation. It obligates housing associations to hire professional agencies to perform research towards the affected housing of specific endangered flowers and animals influenced by renovation works in, for example, facades or roofs of dwellings. These processes are very time consuming and can result in months and even years of delay.

Conclusion influence government on housing associations' pace

Table 17 shows an overview of the given responses. The five experts who stated the government to be a factor of influence on their pace, substantiated this by means of the government being unreliable and because of delaying laws and regulations. The six experts who stated the government to be of no influence argued that either way, they will be following their own paths and therefore, the government does not affect their pace. If the expert perceived the government to be of influence on their pace, a +1 score is given, if not, a -1 score is given (as described in §3.1.1). The summation of these points reflect the perceived influence. Concluding, that opinions differ regarding the influence of the government on their pace and therefore, the government has scored -1. Meaning, that the government is perceived to be slightly more of no influence but that however, opinions are divided.

Influence government on the pace	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11	Total points
Total points												**-1**
Yes			■	■	■	■				■		
No	■	■					■	■	■		■	
Argumentation of the housing association												
Government influences our pace, through:												
Obligations	■									■		
Changing policies / unreliable government			■	■	■							
Delaying laws and regulations				■	■	■						
Government does not influence our pace, because:												
We were going to do it anyway	■											
Sailing our own course		■					■	■	■		■	

Table 17: Summary of argumentations for whether or not the government influences their pace

4.1.3. The municipality

2a) … and on municipal level?

Municipalities are generally perceived to differ a lot between regions and cities, the responses therefore differ also. Some housing associations experience zero influence on their pace by municipalities, and others are significantly delayed due to lengthy and viscous processes. Three experts stated that their pace is not influenced by municipalities because cooperation with them is going smoothly. Additionally, because performance agreements are made together and therefore, you are in control of your own pace through these agreements. The other eight experts claimed that they are indeed influenced by the municipalities due to very lengthy and viscous processes, which is often the result of a lack of personnel at the municipalities.

Conclusion influence municipality on housing associations' pace.

Table 18 shows that the overall score comes down to +5, meaning that more housing associations perceive the municipality to be of influence on their pace than they do not. Interesting to note is that the municipality is perceived as a stronger influence than the government, regarding the housing associations' pace.

Influence municipality on the pace	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11	Total points
Total points												**5**
Yes	■	■	■		■	■	■	■			■	
No				■					■	■		
Argumentation of the housing association												
Municipalities influences our pace, through:												
Municipalities demand extra	■											
Viscous, lengthy processes			■		■	■	■	■			■	
Changing coalition (4 year)			■								■	
Capacity shortage at municipalities							■	■			■	
Municipalities do not influence our pace, because:												
You make your performance agreements together	■			■								
Coöperation goes well, does not affect us									■	■		

Table 18: Summary of argumentations for whether or not the municipality influences their pace

4.1.4. The Standard

3) What are your thoughts regarding 'The Standard' to be achieved by 2050, is it achievable or too ambitious?

All experts agreed that The Standard offers a very much needed dot on the horizon and that it offers perspective, however not all experts perceive The Standard achievable before 2050. Seven out of eleven experts think The Standard is achievable, one expert could not provide an answer to this question whilst three experts think it is not achievable due to financial infeasibility.

The experts who do expect it achievable, actually think that The Standard is not very ambitious at all. It rather offers a good and easy achievable base for an energy efficient dwelling through good insulation. Although, The Standard offers a very well first base, more is however needed for a dwelling to be carbon neutral and therefore, The Standard (slightly) lacks ambition in a sense of carbon-neutrality by 2050. Often stating that achieving carbon-neutrality means that the electricity supplier needs to provide green electricity in order for the dwelling to be entirely carbon neutral.

4.1.5. Governmental and municipal support

4) In what would you like more support from the municipality and central government, for example, in the process, finances, laws and regulations, etc.?

Six experts quickly responded that support is not necessarily something they would need. They would rather see a stronger form of leadership, with a consistent policy and no major changes along the way. This goes together with the earlier statements of the experts, regarding a distrust towards the central government and their changes in past policies. Subsequently, power of perseverance as a manifestation of showing leadership is desired and needed to obligate individual home owners to start insulating their dwellings as well. Additionally, housing associations wish the government to ease the regulation of a 70% needed approval from tenants in the case that a housing association wishes to renovate 10 or more dwellings. To achieve the 70% rule is very often encountered to be a time consuming process. More regarding this topic will follow in §4.1.7.

It is furthermore desired that the government eases the amount of extra needed regulations for sustainability interventions and renovations. By smoothening the regulations, rather than delaying processes due to for instance the obligation of continuously extra needed warrants, they could assist in easier and quicker processes. Finally, extra needed finances is also often mentioned to be desired, but is not necessarily a top priority for now, because almost all experts are financially healthy. Nevertheless, with more money, generally more can be established. One expert responded that extra finances are a result of good leadership. If all housing associations are already running at their financial boundaries, more money will eventually be given to the sector since the objective would otherwise simply not be feasible. Therefore, leadership and clarification of the task at hand is of strong importance, to which finances eventually shall follow.

4.1.6. The market

5) What market influences do you experience that affect the pace at which you make your current housing stock energy efficient/sustainable?

Eleven out of eleven experts stated that the market is of influence on their pace, their answers showed great consensus. Price increases and a lacking capacity at contractors appear to be the biggest market factors of influence on their pace. Higher prices mean less money to spend and less work to realize. As of now, four experts however mentioned that they are not yet influenced by increasing prices or external capacity. In return, they expect that if these factors continue to negatively develop it shall

press their pace in the future and hamper their objectives. One of these four expert mentioned that as so far, they pay and the market delivers:

> *"We are particularly concerned about, because so far, we are paying and they are delivering, so that's okay for now. In that sense, we should not do the market short."*

One expert answered that capacity appears to be no problem at all. Since they are a very small housing association with as good as fixed relations who reserve capacity for them and therefore, are not worried for their pace.

Lastly, four out of eleven experts stated that the sector lacks innovative solutions by particularly the installation branch. A cheaper and more efficient solution is desired, as one expert stated:

> *"I do not yet know of a device that will enable us to keep housing costs low, to get rid of the gas, the energy bill will be less or remain the same, the investment on the part of the housing association is correct, I do not yet know of that solution when it comes to becoming gas-free."*

A lack of availability regarding materials and qualified people within particular the installation branch is a specific mentioned barrier. For some housing associations, this is already causing a bit of delay due to more lengthy required processes. Additionally, the branch lacks integrative engineering systems which are rather splintered and therefore, vulnerable to changes. This in return also negatively contribute to more lengthy and costly processes.

6) How do you experience the cooperation between housing associations and market parties with a perspective to achieve a carbon-neutral sector in 2050…?

Their relationships and experiences with market parties are stated very good. Approximately half of the experts claimed to work with cooperation contracts, between them and market parties. This offers both the housing association and the market parties work and assurance, due to a claim on their capacity and therefore offer each other continuity.

6a) … and with housing association mutually?

Generally, all experts but one concluded that the cooperation between housing associations is not very successful and is lacking due to a similar stated reason; a difference in policy and vision. Two experts mentioned that they have tried to set-up a purchasing programme in which mutual benefits could be achieved, but however failed to launch due to a difference in visions and policies. Sadly the experts state that it appears that it is every housing association for itself. In return, this results in a lack of mutual knowledge-sharing, which has been stated to be a very important aspect for housing associations to learn from each other. More knowledge-sharing and mutual help is desired to help each other fasten their pace.

Aedes, the overarching branch organisation, has been mentioned to play a catalysing role in the increasement of knowledge-sharing amongst social housing associations. Although it is desired that housing associations work more together, they are however preoccupied with getting their own vision and policies concrete. Therefore, almost all experts claim that they are not yet ready to enter into these collaborations with each other.

Conclusion influence market on housing associations' pace

As earlier described, all housing associations perceive the market to be of strong influence on their pace and therefore, the influence of the market scores +11 points as shown in Table 19. The most associated argumentations for this entailed the increasing prices and lacking external capacity. Although some housing associations not yet experience it to be a delaying factor, they all agree that it expectably will in the future.

Influence market on the pace	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11	Total points
Total points												**11**
Yes	■	■	■	■	■	■	■	■	■	■	■	
No												
Argumentation of the housing association												
Markets influences our pace, through:												
Capacity external parties (material, equipment, personnel)	■	■	■	■	■	■	■	■		■	■	
Price increases	■	■	■	■	■	■	■	■	■	■	■	
Innovations	■	■	■						■			
Scaling	■								■			
Lack of integrated engineering systems (installations)	■	■										

Table 19: Summary of argumentations for whether or not the market influences their pace

4.1.7. The tenant

7) How strong do you perceive the influence of tenants on the pace of making your existing housing stock energy efficient?

The responses can very much be split in two. Half of the experts encounter the influence of the tenant on their pace to be a very strong factor, whilst the other half of the experts perceive it to be of no influence on their pace. For half of the experts, it is a very time consuming and time extensive process to meet the 70% agreement rule of the tenants. They additionally state that the burden of having to meet 70% is very target group dependent. Older generations are not always very excited about new changes to their homes, and can therefore delay renovation projects until the housing association gets their cooperation and vote. Suspicion of the tenants towards the housing association is additionally stated to be a main barrier between the tenant and his or her dwelling being made energy efficient. For the experts who perceive the tenant to be a factor of influence on their pace, the 70% is often met but is however a very time consuming process.

For the other half, the tenants are considered of no influence regarding their pace even though these processes can be time extensive. One expert claimed that so far they ask no contribution of the tenant via a rent increase and therefore, the process of making a tenants' dwelling energy efficient proceeds much more easily.

8) Do you experience more support or resistance from residents and if necessary how do you convince the tenant?

Important to note, is that all housing associations are very caring and thoughtful towards their tenants and put them first in any case. All experts eventually experience rather more support than resistance from residents with a number of exceptions. As mentioned before, older target groups are rather suspicious towards the housing association and have a sense of distrust. Each expert stated to have a very personal approach with 'kitchen table meetings' in which the process of for instance, a sustainability related intervention is being discussed, with open and honest communication.

Tenants are being integrated in an as early stage as possible so that he or she is guided and communicated with. To convince the tenant of the euro's that are expected to be regained is often perceived as most difficult. The price increases in gas and electricity are however an impulse for tenants to reconsider their suspicion.

Conclusion influence tenant on housing associations' pace

Four out of eleven experts claimed that their tenants are of no influence on their pace. In contrary, seven experts claimed that they are influenced by their tenants. This results in a total of +3 points as shown in Table 20. Meaning, that the tenant is generally perceived to be an influencing factor regarding the housing associations' pace.

Influence tenant on the pace	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11	Total points
Total points												**3**
Yes	■	■	■	■	■	■				■		
No							■	■	■		■	
Argumentation of the housing association												
Tenants influence our pace, through:												
Perceived resistance				■	■	■						
70%-rule sometimes leads to delay			■	■	■	■						
Target group dependent		■		■	■	■						
Creates more support and thus acceleration	■											
Mistrust towards the housing association						■						
Tenants do not influence our pace, because:												
Support or willingness of tenants	■	■	■				■	■	■	■	■	

Table 20: Summary of argumentations for whether or not the tenant influences their pace

4.1.8. The housing associations' characteristics

9) What characteristics of a housing association do you consider important regarding the pace in which you are making your existing dwelling stock energy efficient?

Housing associations' boards are responsible for deciding where each euro goes to. Since sustainability and making existing dwellings energy efficient is only part of their entire decision-making and tasks, not every available euro is spend on this matter. In return, this causes for boards to affect the pace of the housing association. Subsequently, half of the experts stated that decision-making on itself should not be a delaying factor but however, in practice sometimes due to lengthy decision-making processes actually is. The board deciding to where each euro goes to, is mentioned by six experts to be a characteristic of the housing association influencing their pace:

> *"We think sustainability is very important, but so are affordability, quality and liveability, and they are constantly under pressure with each other. You have to determine properly which euro goes where, the board is very much in charge of this"*

Financial constraints and a lack of budget is for now not a delaying factor since housing associations can carry out their works without running into financial trouble, but is however often mentioned to expectably be a delaying factor in the future. The expected investments to be made cannot be earned back, resulting in less financial budget available for other matters in the future.

As opposed to lacking external capacity as earlier described to be a delaying market factor, internal capacity appears to be not much of a problem for now, for all experts. It is however expected to be a problem in the future. Mainly due to a need for qualified personnel with contemporary knowledge regarding the energy transition and because of a tightened labour market, which could potentially press their pace.

10) How do you perceive the amount of knowledge and experience regarding The Standard and its achievability in 2050?

Six of the eleven experts perceive their knowledge regarding The Standard as not sufficient. Their reasons are similar. The Standard has been brought to life quite little time after the obligation of housing associations to meet an average of energy label B in 2021, and therefore they are still stuck in the mindset of energy labels. These six experts stated that they are steadily learning about the consequences of the implementation of The Standard regarding their portfolios but as of now, their knowledge is still not sufficient enough. The other five experts stated that their knowledge for now is alright, but that they expect problems in the future regarding the attraction of qualified personnel with contemporary knowledge concerning this topic.

Conclusion influence housing associations' characteristics on housing associations' pace

Zero experts stated that the characteristics of the housing association is of no influence on their pace. In total, this results in +11 points for the influence of housing associations' characteristics on their pace. An overview of the responses is shown in Table 21.

Influence housing associations' characteristics on pace	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11	Total points
Total points												**11**
Yes	■	■	■	■	■	■	■	■	■	■	■	
No												
Argumentation of the housing association												
The characteristics of the HA influences our pace, through:												
Internal capacity of personnel				■			■					
Decision-making			■		■		■	■	■	■	■	
General culture of housing associations		■							■			
Board of housing association	■			■		■			■	■	■	
Financial budget/parameters		■		■		■			■			

Table 21: Summary of argumentations for whether or not the characteristics of the Housing association influences their pace

4.1.9. Closing questions

The final questions offered the experts to give their final thoughts regarding the factors influencing their pace, and therefore provided a closing summary of the interview.

11) If you could advise the Minister of Housing and Spatial Planning (Hugo de Jonge), what specifically would you like to see changed tomorrow or in the near future in view of the 2050 goal?

Generally, almost all experts would like to see more perseverance power by the government or like to see a change in contradictory laws and regulations. They would rather see the government to smooth and fasten processes, than to see delaying new regulations on top of additional already existing regulations. It is often stated that the contemporary laws and regulations are not in line with the task of carbon-neutrality by 2050. The experts additionally very much desire the government to show more power of perseverance for both the social housing sector, as well as the private housing sector.

On the other hand, however, some experts still wish to be free in their choices to become carbon neutral, as stated by one expert as follows:

> *"On the one hand, I wish for robust laws and regulations, but not so much that it will become a problem for the choices we make. Other solutions may also be desirable in the future, perhaps better than connecting to a heat network, for example."*

Furthermore, half of the experts stated that they would like the government to facilitate more knowledge-sharing for the entire sector. New innovative technologies or upcoming regulations are therefore being brought to light in an earlier stadium, resulting in fewer surprises for the sector. Consequently, the sector would like to have more saying in the drafting and implementation of certain obligations, such as The Standard. An overview of the responses to the first closing question are shown in Table 22.

Closing question	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11
Power of perseverance	■	■	■			■	■				
Smoothen/ease laws and regulations			■		■	■		■	■		
Subsidizes and more financial budget	■	■			■	■				■	■
Knowledge sharing and facilitation		■		■							
Convince the private home-owners						■	■				
To set realistic goals								■			
Clarification of heating alternatives and its consequences									■		
Stimulate biobased materials/construction											■

Table 22: Summary of responses to the closing question

12) As opposed to what is not (yet) going well, what do you think is going well in the run-up to a CO_2-neutral social housing stock

Undoubtedly, all experts are very proud regarding the amount of effort, willpower, responsibility and supportive base, which has been developed in the past few years and is something they all recognize and acknowledge. The social housing sector is pioneering in the enormous energy transition task whilst having the lowest amount of available budget, but however still manages to be able to make big steps. Morally they are certainly on the right track. Half of the experts have stated that The Standard is a very much needed dot on the horizon together with carbon-neutrality in 2050, recognized as a positive result from the past years.

13) Do you expect to achieve an entire carbon neutral housing portfolio by 2050?

None of the experts expects to be able to realize a carbon neutral portfolio by 2050, at least not without any help. Two out of eleven experts stated that carbon-neutrality in 2050 is overly ambitious. They doubt both the feasibility as well as the substantiality of the objective, since they also think that with the techniques and solutions of today the objective will simply not be met.

Similar to these two experts, the other nine experts also doubted the techniques and innovations of today as best-fitted solutions regarding the objective for 2050. They however do deem carbon-neutrality possible, only if new innovative installation techniques would provide in more suitable and affordable solutions. Subsequently, only if the other stakeholders such as the net suppliers would play their parts and supply green electricity. Finally, one expert mentioned the exception of monumental housing which would expectably not become carbon neutral but besides that, carbon-neutrality in 2050 is deemed possible.

4.2. Conclusion regarding the factors of influence on the pace

A conclusion is drawn regarding the influence of each of the influencing factors on the pace. Table 23 provides an overview of the total amount of points per influencing factor as discussed throughout the previous section.

Government

On the one hand, housing associations perceive the government to have no influence on their pace. This is partly explained by housing associations following their own paths, based on the amount of work they can realize with their available (financial) resources. In other words, the housing associations will do what they can within their capabilities. Whether or not the government demands more, if no more can be done then no more will be done without the help of the government.

Influence independent variables on Housing associations' pace	Points
Government	-1
Municipality	+5
Market	+11
Tenant	+3
Housing associations' characteristics	+11

Table 23: Final scoring of influencing factors

On the other hand, some housing associations claim that by means of delaying laws and regulations, and through fastened obligations, the government do has an influence on their pace. Therefore, the total amount of points came down to -1. Meaning, that opinions are somewhat divided but that the government is generally perceived to have rather no influence on their pace than it does.

Municipality

Eight experts claimed to be influenced in their pace by the municipality, whilst three experts claimed they were not. The overall score of the municipality thus comes down to a +5. Meaning, that the municipality is considered to be of influence on the pace of housing associations. This is clearly explained through viscous and lengthy processes by municipalities, which in return affect the pace in which housing associations are able to make their existing dwelling stock energy efficient. Additionally, some experts stated that a lack of capacity at municipalities and cooperation between the municipality and the housing association also play important roles in delaying processes.

Market

Every expert stated that the market is of significant influence on their pace and therefore, the market scores +11 out of 11 points. The explanatory reasons for its influence is very clear; there is a lack of capacity, materials, equipment and a lack of personnel at external parties. Furthermore, all experts stated the importance of price increases to be a delaying factor. If not now, then they are expected to be of influence in the future.

Tenant

The opinions regarding the tenant to be a factor influencing the housing associations' pace are somewhat divided. Seven experts claim to be influenced regarding their pace by the tenant, whilst four experts claimed they are not. Generally, the 70% rule is experienced to be a very time-consuming and sometimes delaying rule. Whilst some experts stated that the rule affects their actual pace, other experts claimed that the tenants were not, or rather marginally of influence. Nevertheless, the tenant is generally perceived to be of influence on their pace more than it does not have an influence, therefore scoring a +3.

Housing associations' characteristics

Eleven out of eleven experts claimed that the characteristics of their housing associations influences their pace and therefore, scores +11 points. Their board plays an important role as an influencing factor. They decide on what every euro will be spend and since every euro can only be spend once, they decide the pace in which the housing association is going to make their existing dwelling stock energy efficient. Furthermore, decision-making within mostly larger organizations are sometimes perceived viscous and lengthy. Resulting in a delay of processes.

4.3. Criteria of interest for the prioritization and planning

The experts were asked to choose their five most important and their five least important criteria out of a list of 20 predefined criteria as described in §3.1.2. This section will go into further depth regarding the results of Part II.

4.3.1. Prior knowledge regarding The Standard and a Roadmap

To get an immediate impression of the knowledge of the experts regarding the subject of this research relevant to Part II of the interview, they were asked about their experiences with a *Roadmap* and *The Standard*.

Nine out of eleven experts stated that they are already working with a Roadmap in which they inventoried their housing stock, allocated budget, planned sustainability interventions/renovations et cetera, and briefly identified the consequences of needed sustainability investments. The Roadmaps used by the housing associations were often made by the overarching branch organisation Aedes, of which The Roadmap 2021 was mostly mentioned. The Standard has however only been incorporated by four experts. These experts stated that The Standard was already established within their policy and therefore, incorporated in their future and sometimes present projects. For an overview of the aforementioned see Table 24.

Expert	Roadmap	The Standard incorporated
Expert 1	No	No
Expert 2	Yes	Yes
Expert 3	No	No
Expert 4	Yes	Yes
Expert 5	Yes	Yes
Expert 6	Yes	No
Expert 7	Yes	No
Expert 8	Yes	No
Expert 9	Yes	Yes
Expert 10	Yes	No
Expert 11	Yes	No

Table 24: How many experts are already working with a Roadmap and The Standard?

4.3.2. Point scoring of criteria

Generally, the experts did not find it easy to make a cut-off to the five most important criteria, because of overlap amongst the criteria and the difficulty of making choices in this regard. With regard to the five least important criteria, all experts have found it rather easy to make a final cut-off.

Points per categorization of criteria

Due to the categorization of the criteria as shown in Table 13 a quick view of which categories the experts deem important and which they do not can be provided. Note that the experts did not get to see any of the categorizations, but solely the list of 20 criteria. The summation of points administered to the criteria associated with one of the three categories, result in a total amount of points for that particular category.

Categorization of criteria	Points
Housing conditions	+23
External factors	-17
Internal factors	-3

Table 25: Categorization of criteria and their scores

In total, the categorization of *Housing conditions* scored +23 points, *External factors* scored -17 points, and *Internal factors* scored -3 points as shown in Table 25. Concluding, the conditions of the dwelling complexes entail by far the most important criteria taken into account for the prioritization and planning. External factors are very much not of interest. Depending on the criteria within the categorization of the internal factors, some internal criteria are considered important as others do not.

Points per criterion

The total summation of points for the category entailing the administered criteria does not provide an all-encompassing view. The real investigation entails which particular criteria are deemed the most important, of which the weights will be further assessed. Table 26 provides an overview of the point scoring by all experts per criterion. The table shows that every category has some notable criteria. Some categories entail importantly chosen criteria whilst simultaneously within the same category, some of the least important criteria are stated. For instance, the *External factors* score -17 points in total (Table 25). Three of the six least important criteria play an important role within this category, as does one of the seven most important criteria. The categories have a mixture of both important as well as not important considered criteria.

	Energy label	Trias energetica	Construction or renovation year	Combination with planned maintenance	Combination with planned renovation	Combinations with indoor climate quality/noise pollution	Combination with interventions in the direct surroundings	Stage of technologic development	Market influences	Because residents may or may not be interested	Amount of energy bill/energy poverty	Liveability in the neighbourhood	Transition Vision Heating of municipalities	Government	Subsidizes on products	Profitability for the housing association on (partial) intervention	Financial possibilities in the short/long term in relation to the task	Strategy residential portfolio	Input from stakeholders	Positioning in energy transition
	Housing conditions						External factors									Internal factors				
	1	1			1		-1	-1	-1			-1	1				1			-1
				1	1		1	-1	-1	1			1	1	-1		1	1	-1	-1
	1	1					-1	1				-1			-1	1	1		-1	-1
		1	-1		1	1		-1	-1					1	-1			1		-1
	1	1			1			-1	-1		1			-1		-1		1		-1
	1	1			1	-1	-1	-1			-1		1		-1			1		
	1	1	-1	1	1			1	-1					-1		-1			-1	
		1		1	1		-1		-1			-1				-1	1	1		-1
	1	1	-1	1		1								-1	-1	-1		1		-1
	-1		-1		1	-1	1						1	1	-1			1		-1
	1			1				-1	-1				1		-1		1	1	-1	-1
TOTAL	6	8	-4	5	8	0	-2	-4	-7	1	0	-3	5	0	-7	-3	5	8	-4	-9

Table 26: Total overview of point scoring per criterion

4.3.3. Seven most important criteria

Due to the scoring of equal points, seven most important criteria finally came forth from the interviews. This sub-section shall further elaborate on the final list of the most important determinants, shown in Table 27.

Mainly housing conditional characteristics are considered the most important criteria, containing: *Trias energetica, combination with planned renovation, energy label, and combination with planned maintenance*. Additionally, two internal factors: *Strategy housing portfolio* and *Financial possibilities* are also considered as one of the most important criteria. In contrary to the other internal factors which are considered the least important criteria. Furthermore, one external factor: *Transition Vision heating of municipalities* is considered to be of great importance as well. Again, in contrary to the other – more market related – criteria of external factors, which have been chosen to be the least important criteria.

Categorization	Criterion	Points
Internal factors	Strategy housing portfolio	+8
Housing conditions	Trias energetica	+8
Housing conditions	Combination with planned renovation	+8
Housing conditions	Energy label	+6
Housing conditions	Combination with planned maintenance	+5
External factors	Transition Vision Heating of municipalities	+5
Internal factors	Financial possibilities	+5

Table 27: The most important criteria for the prioritization and planning

Strategy housing portfolio (8 points). As one of the most important criterion, eight out of the eleven experts vowed for their portfolio strategy to be leading for making a Roadmap towards 2050. The residential portfolio strategy is often already incorporated within their policy implications. Their policies consist of sustainability investments, amongst others, and is therefore perceived to be the main criterion.

Trias energetica (8 points). Trias energetica follows the following three principles (RVO, 2013): Firstly, reduce the energy demand. Secondly, make us of sustainable/renewable energy. Thirdly, use the remaining needed fossil energy as efficiently and cleanly as possible. The principles of the Trias energetica are very much leading in the objective of carbon-neutrality by 2050 and therefore, this criterion has been granted eight points by the experts. The Standard in return offers a very good first investment towards reducing the energy demand (step 1 of the Trias energetica).

Combination with planned renovation (8 points). To make use of time and resources as efficient as possible is considered one of the most important criterion for housing associations to plan. Meaning, that they favour prioritization and planning of dwellings to be made energy efficient at natural moments during planned renovation works. In this way, the tenant is not bothered more than needed, and time, money and other resources are efficiently put to use.

Energy label (6 points). The government prohibits housing associations to rent out dwellings which do not have a better energy label than E, F and G by the year of 2030 (Rijksoverheid, 2022). Meaning, that housing associations are giving priority to the dwellings with a poor energy label to be made energy efficient. The energy label has therefore been chosen six times to be one of the five most important criterion for the housing associations' prioritization and planning.

Combination with planned maintenance (5 points). In relation to the previous mentioned criterion of *Combination with planned renovation* the same line of thought applies to this particular criterion. To make use of natural planned moments in combination with making a dwelling energy efficient is desirable. This criterion has however been chosen fewer times than *Combination with planned renovation* as one of the five most important. The reasoning behind this, is because some experts have found it sufficient enough to pick one of the two, whilst others choose them both.

Transition Vision heating of municipalities (5 points). In the light of making efficient use of time and resources, the Transition Vision heating by the municipalities has been picked due to the combination of municipal plans with the housing associations' plans. In other words, if the municipality decides to remove a chosen neighbourhood from gas supply in a particular year, and switches the neighbourhood its heating source to for instance heating grids, the housing association perceives the plans of the municipality as a key criterion to their prioritization and planning.

Financial possibilities (5 points). Housing associations can simply not spend more money than they have. Additionally, to make existing dwellings energy efficient in compliance with The Standard and to become carbon neutral by 2050 is not the only thing which they are planning to do. Since every euro can only be spend once, their financial possibilities on the short and long term in relation to their task has been chosen five times to be one of the five most important criteria for their prioritization and planning.

4.3.4. Six least important criteria

In addition to the five most important criteria, the experts were also asked to pick the five least important criteria for their prioritization and planning towards carbon-neutrality by 2050. Again, due to the scoring of equal points, the final list of least important criteria consists of more than five. The six least important criteria are shown in Table 28.

Categorization	Criterion	Points
Internal factors	Positioning in energy transition	-9
External factors	Subsidizes on product	-7
External factors	Market influences	-7
Internal factors	Input from stakeholders	-4
Housing conditions	Construction or renovation year	-4
External factors	Stage of technologic development	-4

Table 28: The least important criteria for the prioritization and planning

Only one criterion related to the category of housing conditions has been chosen to be of least importance, namely: *Construction or renovation year.* Furthermore, three external factors (related to the market) have been concluded as least important, as well as two internal factors.

Positioning in energy transition (-9 points). With nine out of eleven points, this criterion is by far the least important for housing associations' planning and prioritization. The main reasoning behind this, is that housing associations are working with the resources they have, and in that sense are not looking for a specific positioning in the energy transition. They rather end up in a position which suits their capacities then to base their plannings on.

Subsidizes on product (-7 points). Whether or not extra financials can be acquired through subsidizes is not necessarily a criterion which they take into consideration during their planning. If it happens that a subsidy can be acquired that is naturally a good thing, but however not leading in which dwellings will or will not be prioritized.

Market influences (-7 points). Waiting for the market to change for the better is no option for many of the housing associations. Meaning, that either way, whatever market influences there might be, housing associations will currently not let their planning and prioritization be interfered by influences from the market. As opposed to the strong effect of the market on their pace (§4.2), the experts state that it does not have any effect on their prioritization and planning yet.

Input from stakeholders (-4 points). Performance agreements, between for instance municipalities and housing associations, are made in accordance with each other. Meaning, that you are in control (together with the municipality) of your own agreements and therefore, in control of the pace which you agree upon with the municipality or other stakeholders. So, it does not affect their planning.

Construction or renovation year (-4 points). In contrary to the energy label being an important criterion as a housing condition for the prioritization and planning, the construction or renovation year of a dwelling is very much less important. The statement behind this is because a dwelling can be constructed or renovated one year ago, and still not be in accordance with The Standard or carbon-neutrality.

Stage of technologic development (-4 points). Similar to market influences being one of the least important criterion, the stage of technologic developments is also not important for housing associations' planning. Again, they will not postpone sustainability investments depending on technologic developments and therefore, the stage of technologic developments are considered to be of no influence on their planning.

4.4. Criteria weightings and preferences for categoric options

This section will provide the final list of the five most important criteria. Subsequently, the categoric options associated per criterion are established and will be further discussed. Additionally, the weights of criteria will be assessed by means of the AHP-tool and furthermore, the results of the preference scoring for categoric options will be provided.

4.4.1. Finalizing the list to five most important criteria to be assessed

The list of seven most important criteria show some overlap. To be economical in the pairwise comparisons is, however, a prerequisite of the Analytical Hierarchy Process (Saaty, 1987). Therefore, in addition to keeping the pairwise comparisons within reasonable proportions, some criteria have been merged to provide a final list of five most important criteria to be further assessed.

The criterion *Combination with planned maintenance* has been merged with *Combination with planned renovation* into *Process in which the complex will be made energy efficient*. Furthermore, the criterion *Trias energetica* has been merged with *Energy label* into *Average existing energy quality of complex to be made energy efficient*. The final five criteria assessed are shown in Table 29.

Final five most important criteria
Strategy of housing portfolio for dwelling complex to be made energy efficient
Process in which the dwelling complex will be made energy efficient
Average existing energy quality of dwelling complex
Indicative budget per dwelling to be made energy efficient in euros
Transition vision heating of governments for dwelling complex

Table 29: Final five most important criteria

4.4.2. Assessing the weights of the criteria

The weightings of the final five most important criteria have been assessed through pairwise comparisons, in accordance with their relative importance for establishing a prioritization and planning. For an overview of the questionnaire regarding the pairwise comparisons, see Appendix A. The summary sheet of the AHP-tool displays the final weightings of the criteria based on *The Eigenvalue Method (EVM)*, the overall *Consistency Ratio (CR)*, a bar-graphical overview of the ranges of weights based on *Absolute errors*, the *Mean Relative Error (MRE),* a *Comparison Matrix,* and it additionally displays general information regarding the amount of criteria and participants. For an explanation regarding the latter definitions and the AHP-tool, see §2.7.3. Figure 8 provides a summarizing overview of the scores by means of the AHP-Excel tool.

AHP Analytic Hierarchy Process (EVM multiple inputs)

K. D. Goepel Version **15.09.2018** | Free web based AHP software on: http://bpmsg.com

Only input data in the light green fields and worksheets!

n=	5	Number of criteria (2 to 10)	Scale:	1		AHP 1-9
N=	10	Number of Participants (1 to 20)	α:	0,1	Consensus:	78,5%
p=	0	selected Participant (0=consol.)	2	7		Consolidated

Objective To establish the relative importance (weightings) of the most important criteria for the planning and prioritization of dwellings.

Author JLVDH

Date 1-Jun-22 Thresh: 1E-08 Iterations: 6 EVM check: 4,6E-10

Table

	Criterion	Comment	Weights	+/-
1	Process		14,3%	3,1%
2	Transitionvision He		8,7%	3,0%
3	Energetic quality		16,1%	2,3%
4	Indicative budget		13,1%	3,2%
5	Strategy portfolio		47,9%	14,4%
6			0,0%	0,0%
7			0,0%	0,0%
8			0,0%	0,0%
9		for 9&10 unprotect the input sheets and expand the	0,0%	0,0%
10		question section ("+" in row 66)	0,0%	0,0%

Result

Eigenvalue			Lambda:	5,134	MRE:	25,9%	
Consistency Ratio	0,37	GCI: 0,11	Psi: 20,0%	CR: 3,0%			

Figure 8: Summary sheet of the AHP

It is important to note that the Consistency Ratio (CR) needs to be below 10% for the results to be reliable (Goepel, 2013). Although some of the experts provided inconsistent responses, resulting in a CR of more than 10% on their individual sheets, the CR on the summarizing sheet however resulted in 3.0%, which is considered acceptable (Saaty, 1987).

The summary sheet additionally provides a bar graphical overview of the weights of the criteria and their associated ranges. The absolute ranges of weights are defined by adding and subtracting the absolute error of a criterion to and from the relative weight of a criterion. These absolute errors are shown in the column next to the weights of the criteria in Figure 8. The bar graphical summaries and the ranges of the criteria are shown in Figure 9.

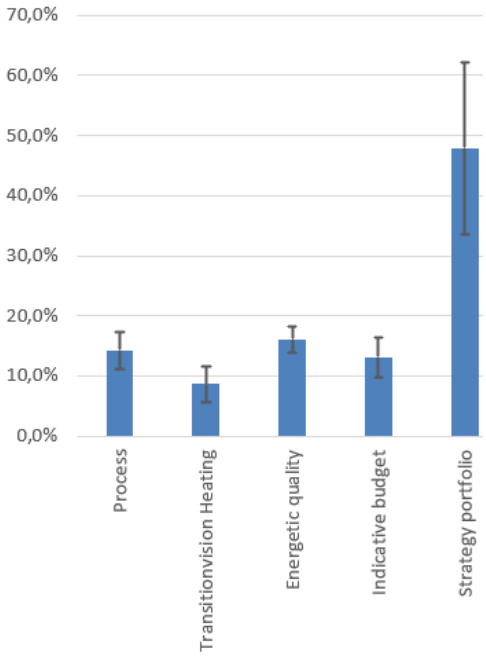


Figure 9: Criteria and ranges of weights

Furthermore, a comparison matrix is displayed on the summarizing sheet as shown in Figure 10. This matrix shows the importance of one criterion compared to another and should be interpreted from left to right. For example, *Process* is considered 1 7/8th times more important than *Transition Vision Heating* and 6/7th as important as *Energetic quality*. Additionally, the matrix shows the normalized principal Eigenvector or in other words, the relative weight of each criterion.

Matrix		Process	Transitionvision Heating	Energetic quality	Indicative budget	Strategy portfolio	0	0	0	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
Process	1	1	1 7/8	6/7	1 3/7	1/5	-	-	-	-	-	14,28%
Transitionvision Heating	2	1/2	1	1/2	1/2	2/7	-	-	-	-	-	8,66%
Energetic quality	3	1 1/6	2	1	1 1/2	1/4	-	-	-	-	-	16,07%
Indicative budget	4	5/7	2 1/8	2/3	1	1/3	-	-	-	-	-	13,13%
Strategy portfolio	5	4 5/7	3 3/8	3 2/3	3 2/9	1	-	-	-	-	-	47,86%
0	6	-	-	-	-	-	1	-	-	-	-	0,00%
0	7	-	-	-	-	-	-	1	-	-	-	0,00%
0	8	-	-	-	-	-	-	-	1	-	-	0,00%
0	9	-	-	-	-	-	-	-	-	1	-	0,00%
0	10	-	-	-	-	-	-	-	-	-	1	0,00%

Figure 10: Comparison matrix of criteria

The pairwise comparisons made by the experts are filed in individual sheets, one sheet per expert. Appendix B offers the results and a total overview of the individual sheets.

4.4.3. Establishing categoric options per criterion

To achieve the overarching goal of finding the most optimal prioritization and planning, several criteria are used to assess the alternatives with. Each criterion consist of multiple categoric options. In return, they are needed for the assessment of the alternatives based on the criterion to which the categories are associated, with respect to the overarching goal. The various categories of options are considered as different procedures, or executions, or characteristics, of which some of these categories can be more preferred than others (see §2.8.1.).

The list of categorized options per associated criterion have been established together with experts of Atriensis. They have offered contemporary insights into the different possible relevant categoric options for each particular criterion. Figure 11 shows an overview of the final five most important criteria and their associated categoric options, per criterion.

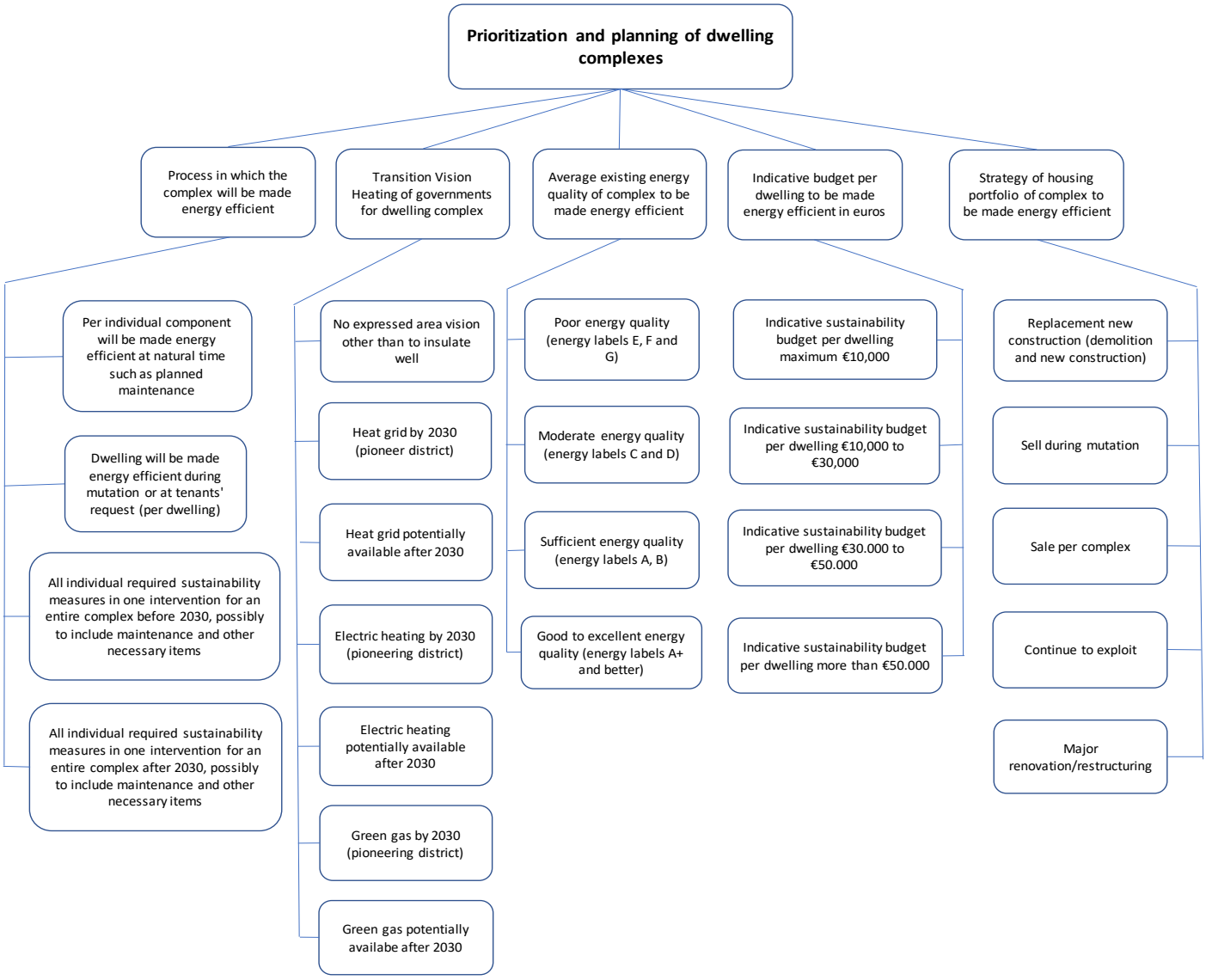


Figure 11: Five most important criteria and associated categoric options

4.4.4. Assessing the preferences of the categories

The experts have been asked to rate their preferences per categoric options related to each of the five most important criteria. The preference scoring was performed according to the division of 100 points, as described in §3.2.2. Table 30 provides the final preference scores of each categoric option with respect to its associated criterion, and additionally shows the assessed weights of the criteria.

Weights of criteria and preference scores for associated categoric options	
47.9%	**Strategy of housing portfolio for dwelling complex to be made energy efficient**
25	Replacement new construction (demolition and new construction)
11	Sell during mutation
5	Sale per complex
17	Continue to exploit
42	Major renovation/restructuring
16.1%	**Average existing energy quality of dwelling complex**

46	Poor energy quality (energy labels E, F and G)
33	Moderate energy quality (energy labels C and D)
19	Sufficient energy quality (energy labels A, B)
3	Good to excellent energy quality (energy labels A+ and better)
14.3%	**Process in which the dwelling complex will be made energy efficient**
20	Per individual component will be made energy efficient at natural time such as planned maintenance
17	Dwelling will be made energy efficient during mutation or at tenants' request (per dwelling)
36	All individual required sustainability measures in one intervention for an entire complex before 2030, possibly to include maintenance and other necessary items
29	All individual required sustainability measures in one intervention for an entire complex after 2030, possibly to include maintenance and other necessary items
13.1%	**Indicative budget per dwelling to be made energy efficient in euros**
12	Indicative sustainability budget per dwelling maximum €10,000
26	Indicative sustainability budget per dwelling €10,000 to €30,000
47	Indicative sustainability budget per dwelling €30,000 to €50,000
16	Indicative sustainability budget per dwelling more than €50,000
8.7%	**Transition vision heating of governments for dwelling complex**
18	No expressed area vision other than to insulate well
12	Heat grid by 2030 (pioneer district)
19	Heat grid potentially available after 2030
8	Electric heating by 2030 (pioneering district)
20	Electric heating potentially available after 2030
15	Green gas by 2030 (pioneering district)
8	Green gas potentially available after 2030

Table 30: Final overview of the weights of criteria and preference scores of categoric options

Appendix C offers an overview of the follow-up questionnaire associated with the preference scoring of categoric options.

4.5. Establishing the model for planning and prioritization

The results of the AHP have provided the weights of the criteria and the preferences for each categoric option. These results are used as variables for a model to find the most logical prioritization and planning. This section will further elaborate on the establishment of a prioritization modelling-tool and the associated formula used for the final ranking of dwelling complexes.

4.5.1. The equation for the model

As discussed and concluded in Chapter 2, the Linear additive model, based on the assessment of criteria and their weights and preference scores for categoric options, is applicable for ranking the alternatives. The basic formula for Linear additive modelling is shown in Equation 2 (§2.6.3.).

The previous mentioned formula has however been slightly changed to incorporate the preference scores of additional categoric options. Additionally, the designation of *options* has been changed to *dwelling complexes*.

The new formula – used for the model for prioritizing and planning which dwellings should be first in line for being made energy efficient, in accordance with the decision makers most important criteria, their weights, and the preferences for each associated categoric option – is shown in Equation 3.

$$S_i = w_1 p_{i1} + w_2 p_{i1} + \cdots + w_n p_{in} = \sum_{j=1}^{n} w_j p_{ij}$$

Equation 3: Formula used for the prioritization model (adapted linear additive model)

- S_i is the total summation of weighted scores of criteria w_n and preference score for categoric option p_n for dwelling complex i
- n is the number of the applicable criteria
- w_j is the weight of criterion j
- p_{ij} is the preference score for categoric option i on criterion j

4.5.2. Excel-modelling a prioritization

The model for calculating the priority ranking per dwelling complex has been established by means of Excel. The model consists of four tabs in which the calculations for a priority ranking are linked to the information achieved from the other tabs. The four tabs are as follows.

Tab 1) The equation

The first tab consists of the weights of the criteria and the preference scores per categoric option, relevant to its mother criterion. The weights and preference scores are the results of the performed interviews and the follow-up questionnaire, and function as the backbone for the prioritization model of dwelling complexes.

Tab 2) Housing data

In the second tab, data needs to be uploaded containing at least the following characteristics:

- Dwelling complex number
- Average energy label dwelling complex
- Exploitation strategy housing association
- Planned renovation, maintenance or execution of sustainability measures
- Transition Vision Heating by municipality
- Date/Year of planned execution of Transition Vision Heating by the municipality
- Investment per dwelling in euros, regarding the costs for the execution of sustainability measures
- Whether or not the dwelling is planned to be comprised with The Standard by 2050

The Excel sheet will be able to calculate the prioritization ranking by means of the information received from Tab 1 and 2. If specific data of a dwelling complex is missing, certain assumptions will have to be made in order for the model to calculate a final priority ranking of that particular complex.

Tab 3) Scoring

The third tab offers an overview of the score per criterion and per associated categoric option of each dwelling complex. This tab exists of multiple linked formulas using IF-scenarios in which a score is calculated if a certain restriction is met. The scoring is based on the weights of the criteria, and the scores of the categoric option relevant to the dwelling complex assessed. The information is gathered from Tab 1 and Tab 2. For instance, Tab 3 recognizes the energy label F of a dwelling complex and then uses the weight of the criterion *Energy label* (16.1%), and the preference score of the categoric option *Poor energy quality E, F and G* (0.46). Then, the score of that particular dwelling complex regarding its

energy label would come down to 0.074 (=0.161*0.46). This is executed for all criteria and their categoric options, for each dwelling complex. Finally, the summation of scores leads to a final score which is converted to a score ranging from 0-10. The base for this summation of scores is in compliance with the formula discussed at the start of this section.

Tab 4) Prioritization overview

The fourth tab provides an overview of the final priority ranking of dwelling complexes, accompanied by the relevant information per complex. The prioritization sequence entails a ranking score, ranging from 1 to the amount of dwelling complexes assessed.

4.6. Prioritization of dwelling complexes

In this section, a Roadmap, containing the required housing data of a Dutch social housing association, has been used as input for a first calculation of a priority ranking by means of the model.

4.6.1. Final list of priority ranking

The model has been implemented in Excel and uses the weights of criteria and the preferences for categories to calculate a score, representing the priority of a complex to be made energy efficient. Thus, showing the prioritization of complexes which should be made energy efficient in accordance with the importance of their criteria and the preference for certain categoric options. The first 25 and the least 15 prioritized complexes according to the model are shown in Figure 12. For an overview of the entire list of rank scores, see Appendix E.

Priority ranking	Complex number	Average energy label complex	TVH Municipality	Construction year	Planned sustainability intervention	Exploitation strategy in line with naming of criteria	Budget (in euros) per dwelling fitting TVH of municipality	Planned to comprise with The Standard by 2050 (according to HA)
1	602	F	AE	1968	2036-2040	Doorexploiteren	65654	Yes
2	804	D	WN	1956	2024	Doorexploiteren	42770	Yes
3	806	C	WN	1964	2026-2030	Doorexploiteren	41194	Yes
4	807	D	WN	1965	2023	Doorexploiteren	47840	Yes
5	810	E	WN	1968	0	Doorexploiteren	38023	Yes
6	104	C	AE	1977	2024	Doorexploiteren	44752	Yes
7	202	C	AE	1975	2022	Doorexploiteren	49836	Yes
8	811	C	WN	1969	2036-2040	Doorexploiteren	42042	Yes
9	814	C	WN	1976	2036-2040	Doorexploiteren	40412	Yes
10	815	D	WN	1978	2036-2040	Doorexploiteren	32526	Yes
11	817	C	WN	1987	2031-2035	Doorexploiteren	36212	Yes
12	818	C	WN	1989	2031-2035	Doorexploiteren	34986	Yes
13	820	C	WN	1992	2041-2045	Doorexploiteren	34502	Yes
14	825	C	WN	1988	2041-2045	Doorexploiteren	33788	Yes
15	905	C	WN	1958	2046-2050	Doorexploiteren	45690	Yes
16	906	C	WN	1963	2036-2040	Doorexploiteren	41484	Yes
17	918	C	WN	1959	2036-2040	Doorexploiteren	45218	Yes
18	919	C	WN	1965	2036-2040	Doorexploiteren	34430	Yes
19	922	D	WN	1968	2046-2050	Doorexploiteren	39681	Yes
20	927	C	WN	1978	2031-2035	Doorexploiteren	40976	Yes
21	929	D	WN	1980	0	Doorexploiteren	46460	Yes
22	401	E	AE	1960	2022	Doorexploiteren	26000	No
23	404	C	AE	1985	2046-2050	Doorexploiteren	47816	Yes
24	605	B	AE	1995	2026-2030	Sloop	34900	Yes
25	604	C	AE	1987	2023	Doorexploiteren	26000	No

95	953	A	WN	2013	0	Doorexploiteren	28310	No
96	956	A	WN	2014	0	Doorexploiteren	23788	No
97	982	B	WN	1981	0	Doorexploiteren	27240	No
98	831	A+	WN	2018	2023	Doorexploiteren	18500	Yes
99	912	B	WN	1931	2026-2030	Doorexploiteren	0	Yes
100	917	B	WN	1956	2023	Doorexploiteren	0	No
101	830	A+	WN	2018	2036-2040	Doorexploiteren	18500	Yes
102	832	A+	WN	2020	2036-2040	Doorexploiteren	18500	No
103	833	A+	WN	2020	2046-2050	Doorexploiteren	20500	No
104	405	A+	AE	2018	2036-2040	Doorexploiteren	22500	Yes
105	954	A+	WN	2015	0	Doorexploiteren	20500	Yes
106	955	A+	WN	2015	0	Doorexploiteren	18500	Yes
107	Onbekend	A	WN	2020	0	Doorexploiteren	0	Yes
108	950	A+	WN	2012	0	Doorexploiteren	9080	Yes
109	951	A+	WN	2012	0	Doorexploiteren	9000	Yes

Figure 12: Prioritization of 109 dwelling complexes

4.7. Sensitivity analysis

A sensitivity analysis is performed to check the sensitiveness of the results when changes are made to the weights of the experts' contribution. A change in weights is established in accordance with the assumed knowledge of the experts regarding the topic of this research.

4.7.1. Sensitiveness of rank scores based on a change in experts' weightings

Each expert has had an equal weighing and contribution in the weighting of criteria. Meaning, that the answers of the experts are equally taken into account. Table 24, at the start of §4.3, provides information about the knowledge of the experts regarding the use of a Roadmap and The Standard. Based on their knowledge, it is assumed that the experts who have not made use of a Roadmap before, nor have incorporated The Standard, have less knowledge regarding the importance of criteria and categoric options needed for such planning and prioritization. The answers of experts should thus be weighed more or less, based on their knowledge regarding the subject of this research. Hence, the sensitivity analysis entails a change in the weight of each expert. Depending on whether or not they are making use of a Roadmap and additionally, whether or not they have already incorporated The Standard in their planning.

Changing the weight of experts

If the expert is already using a Roadmap, but has not yet incorporated The Standard into his planning, his responses will be weighted with 1.5 points. If the expert has incorporated The Standard into his planning, and additionally has already made use of a Roadmap, his responses will be weighted with 2.0 points. If the expert has neither incorporated The Standard, nor has made use of a Roadmap, his answers will be taken into account with a 1.0 in weight. The knowledge of the experts, and therefore the weight of their answers, is assessed by means of the classification as shown in Table 31.

Expert	Roadmap	The Standard incorporated	Weighing (ranging from 0-1)
Expert 1	No	No	1
Expert 2	Yes	Yes	2
Expert 3	No	No	1
Expert 4	Yes	Yes	2
Expert 5	Yes	Yes	2
Expert 6	Yes	No	1.5
Expert 7	Yes	No	1.5
Expert 8	Yes	No	1.5
Expert 9	Yes	Yes	2
Expert 10	Yes	No	1.5
Expert 11	Yes	No	1.5

Table 31: Weighting of experts' opinions

The changes in the weights of the experts' responses directly impacts the overall weighting of each criterion, and additionally the preference scoring of the associated categoric options. Table 32 shows the differences of the weights of the criteria, and the preference scores of the categoric options when changing the weighting of the experts in accordance with Table 31.

Change	Criteria weights and Preference score (sensitivity analysis)	Criteria weights and Preference score	
+0.50	**48.40%**	**47.90%**	**Strategy of housing portfolio of complex to be made energy efficient**
-1	24	25	Replacement new construction (demolition and new construction)
1	12	11	Sell during mutation
1	6	5	Sale per complex
1	18	17	Continue to exploit
-3	39	42	Major renovation/restructuring
-0.50	**15.60%**	**16.10%**	**Average existing energy quality of complex to be made energy efficient**
1	47	46	Poor energy quality (energy labels E, F and G)
0	33	33	Moderate energy quality (energy labels C and D)
-1	18	19	Sufficient energy quality (energy labels A, B)
0	3	3	Good to excellent energy quality (energy labels A+ and better)
-0.30	**14.00%**	**14.30%**	**Process in which the complex will be made energy efficient**
0	20	20	Per individual component will be made energy efficient at natural time such as planned maintenance
0	17	17	Dwelling will be made energy efficient during mutation or at tenants' request (per dwelling)

0	36	36	All individual required sustainability measures in one intervention for an entire complex before 2030, possibly to include maintenance and other necessary items
-2	27	29	All individual required sustainability measures in one intervention for an entire complex after 2030, possibly to include maintenance and other necessary items
+0.70	**13.80%**	**13.10%**	**Indicative budget per dwelling to be made energy efficient in euros**
0	12	12	Indicative sustainability budget per dwelling maximum €10,000
-1	25	26	Indicative sustainability budget per dwelling €10,000 to €30,000
0	47	47	Indicative sustainability budget per dwelling €30.000 to €50.000
0	16	16	Indicative sustainability budget per dwelling more than €50.000
-0.50	**8.20%**	**8.70%**	**Transition Vision Heating of governments for dwelling complex**
0	18	18	No expressed area vision other than to insulate well
1	13	12	Heat grid by 2030 (pioneer district)
1	20	19	Heat grid potentially available after 2030
1	9	8	Electric heating by 2030 (pioneering district)
-3	17	20	Electric heating potentially available after 2030
0	15	15	Green gas by 2030 (pioneering district)
0	8	8	Green gas potentially available after 2030

Table 32: Changes in weights and preference scores due to a change in weight of experts' opinions

The new weights of the criteria and the new preference scores are used as input for the prioritization ranking of dwelling complexes of the same housing association dataset, as used in the previous section. The sensitivity analysis results in a different prioritization. 33 out of the 109 complexes did not change in ranking, 32 dwelling complexes changed by one rank score, and 17 complexes changed by two rank scores. The other 27 complexes changed by either 3, 5, 6, 8, 9, 10, 13 or 14 rank scores.

Table 33 shows the change in priority rankings of dwelling complexes according to the base scenario, compared with the new sensitivity analysis scenario. Again, only the first 25 and the last 15 complexes are shown.

Complex number	Base scenario prioritization	Sensitivity analysis scenario prioritization	Change in priority
602	1	7	-6
804	2	1	1
806	3	2	1
807	4	3	1
810	5	4	1
104	6	5	1
202	7	6	1
811	8	9	-1
814	9	10	-1
815	10	11	-1
817	11	12	-1
818	12	13	-1
820	13	14	-1
825	14	15	-1

905	15	16	-1
906	16	17	-1
918	17	18	-1
919	18	19	-1
922	19	20	-1
927	20	21	-1
929	21	22	-1
401	22	8	14
404	23	23	0
605	24	24	0
604	25	39	-14
(Upper are 25 most prioritized, lower are 15 least prioritized)			
953	95	93	2
956	96	94	2
982	97	95	2
831	98	96	2
912	99	99	0
917	100	100	0
830	101	101	0
832	102	102	0
833	103	103	0
405	104	104	0
954	105	105	0
955	106	106	0
Onbekend	107	107	0
950	108	108	0
951	109	109	0

Table 33: Change in priority due to a change in weighing of experts' opinions

4.8. Conclusion

This chapter has provided the most important results of the thesis and has offered the information needed for answering the main research question and additionally, for answering the associated sub-questions. The final section of Chapter 4 will provide the conclusions following from the results of the interviews, the follow-up questionnaire, the priority ranking made by the model, and the associated sensitivity analysis. The following chapter will further outline the answers to the main research question and associated sub-questions.

Factors influencing housing associations' pace

The investigated factors influencing the housing associations' energy efficiency renovation pace are; *The Government, Municipality, Market, Tenant, and The Characteristics of the Housing association*. The results of their influences, as perceived by the interviewed experts, are shown in Table 23 of §4.2.

It is concluded that the *Government* is perceived to be of minor influence and scored -1 points, the opinions are therefore divided. Meaning, that some experts claimed the government to be of no influence, whilst others claimed that their pace is indeed influenced by the government. The most important statement for the government not being of influence, is because some housing associations claim to follow their own path. Despite what the government obliges them to do. The experts claim that they will do what they can, with the resources and finances available to them and therefore, whether or not the government obliges them, they cannot do more with what they have.

The *Municipality* is stated to be of bigger influence than the government, and scored +5 points. The statement behind their influence mainly regards a shortage of capacity, together with viscous, lengthy processes. All experts mentioned the *Market* to be of very strong influence and therefore, scored +11 points. Price increases, a lack of innovation and most important of all, a shortage of capacity at external parties regarding material and personnel are perceived as the main influencing factors.

The opinions regarding the *Tenant* are somewhat divided. Some experts claimed their pace is indeed influenced by tenants, because of lengthy and time-extensive processes with regard of achieving the 70% rule. Whilst others claimed that although the process is time-extensive, they are however not influenced in their actual pace. The score came down to +3. Meaning that the tenants are generally perceived more to be of influence than not.

Finally, all experts agreed that the *Characteristics of their Housing association* is of influence on their pace, thus scoring +11 points. The board of the housing association gets to decide on which each euro is spend and therefore, get to decide the pace of energy efficiency renovations. Subsequently, the available financial budget/parameters of the housing association are evident to the amount of work that can be established. Lastly, the experts claim that the decision-making processes within their organization sometimes, either positively or negatively, influences their pace.

Criteria of interest for the prioritization of complexes

The performed interviews have subsequently offered conclusions regarding the most, and the least important perceived criteria for the establishment of a prioritization. The experts were asked to make a cut-off to the five most and the five least important criteria, out of a predefined list of 20 criteria. The five most important criteria have been further assessed regarding their importance for making a prioritization, to be discussed in the following sub-section.

Due to a similar scoring of points, the final list of the most important criteria came down to seven criteria (Table 27). In addition, the final list of least important criteria came down to six criteria, also due to similar scoring (Table 28). The results concluded that the most important criterion is the *Strategy of the housing* portfolio, and additionally the criteria associated with the *Housing conditions*. Furthermore, the *Positioning in the energy transition* was by far considered to be the least important criteria, in addition to criteria related to *External factors*.

The weights of the criteria

By means of pairwise comparing the final five most important criteria, a weighting for each of the criterion has been established. The experts were asked in a follow-up survey to pairwise compare each criterion with all other criteria, relative to its importance for establishing a prioritization and planning towards carbon-neutrality by 2050 in compliance with The Standard. Each individual assessment of results has led to a final weighting of the five most important criteria (Table 30).

It is concluded that the strategy of the housing portfolio is by far the most important criterion, with a weight of 47.9%. Experts stated that the policies and strategies of the housing association are reflected within their housing portfolio strategy and therefore, leading for their prioritization and planning. The average existing energetic quality of the complex weights 16.1% and the process in which the complex will be made energy efficient weights 14.3%. Furthermore, the indicative budget per dwelling weights 13.1%. The Transition Vision Heating of the municipalities are considered to be of least importance, compared to the other four most important criteria. The criterion has been weighted to be of 8.7% importance to their planning. This goes together with housing associations claiming that they are rather following their own paths.

Preference scores of the categoric options

In addition to the pairwise comparisons, the experts were asked to provide their preferences for each categoric option. The results are shown in Table 30. It is concluded that the most preferred options of making a dwelling complex energy efficient, entail: The complex being labelled to be major renovated/restructured in the future; whilst all individual required sustainability measures for the entire complex are realised in one intervention, before 2030; the dwelling complex having an average energy label of E, F or G; with an indicative budget of €30,000 to €50,000 per dwelling; and with Electric heating being potentially available after 2030, as the associated Transition Vision Heating plan.

The established priority ranking model

Based on the established weights of criteria and preference scores for categoric options, a model for the prioritization of dwelling complexes has been established. A housing dataset has been used to perform a first test-run of the model, resulting in a prioritization ranking of 109 dwelling complexes. Appendix E provides a full list of the prioritization ranking.

Sensitivity of results

A sensitivity analysis has been performed to check whether or not the results (priority ranking of dwelling complexes) are sensitive to changes in weightings of the assessors' opinions. It is concluded that the results are barely sensitive to a change in weights of the experts' opinions based on their perceived knowledge regarding The Standard and the prioritization and planning of dwelling complexes.

5. Conclusions, recommendations and discussion

The final chapter of this thesis discusses the main conclusions of the research by answering the main research question and the associated sub-questions. Furthermore, recommendations for the Dutch social housing sector will be provided, followed by suggestions for future follow-up research. Lastly, the final section of this chapter offers a discussion regarding the results and limitations of the research.

5.1. Conclusions

This section will answer the main research question of this thesis, by answering each of the five associated sub-questions. The main research question answered, as discussed in Chapter 1, is as follows:

What are the factors influencing the pace in which housing associations are making their existing dwelling stock energy efficient and what are the determinants of influence for the prioritization of complexes by means of a model?

Preconditions for making an existing dwelling energy efficient

1. *What are the preconditions for making an existing dwelling energy efficient?*

The Dutch social housing sector aims to reduce their CO_2-emissions to zero by 2050 as agreed in the Climate Agreement (2019). Additionally, the government aims to have achieved 60% of this target by 2030, as compared to their net emissions in 1990. To help the sector in achieving this objective, the landlord tax will be reduced to zero, starting from 2023. In return for the abolishment of this tax, the Dutch social housing sector has come to National Performance Agreements (2022) with the government. To provide an answer to the first sub-question of this thesis, the agreements regarding the energy efficiency of the dwellings are of interest.

By 2030, 675,000 additional existing dwellings need to be insulated in compliance with *The Standard*. This comes down to approximately 30% of the Dutch social housing stock. In accordance with the Climate Agreement (2019), The Standard will expectably be obligated for all social rental dwellings by 2050. The minimum required values of The Standard function as the preconditions for making an existing dwelling energy efficient. Therefore, a dwelling which meets the minimum required values of The Standard is considered as energy efficient.

Factors influencing the energy efficiency renovation pace

2. *Which factors are influencing the pace of housing associations?*

Aedes (2021) has expressed their great worries regarding the requirements of The Standard and the objective of carbon-neutrality by 2050. The pace in which the sector is making their existing housing stock energy efficient is strongly influenced by a variety of factors. The overarching factors influencing their pace, following from the literature study, entail: *The government, municipality, market, tenant, and the characteristics of the housing association.*

Eleven experts have been interviewed to investigate the strength of the factors' influence on their pace. The Government is perceived to be of neutral influence. Meaning, that the opinions amongst the experts, regarding the influence of the government on their pace, were strongly divided. In contrary to the government, the municipality was perceived to be an influencing factor by the majority of the experts. All experts agreed that the market is of strong influence. The majority of the experts agreed that the tenant is also an influencing factor, the opinions were however slightly divided. Finally, all

experts again agreed to the characteristics of their housing association being an influencing factor with respect to their pace.

The determinants of influence on the prioritization and planning

3. *What are the determinants influencing the prioritization and planning?*

Housing associations already have, or are starting to prioritize and plan which dwellings should be first in line for being made energy efficient and carbon-neutral by 2050. The prioritization of dwelling complexes is influenced by many different factors. These factors consist of housing conditions, external factors and internal factors. They can be either tangible or non-tangible.

In total, seven most important criteria have been concluded. The three most important criteria according to the experts are: *Trias energetica,* to make a complex energy efficient in *Combination with planned maintenance,* and the S*trategy of the housing portfolio*. The fourth most important criteria is the *Energy label* of the dwelling complex. Followed by the final three most important criteria: To make a complex energy efficient *in combination with planned renovation,* the *Transition Vision Heating* of municipalities, and the *Financial possibilities in the short/long term in relation to the task.*

The *Positioning in the energy transition* is stated to be the least important criteria for their planning. Followed by *Market influences, Subsidizes on products*, the *Construction or renovation year* of the dwelling complex, the *Stage of technologic development,* and the *Input from stakeholders*.

Due to overlap amongst the criteria, the criteria *Trias energetica* and *Energy label* have been merged to *Average existing energy quality of the complex*. Additionally, the criteria *Combination with planned renovation* and *Combination with planned maintenance* have been merged into *Process in which the complex will be made energy efficient*. This has resulted in the final five most important criteria, which have been pairwise compared to derive their weights (importance) for the planning and prioritization of dwellings. In addition to these criteria, subsequent categoric options per criterion have been established.

The weights of criteria relative to their importance

4. *What is the size of influence (weight) of the determinants on the prioritization and planning?*

By pairwise comparing the five most important criteria, with respect to the overarching goal of establishing a planning and prioritization of dwelling complexes, their weights have been established.

It is concluded that the *Strategy of the housing portfolio of the complex to be made energy efficient* is by far the most important criterion. This is logically explained by reasoning that a dwelling complex will likely not be prioritized to be made energy efficient, if it is not continued to be exploited. The *Average existing energetic quality of the complex* is the second most important criteria. Then the *Process in which the complex will be made energy efficient*. Followed by the *Indicative budget per dwelling to be made energy efficient* (in euros). Lastly, the *Transition Vision Heating* of governments.

In addition to the weights of criteria, the experts were asked to score their preferences for the categoric options associated to each individual criterion. By distributing 100 points in accordance with their preferences, a preference score has been derived. Both the weights of the criteria and the preference scores of categoric options are used for the establishment of a priority ranking model.

Modelling a priority ranking

5. *To what extent can a model predict the planning and prioritization of energy efficiency renovations by a housing association?*

Based on the weights of criteria and preference scores for categoric options, a model has been established for the prioritization of dwelling complexes. A Roadmap containing the required characteristics and information of 109 dwelling complexes has been used to establish a first test-run of the model's prioritization ranking. Furthermore, a sensitivity analysis shows that the priority ranking of the model are barely sensitive to a change in weights of the experts' opinions, in accordance with their perceived knowledge regarding the research topic.

The model, however, needs to be validated in practice to conclude the extent to which the model can predict a prioritization and planning, as established by a housing association. A first validation is established.

A first validation of the model in practice

The priority ranking of the model is compared with the priority ranking of a Roadmap, thereby offering a first validation of results in practice. The housing portfolio dataset of a Dutch social housing association (acquired from Atriensis) was used for the priority ranking of 109 dwelling complexes. The housing association of the acquired dataset was also already in use of a Roadmap and therefore, their Roadmap is used as a comparison of priority ranking scores.

The results of comparing the priority ranking of the model with the priority ranking of The Roadmap, shows that the model has been able to predict 7 of the 109 (6.4%) dwelling complexes correct.

Furthermore, for each priority ranking, a comparison is made of the characteristics of the associated complex as prioritized by both the model and The Roadmap. The results show that the highest priority ranked complexes, according to the model, score better on the criteria *Budget* and *Average energy labels*, as compared to the complexes of The Roadmap on that same rank score. Additionally, they score worse on *The process in which the dwelling will be made energy efficient*. Concluding, that the priority ranking of the model stronger weighs the *Average energy label* of the complexes and the *Budget* for making them energy efficient, as compared to how strong The Roadmap weighs these criteria. Lastly, according to the comparison, *The process in which the complexes will be made energy efficient* is weighted less than the priority ranking of The Roadmap does.

It is thus concluded that the priority ranking of dwelling complexes by the model, by means of the weights of criteria and the preferences for categoric options according to the experts, is different than the priority ranking of a Roadmap in practice. Further conclusions can be drawn from the differences in priority rankings and subsequently, the differences of the characteristics of the dwellings regarding the same priority rank. However, a single validation of the model in practice do not provide sufficient information to draw general conclusions regarding the rationality of the model, or the Roadmap. Therefore, the model needs to be validated more in practice. Recommendations and suggestions for follow-up research, regarding the validation of the priority ranking model in practice, will be provided in the following section.

5.2. Recommendations

This section provides recommendations for the sector and will additionally discuss some suggestions for needed follow-up research.

5.2.1. Recommendations for the sector

The results of this research offer contemporary insights to Dutch social housing associations. It shows which criteria, and to what extent, are considered important for the prioritization and planning of dwelling complexes towards a carbon-neutral housing stock in compliance with The Standard.

The established model, using the investigated criteria, their weights and preference scores for categoric options, is methodologically correct. It is thus a theoretical substantiated tool, offering a different and additional perspective to the priority ranking of dwelling complexes. The first recommendation is therefore, to use the model to help fasten the actualisation of a housing associations' portfolio.

The interviews have, however, been performed in April and May 2022, prior to the publication of the National Performance Agreements on June the 30th (2022). Within the National Performance Agreements, the sector and the government have made some commitments which can be of influence on both the pace, as well as the prioritization and planning of the housing associations. Two additional recommendations follow from this remark.

Firstly, the Transition Vision Heating by municipalities will be clear by 2024, and more decisive for where, when, what is going to happen to neighbourhoods. According to the results of this research, the Transition Vision Heating was the fifth most important criterion considered for the prioritization and planning of complexes (weighing only 8.7%). It is recommended to prioritize dwelling complexes more in line with the Transition Vision Heating plans, to be more efficient and economical. Thus, to stronger reconsider the importance of the Transition Vision Heating plans of municipalities with respect to the prioritization of dwelling complexes by housing associations.

Secondly, The Standard will prominently be the new minimum required energy efficiency standard regarding existing dwellings' yearly net energy demand per m^2. The interviews showed that seven out of eleven experts did not incorporate The Standard, or claimed to have no experience regarding The Standard. It is strongly recommended to start learning about the consequences of, and start working with The Standard, regarding changes in your portfolio, finances, capacity etc.

5.2.2. Suggested follow-up research

Given the before mentioned recommendations, four additional suggestions for follow-up research follow.

Firstly, the next step for follow-up research entails the validation of the established model in practice. A first comparison of the priority ranking of the model with a priority ranking of a Roadmap has proven the differences in ranking. A single validation is however not enough for the model to be validated. Follow-up research should therefore, further validate the model in practice by comparing more priority rankings of Roadmaps with the priority rankings of the model. In this way, conclusions can be drawn regarding the logic of the priority ranking of the model, or regarding the logic of the priority ranking of a Roadmap in practice.

Secondly, a more specific dataset needs to be investigated, in which each complex can be assessed and scored in accordance with the moments in which they will be made energy efficient. As of now, assumptions had to be made regarding whether or not the planned moments in the dataset were taken together with renovation works. More specific data, results in more precise results.

Thirdly, in addition to more specific data, research towards a more specified model is also recommended. In some way this already exists by means of The Roadmap, which sets out in time when each complex is planned to be made energy efficient. However, The Roadmap does not prioritize the complexes in accordance with theoretical substantiated weighting of contemporary criteria and preference scoring for categoric options. Therefore, a combination of more specific data, a more specified model, the use of contemporary criteria and their weights and preference scores for categoric options, will result in a much more specific and complete prioritization ranking.

Fourthly, and finally, due to the fast-developments within the sector, a change in weights might be the result of the publication of the new National Performance Agreements (2022). The final suggestion for follow-up research thus entails a re-examination of the weights of the criteria and additionally, to interview more than eleven experts to increase the power of the results. This time, to perform the interviews after the sector has made their agreements public and so be able to provide a more encompassing model for the entire sector.

5.3. Discussion

The final section of this chapter will discuss the limitations of this research and the results.

5.3.1. Limitations of the results

The results of this thesis entail four limitations worth discussing.

Firstly, the individual weightings of criteria by means of pairwise comparisons have sometimes exceed the acceptable 10% threshold of Consistency Ratio. Although the overall CR was 3.0% and therefore acceptable, some individual weightings may however still provide unreliable results.

Secondly, the dataset used as input for the priority ranking of dwelling complexes by means of the model, did not entail specific information regarding the *Process in which the complex will be made energy efficient.* Assumptions had to be made regarding whether or not the dwelling would be made energy efficient during a renovation or maintenance works, or that all individual required sustainability measures would be performed in one intervention for the entire complex.

Thirdly, the model is used as a supportive tool for decision makers' prioritization and planning, using the weights of criteria according to their assessments. The model provides a ranking of dwelling complexes to be made energy efficient, of all measures being considered. The model does however not provide a prioritization of measures. It is thus a simplification of the reality, in which certain measures may be prioritized as well, rather than prioritizing complexes in which all measures are taken at once.

Fourthly, a Roadmap, used for comparing the priority ranking of the model with the priority ranking according to The Roadmap, does not indicate a specific priority ranking. The Roadmap shows that, for instance, 10 complexes will be made energy efficient within a certain year, but it does however not show which complex would be first and which would be the tenth within that year. Therefore, the comparison of priority rankings by the model with the priority rankings of The Roadmap do not give exact results, rather an indication.

5.3.2. Discussion of the results

It is interesting to note that the government is perceived to be of rather no influence on their pace. This has been mainly explained by housing associations following their own paths towards 2050, by means of their own capacities and budgets. The government has a very important role in steering towards that particular goal by means of legislations. As perceived by the experts, however, they are claimed to not have a very large influence on the pace in which they are going to do so.

Furthermore, the criteria used within the model do not give an all-encompassing result of the prioritization made in practice. In reality, there are many more accompanying factors of influence, such as incidental factors, flanking factors, and personal experiences. In real-life decision-making, these additional factors make up for a great part of how a prioritization and planning is actually made. The model does however offer a different perspective and is methodologically correct, it is thus recommended to use the model and the priority ranking as a different perspective on a planning and prioritization.

By comparing the priority ranking of the model with a priority ranking of, for instance a Roadmap, the decision maker will be able to draw conclusions regarding their already established priority ranking. Questions can then be raised regarding the rationality of the existing priority ranking and whether or not changes might be needed. The model thus not only offers a priority ranking on its own, it can additionally be used as a comparison with an already existing prioritization and planning from which conclusions and questions may follow.

Lastly, the comparison of the characteristics of the prioritized dwellings by the model and The Roadmap, showed that in reality the process in which a dwelling will be made energy efficient is much more valued. On the other hand, the budget and the average energy label are much less valued. This might be the case because the housing association prefers to make use of natural planned moments, no matter the energy label or the budget available. Again, however, more validations need to be performed to provide a more encompassing conclusions.

Bibliography

Aedes. (2018). *Sectorrapport CO2-neutraal.* Aedes.

Aedes. (2018). *Uitkomsten Aedes-Routekaart CO2-neutraal 2050 (routekaart 2018)*. Opgehaald van Aedes.nl: https://aedes.nl/verduurzaming/uitkomsten-aedes-routekaart-co2-neutraal-2050-routekaart-2018

Aedes. (2019). *Woningvoorraad corporaties naar bouwperiode*. Opgehaald van Aedesdatacentrum.nl: https://aedesdatacentrum.nl/dashboard/dashboard--aedes-datacentrum/kenmerken-woningen-2/

Aedes. (2021, November 29). *Corporaties verduurzamen met voorrang label E, F en G-woningen*. Opgehaald van Aedes.nl: https://aedes.nl/verduurzaming/corporaties-verduurzamen-met-voorrang-label-e-f-en-g-woningen

Aedes. (2021, Maart 18). *Nieuwe Standaard voor maximale warmtevraag bekend*. Opgehaald van Aedes.nl: https://aedes.nl/verduurzaming/nieuwe-standaard-voor-maximale-warmtevraag-bekend

Aedes. (2021, September 6). *Standaard en streefwaarden*. Opgehaald van Aedes.nl: https://aedes.nl/verduurzaming/standaard-en-streefwaarden

Aedes. (2021, November 29). *Woningbouwproductie corporaties weer toegenomen*. Opgehaald van Aedes.nl: https://aedes.nl/aedes-benchmark/woningbouwproductie-corporaties-weer-toegenomen#:~:text=Woningcorporaties%20bouwden%20vorig%20jaar%2015.199,de%20woningbouwproductie%20door%20corporaties%20omgebogen.

Aedes. (2022). *Routekaart verduurzaming*. Opgehaald van Aedes.nl: https://aedes.nl/routekaart-verduurzaming

Atriensis. (2021, Maart 20). *De Standaard opvolger van energielabel als kompas* . Opgehaald van Atriensis.nl: https://www.atriensis.nl/nieuwsbericht-projecten/de-standaard-opvolger-van-energielabel-als-kompas

Belton, V., & Gear, T. (1983). On a Short-coming of Saaty's Method of Analytic Hierarchies. *Omega*, 228-230.

Bosch. (sd). *Bosch Compact Dryer - Home Connect(TM) - 4 cu. ft. - White*. Opgehaald van www.Rona.ca: https://www.rona.ca/en/product/bosch-compact-dryer-home-connecttm-4-cu-ft-white-wtg865h3uc-30855247

CBS. (2021). *Welke sectoren stoten broeikasgassen uit?* Opgehaald van CBS.nl: https://www.cbs.nl/nl-nl/dossier/dossier-broeikasgassen/hoofdcategorieen/welke-sectoren-stoten-broeikasgassen-uit-

Dallas, G. (2019). *Principal Component Analysis 4 Dummies: Eigenvectors, Eigenvalues and Dimension Reduction*. Opgehaald van Georgemdallas.wordpress.com: https://georgemdallas.wordpress.com/2013/10/30/principal-component-analysis-4-dummies-eigenvectors-eigenvalues-and-dimension-reduction/

De Nederlandse Coalitie . (2021). *Coalitieakkoord 2021-2025.* Den Haag.

DeCorporatieStrateeg. (2017). *Wat is de beleidsachtbaan?* Opgehaald van decorporatiestrateeg.nl: https://corporatiestrateeg.nl/corporatiebeleid/vastgoedsturing/wat-is-de-beleidsachtbaan/

Dieperink, C., Brand, I., & Vermeulen, W. (2004). Diffusion of energy-saving innovations in industry and the built environment: Dutch studies as inputs for a more integrated analytical framework. *Energy Policy*, 773-784.

Dodgson, J., Spackman, M., Pearman, A., & Philips, L. (2000, December 1). DLTR multi-criteria analysis manual. National Economic Research Associates.

EarthOvershootDay. (2021). *Earth Overshoot Day 2021*. Opgehaald van overshootday.org: https://www.overshootday.org/

Edwards, W., & Hutton, B. (1994). SMARTS and SMARTER: Improved Simple Methods for Multiattribute Utility Measurement. *Organizational behavior and human decision processes*, 306-325.

European Commission. (2020, February 17). *Energy efficiency in buildings*. Opgehaald van ec.europa.eu: https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-lut-17_en

European Commission. (2021). *A European Green Deal*. Opgehaald van ec.europa.eu: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

Filippidou, F. (2018). *Energy performance progress of the Dutch non-profit housing stock: a longitudinal assessment.* Delft University of Technology, Faculty of Architecture and the Built Environment, Department of OTB - Research for the Built Environment.

Goepel, K. D. (2013). Implementing the Analytical Hierarchy Process as a Standard Method for Multi-Criteria Decision Making In Corporate Enterprises - A New AHP Excel Template with Multiple Inputs. *Proceedings of the International Symposium on the Analytical Hierarchy Process*, 1-10.

Hoppe, T. (2012). Adoption of innovative energy systems in social housing: Lessons from eight large-scale renovation projects in The Netherlands. *Energy Policy*, 791-801.

Jansen, S. (2011). *The Multi-attribute Utility Method.* Delft: Delft University of Technology.

Klimaat.be. (2019). *Het VN-Klimaatverdrag : van Rio tot Kyoto*. Opgehaald van klimaat.be: https://klimaat.be/klimaatbeleid/internationaal/vn-klimaatverdrag

Lambrechts, W., Mitchell, A., Lemon, M., Usman Mazhar, M., Ooms, W., & van Heerde, R. (2021). The Transition of Dutch Social Housing Corporations to Sustainable Business Models for New Buildings and Retrofits. *Energies*.

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties . (2021, December 24). *Afspraak met kabinet: extra investeringen woningcorporaties na verlaging verhuurderheffing*. Opgehaald van Volkshuisvestingnederland.nl: https://www.volkshuisvestingnederland.nl/actueel/nieuws/2021/12/23/extra-investeringen-woningcorporaties-na-verlaging-verhuurderheffing

Moutinho, L., Curry, B., Davies, F., & Rita, P. (1994). Chapter 4: The Analytical Hierarchy Process. In L. Moutinho, B. Curry, F. Davies, & R. P, *Computer Modelling and Expert Systems in Marketing.* London.

Nieman. (2021). *Rapport Standaard en streefwaardes bestaande bouw.* RVO.

Pant, S., Kumar, A., Ram, M., Klochkov, Y., & Sharma, H. K. (2022). Consistency Indices in Alaytical Hierarchy Process: A Review. *Mathematics*.

PAW. (2021, September). *Voortgang transitievisie warmte*. Opgehaald van www.aardgasvrijewijken.nl: https://www.aardgasvrijewijken.nl/themas/regieenorganisatie/transitievisie+warmte2/voortgang+transitievisie+warmte/default.aspx

Plan A Academy . (2022). *Earth Overshoot Day 2022*. Opgehaald van plana.earth: https://plana.earth/academy/earth-overshoot-day-2022/

Qin, Y., Xu, Z., Wang, X., & Skare, M. (2022). Green energy adoption and its determinants: A bibliometric analysis. *Renewable and Sustainable Energy Reviews*.

Raiffa, H., & Keeney, R. (1975). *Decision analysis with multiple conflicting objectives preferences and value tradeoffs.*

RIGO. (2021, December 17). *De Beleidsachtbaan in acht episodes*. Opgehaald van rigo.nl: https://www.rigo.nl/de-beleidsachtbaan-in-acht-episodes/

Rijksoverheid. (2019, Januari 8). *Achtergrondnotitie 'De Renovatieversneller' ten behoeve van de sectortafel Gebouwde omgeving.*

Rijksoverheid. (2019, Juni 28). Klimaatakkoord. *Klimaatakkoord*. Den Haag.

Rijksoverheid. (2021, October 28). *Klimaatnota 2021: klimaatbeleid leidt tot meer CO2-redcutie, maar extra stappen blijven nodig*. Opgehaald van Rijksoverheid.nl: https://www.rijksoverheid.nl/actueel/nieuws/2021/10/28/klimaatnota-2021-klimaatbeleid-leidt-tot-meer-co2-reductie-maar-extra-stappen-blijven-nodig#:~:text=Aanscherping%20EU%2Dklimaatdoel,klimaatneutraliteit%20in%202050%20zijn%20vastgelegd.

Rijksoverheid. (2022). *Nationale Prestatieafspraken Woningcorporaties.* Rijksoverheid.

Roy, B. (1991). The Outranking approach and the foundation of Electre methods. *Theory and Decision*, 49-73.

RVO. (2013). *Infoblad Trias Energetica en energieneutraal bouwen.*

RVO. (2022, Januari 17). *Energieprestatie-eisen bij verbouw en renovatie*. Opgehaald van RVO.nl: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/bestaande-bouw/energieprestatie-eisen-bij-verbouw-en-renovatie

Saaty, T. (1987). The Analytical Hierarchy Process - What it is and how it is used. *Math Modelling*, 161-176.

Scribbr. (2019, Juli 3). *Reliability vs Validity in Research | Differences, Types and Examples*. Opgehaald van Scribbr.com: https://www.scribbr.com/methodology/reliability-vs-validity/#:~:text=Validity%20refers%20to%20how%20accurately,the%20physical%20or%20social%20world.

Seebauer, S. (2021). How to make building renovation work for low-income renters: Preferences for distributional principles and procedural options in Austria. *Energy Research & Social Science*.

Shanmuganathan, M., Kajendran, K., Sasikumar, A., & Mahendran, M. (2018). Multi Attribute Utility Theory – An Overview. *International Journal of Scientific & Engineering Research*, 698-706.

Simon, H. (1960). *The new science of management decisions.* New York: Harper and Row.

SpiceLogicInc. (2022, June 14). *AHP Calculation Methods*. Opgehaald van SpiceLogicInc.com: https://www.spicelogic.com/docs/ahpsoftware/intro/ahp-calculation-methods-396

United Nations. (sd). *What is the Kyoto Protocol?* Opgehaald van unfccc.int: https://unfccc.int/kyoto_protocol

van Middelkoop, M., Vringer, K., & Visser, H. (2017). Are Dutch residents ready for a more stringent policy to enhance the energy performance of their homes? *Energy policy*, 269-282.

Van Os, P. (2007). *Vastgoedbeleid bij woningcorporaties; een procesbenadering.*

Van Os, P. (2021, December 17). *De beleidsachtbaan in 8 episodes*. Opgehaald van rigo.nl: https://sway.office.com/bLSdbEY1l6hiuRBP?ref=Link

Whitaker, R., Saaty, T., & Vargas, L. (2009). Addressing with brevity criticism of the Analytical Hierarchy Process. *International Journal of the Analyitcal Hierarchy Process*.

Woonbond. (2017). *Effecten verhuurderheffing.*

Woonbond. (2019, Juli 24). *De grootste particuliere verhuurders van Nederland*. Opgehaald van Woonbond.nl: https://www.woonbond.nl/nieuws/grootste-particuliere-verhuurders-nederland

Appendices

Appendix A – Follow-up questionnaire of pairwise comparisons

The 5 most important criteria are compared according to their importance for the establishment of The Roadmap

If you had to make a Roadmap in compliance with 'The Standard' towards CO2-neutrality by 2050, what would you consider more important...?

Please mark each line with a blue colour, indicating your choice of one of the orange shaded boxes

	The Process in which the dwelling complex will be made energy efficient or The Transition vision heating of governments for dwelling complex									
The process	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Transitionvision Heating**
	The Process in which the dwelling complex will be made energy efficient or The Average existing energy quality of dwelling complex									
The process	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Energetische kwaliteit**
	The Process in which the dwelling complex will be made energy efficient or The Indicative budget per dwelling to be made energy efficient in euros									
The process	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Indicative budget**
	The Process in which the dwelling complex will be made energy efficient or The Strategy of housing portfolio for dwelling complex to be made energy efficient									
The process	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Strategy housing portfolio**
	The Transition vision heating of governments for dwelling complex or The Average existing energy quality of dwelling complex									
Transitionvision Heating	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Energetic quality**
	The Transition vision heating of governments for dwelling complex or The Indicative budget per dwelling to be made energy efficient in euros									
Transitionvision Heating	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Indicative budget**
	The Transition vision heating of governments for dwelling complex or The Strategy of housing portfolio for dwelling complex to be made energy efficient									
Transitionvision Heating	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Strategy housing portfolio**
	The Average existing energy quality of dwelling complex or The Indicative budget per dwelling to be made energy efficient in euros									
Energetic quality	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Indicative budget**
	The Average existing energy quality of dwelling complex or The Strategy of housing portfolio for dwelling complex to be made energy efficient									
Energetic quality	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Strategy housing portfolio**
	The Indicative budget per dwelling to be made energy efficient in euros or The Strategy of housing portfolio for dwelling complex to be made energy efficient									
Indicative budget	9) Extremely more important	7) Much more important	5) More important	3) Slightly more important	1) Evenly important	3) Slightly more important	5) More important	7) Much more important	9) Extremely more important	**Strategy housing portfolio**

Appendix B – Individual sheets of AHP-results

n	Criteria	Comment	RGMM	+/-
1	Process		17,8%	7,3%
2	Transitionvision Heating		8,7%	2,3%
3	Energetic quality		32,4%	8,5%
4	Indicative budget		8,7%	2,3%
5	Strategy portfolio		32,4%	8,5%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 1	1	2-1-1900	α: 0,1	CR: 4%
Name	Weight	Date		Consistency Ratio

		Criteria		more important ?	Scale
i	j	A	B	A or B	(1-9)
1	2	Process	Transitionvision Heating	A	3
1	3		Energetic quality	B	3
1	4		Indicative budget	A	3
1	5		Strategy portfolio	B	3
1	6				
1	7				
1	8				
2	3	Transitionvision Heating	Energetic quality	B	3
2	4		Indicative budget	A	1
2	5		Strategy portfolio	B	3
2	6				
2	7				
2	8				
3	4	Energetic quality	Indicative budget	A	3
3	5		Strategy portfolio	A	1
3	6				
3	7				
3	8				
4	5	Indicative budget	Strategy portfolio	B	3

n	Criteria	Comment	RGMM	+/-
1	Process		14,5%	10,9%
2	Transitionvision Heating		3,1%	1,6%
3	Energetic quality		17,7%	11,7%
4	Indicative budget		10,0%	6,6%
5	Strategy portfolio		54,7%	29,9%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 2	1	1-6-2022	α: 0,1	CR: 25%	1
Name	Weight	Date		Consistency Ratio	

		Criteria		more important ?	Scale		
i	j	A		B	A or B	(1-9)	
1	2	Process		Transitionvision Heating	A	5	
1	3			Energetic quality	B	5	2 B1
1	4			Indicative budget	A	5	1 A1
1	5			Strategy portfolio	B	7	
1	6						
1	7						
1	8						
2	3	Transitionvision Heating		Energetic quality	B	5	
2	4			Indicative budget	B	5	
2	5			Strategy portfolio	B	7	
2	6						
2	7						
2	8						
3	4	Energetic quality		Indicative budget	A	1	
3	5			Strategy portfolio	B	7	3 B3
3	6						
3	7						
3	8						
4	5	Indicative budget		Strategy portfolio	B	5	

A
B

n	Criteria	Comment	RGMM	+/-
1	Process		11,4%	7,0%
2	Transitionvision Heating		4,5%	1,4%
3	Energetic quality		31,1%	20,5%
4	Indicative budget		5,5%	3,2%
5	Strategy portfolio		47,5%	32,0%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 3	1	3-6-2022	α: 0,1	CR: 29%	1	
Name	Weight	Date		Consistency Ratio		

		Criteria		more important ?	Scale		
i	j	A		B	A or B	(1-9)	
1	2	Process		Transitionvision Heating	A	3	
1	3			Energetic quality	B	7	2 B3
1	4			Indicative budget	A	5	
1	5			Strategy portfolio	B	5	
1	6						
1	7						
1	8						
2	3	Transitionvision Heating		Energetic quality	B	7	
2	4			Indicative budget	A	1	
2	5			Strategy portfolio	B	5	
2	6						
2	7						
2	8						
3	4	Energetic quality		Indicative budget	A	5	
3	5			Strategy portfolio	B	5	1 B2
3	6						
3	7						
3	8						
4	5	Indicative budget		Strategy portfolio	B	3	3 B8

A
B

n	Criteria	Comment	RGMM	+/-
1	Process		7,9%	3,4%
2	Transitionvision Heating		7,3%	1,5%
3	Energetic quality		31,4%	10,8%
4	Indicative budget		19,3%	9,3%
5	Strategy portfolio		34,2%	10,4%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 4	1	6-6-2022	α: 0,1	CR: 7%
Name	Weight	Date		Consistency Ratio

		Criteria		more important ?	Scale
i	j	A		B	A or B	(1-9)
1	2	Process		Transitionvision Heating	A	1
1	3			Energetic quality	B	3
1	4			Indicative budget	B	5
1	5			Strategy portfolio	B	3
1	6					
1	7					
1	8					
2	3	Transitionvision Heating		Energetic quality	B	3
2	4			Indicative budget	B	3
2	5			Strategy portfolio	B	5
2	6					
2	7					
2	8					
3	4	Energetic quality		Indicative budget	A	3
3	5			Strategy portfolio	A	1
3	6					
3	7					
3	8					
4	5	Indicative budget		Strategy portfolio	B	3

n	Criteria	Comment	RGMM	+/-
1	Process		16,8%	8,0%
2	Transitionvision Heating		5,4%	1,8%
3	Energetic quality		4,9%	1,4%
4	Indicative budget		32,6%	8,3%
5	Strategy portfolio		40,4%	15,5%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 5	1	9-6-2022	α: 0,1	CR: 7%	1
Name	Weight	Date		Consistency Ratio	

		Criteria		more important ?	Scale	
i	j	A		B	A or B	(1-9)
1	2	Process		Transitionvision Heating	A	5
1	3			Energetic quality	A	5
1	4			Indicative budget	B	3
1	5			Strategy portfolio	B	5
1	6					
1	7					
1	8					
2	3	Transitionvision Heating		Energetic quality	A	1
2	4			Indicative budget	B	5
2	5			Strategy portfolio	B	5
2	6					
2	7					
2	8					
3	4	Energetic quality		Indicative budget	B	5
3	5			Strategy portfolio	B	7
3	6					
3	7					
3	8					
4	5	Indicative budget		Strategy portfolio	A	1

A
B

n	Criteria	Comment	RGMM	+/-
1	Process		6,7%	1,1%
2	Transitionvision Heating		25,4%	7,2%
3	Energetic quality		5,6%	1,6%
4	Indicative budget		20,0%	9,4%
5	Strategy portfolio		42,2%	19,9%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 6	1	13-6-2022	α: 0,1	CR: 9%
Name	Weight	Date		Consistency Ratio

		Criteria		more important ?	Scale
i	j	A	B	A or B	(1-9)
1	2	Process	Transitionvision Heating	B	3
1	3		Energetic quality	A	1
1	4		Indicative budget	B	3
1	5		Strategy portfolio	B	5
1	6				
1	7				
1	8				
2	3	Transitionvision Heating	Energetic quality	A	5
2	4		Indicative budget	A	1
2	5		Strategy portfolio	A	1
2	6				
2	7				
2	8				
3	4	Energetic quality	Indicative budget	B	5
3	5		Strategy portfolio	B	5
3	6				
3	7				
3	8				
4	5	Indicative budget	Strategy portfolio	B	5

n	Criteria	Comment	RGMM	+/-
1	Process		25,9%	22,1%
2	Transitionvision Heating		14,4%	10,1%
3	Energetic quality		3,3%	1,0%
4	Indicative budget		22,1%	18,5%
5	Strategy portfolio		34,2%	26,0%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 7	1	13-6-2022	α: 0,1	CR: 66%
Name	Weight	Date		Consistency Ratio

		Criteria		more important ?	Scale		
i	j	A	B	A or B	(1-9)		
1	2	Process	Transitionvision Heating	A	1		
1	3		Energetic quality	A	5		
1	4		Indicative budget	A	7	1	A1
1	5		Strategy portfolio	B	9	2	B2
1	6						
1	7						
1	8						
2	3	Transitionvision Heating	Energetic quality	A	5		
2	4		Indicative budget	B	5	3	B1
2	5		Strategy portfolio	A	1		
2	6						
2	7						
2	8						
3	4	Energetic quality	Indicative budget	B	3		
3	5		Strategy portfolio	B	5		
3	6						
3	7						
3	8						
4	5	Indicative budget	Strategy portfolio	A	1		

A
B

n	Criteria	Comment	RGMM	+/-
1	Process		27,0%	11,1%
2	Transitionvision Heating		10,1%	4,2%
3	Energetic quality		15,7%	6,5%
4	Indicative budget		5,1%	1,6%
5	Strategy portfolio		42,0%	17,2%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 8	1	20-6-2022	α: 0,1	CR: 9%	1
Name	Weight	Date		Consistency Ratio	

		Criteria		more important ?	Scale
i	j	A	B	A or B	(1-9)
1	2	Process	Transitionvision Heating	A	3
1	3		Energetic quality	A	3
1	4		Indicative budget	A	5
1	5		Strategy portfolio	B	3
1	6				
1	7				
1	8				
2	3	Transitionvision Heating	Energetic quality	B	3
2	4		Indicative budget	A	3
2	5		Strategy portfolio	B	3
2	6				
2	7				
2	8				
3	4	Energetic quality	Indicative budget	A	3
3	5		Strategy portfolio	B	3
3	6				
3	7				
3	8				
4	5	Indicative budget	Strategy portfolio	B	5

A
B

n	Criteria	Comment	RGMM	+/-
1	Process		11,5%	6,9%
2	Transitionvision Heating		3,4%	2,0%
3	Energetic quality		28,7%	18,2%
4	Indicative budget		5,3%	1,8%
5	Strategy portfolio		51,1%	32,4%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 9	1	20-6-2022	α: 0,1	CR: 25%	1
Name	Weight	Date		Consistency Ratio	

		Criteria		more important ?	Scale		
i	j	A	B	A or B	(1-9)		
1	2	Process	Transitionvision Heating	A	7	3	A3
1	3		Energetic quality	B	7	1	B2
1	4		Indicative budget	A	3		
1	5		Strategy portfolio	B	5		
1	6						
1	7						
1	8						
2	3	Transitionvision Heating	Energetic quality	B	7		
2	4		Indicative budget	B	3		
2	5		Strategy portfolio	B	5		
2	6						
2	7						
2	8						
3	4	Energetic quality	Indicative budget	A	5		
3	5		Strategy portfolio	B	5	2	B2
3	6						
3	7						
3	8						
4	5	Indicative budget	Strategy portfolio	B	7		

A
B

n	Criteria	Comment	RGMM	+/-
1	Process		14,5%	13,1%
2	Transitionvision Heating		7,2%	5,3%
3	Energetic quality		22,8%	20,7%
4	Indicative budget		17,1%	13,7%
5	Strategy portfolio		38,4%	11,4%
6				
7				
8				
9		for 9&10 unprotect the input sheets and expand the		
10		question section ("+" in row 66)		

Respondent 10	1	24-6-2022	α: 0,1	CR: 46%	1
Name	Weight	Date		Consistency Ratio	

		Criteria		more important ?	Scale			A
i	j	A		B	A or B	(1-9)		B
1	2	Process		Transitionvision Heating	B	3	3	A1
1	3			Energetic quality	A	7	1	B2
1	4			Indicative budget	B	5		
1	5			Strategy portfolio	B	5		
1	6							
1	7							
1	8							
2	3	Transitionvision Heating		Energetic quality	B	5		
2	4			Indicative budget	B	5		
2	5			Strategy portfolio	B	5		
2	6							
2	7							
2	8							
3	4	Energetic quality		Indicative budget	A	5	2	B1
3	5			Strategy portfolio	B	5		
3	6							
3	7							
3	8							
4	5	Indicative budget		Strategy portfolio	B	5		

Appendix C – Follow-up questionnaire for the preference scoring of options

How strong is your preference for each of the categoric options per criterion of the complex to be made energy efficient? You have 100 points to divide amongst the categoric options per criterion

Divide 100 points between the yellow coloured squares per criterion

Example: You prefer to make dwelling complexes with energy labels E, F and G energy efficient, but also dwelling complexes with energy labels C and D. You could then give 70 points to E, F and G because you have the strongest preference for making complexes and energy efficient with those labels, and 30 points to C and D.

0	***Process in which the dwelling complex will be made energy efficient (Total = 100 points)***
	Below are 4 methods to make dwellings energy efficient. Divide 100 points between the methods according to your preference for making a complex energy efficient.
0	Per individual component will be made energy efficient at natural time such as planned maintenance
0	Dwelling will be made energy efficient during mutation or at tenants' request (per dwelling)
0	All individual required sustainability measures in one intervention for an entire complex before 2030, possibly to include maintenance and other necessary items
0	All individual required sustainability measures in one intervention for an entire complex after 2030, possibly to include maintenance and other necessary items

0	***Transition Vision Heating of governments for dwelling complex (Total = 100 points)***
	Below are 7 possible Transitionvision Heating plans by municipality for the dwelling complex to be made energy efficient. Divide 100 points over the visions according to your preference for the dwelling complex to be made energy efficient.
0	No expressed area vision other than to insulate well
0	Heat grid by 2030 (pioneer district)
0	Heat grid potentially available after 2030
0	Electric heating by 2030 (pioneering district)
0	Electric heating potentially available after 2030
0	Green gas by 2030 (pioneering district)
0	Green gas potentially available after 2030

0	***Average existing energy quality of dwelling complex (Total = 100 points)***
	Below are 4 possible grouped characteristics of energy labels of the dwelling complex to be made energy efficient. Divide 100 points over the group of characteristics you prefer for the complex to be made energy efficient.
0	Poor energy quality (energy labels E, F and G)
0	Moderate energy quality (energy labels C and D)
0	Sufficient energy quality (energy labels A, B)
0	Good to excellent energy quality (energy labels A+ and better)

0	***Indicative budget per dwelling to be made energy efficient in euros (Total = 100 points)***
	Below are 4 possible budgets for making one dwelling energy efficient. Divide 100 points over the possible budgets according to your preference for a dwelling to be made energy efficient.
0	Indicative sustainability budget per dwelling maximum €10,000
0	Indicative sustainability budget per dwelling €10,000 to €30,000
0	Indicative sustainability budget per dwelling €30.000 to €50.000
0	Indicative sustainability budget per dwelling more than €50.000

0	***Strategy of housing portfolio for dwelling complex to be made energy efficient (Total = 100 points)***
	Below are 5 possible housing portfolio strategies for the dwelling complex to be made energy efficient. Divide 100 points between the strategies according to your preference for the dwelling complex to be made energy efficient.
0	Replacement new construction (demolition and new construction)
0	Sell during mutation
0	Sale per complex
0	Continue to exploit
0	Major renovation/restructuring

Appendix D – Tabs of the planning and prioritization model

Tab 1) Formula

Weight of criteria and preference scores of categories

0,143	**Process in which the complex will be made energy efficient**	Criterion 1
0,20	Per individual component will be made energy efficient at natural time such as planned maintenance	
0,17	Dwelling will be made energy efficient during mutation or at tenants' request (per dwelling)	
0,36	All individual required sustainability measures in one intervention for an entire complex before 2030, possibly to include maintenance and other necessary items	
0,29	All individual required sustainability measures in one intervention for an entire complex after 2030, possibly to include maintenance and other necessary items	

0,087	**Transition Vision Heating of governments for dwelling complex**	Criterion 2
0,18	No expressed area vision other than to insulate well	
0,12	Heat grid by 2030 (pioneer district)	
0,19	Heat grid potentially available after 2030	
0,08	Electric heating by 2030 (pioneering district)	
0,20	Electric heating potentially available after 2030	
0,15	Green gas by 2030 (pioneering district)	
0,08	Green gas potentially available after 2030	

0,161	**Average existing energy quality of complex to be made energy efficient**	Criterion 3
0,46	Poor energy quality (energy labels E, F and G)	
0,33	Moderate energy quality (energy labels C and D)	
0,19	Sufficient energy quality (energy labels A, B)	
0,03	Good to excellent energy quality (energy labels A+ and better)	

0,131	**Indicative budget per dwelling to be made energy efficient in euros**	Criterion 4
0,12	Indicative sustainability budget per dwelling maximum €10,000	
0,26	Indicative sustainability budget per dwelling €10,000 to €30,000	
0,47	Indicative sustainability budget per dwelling €30.000 to €50.000	
0,16	Indicative sustainability budget per dwelling more than €50.000	

0,479	**Strategy of housing portfolio of complex to be made energy efficient**	Criterion 5
0,25	Replacement new construction (demolition and new construction)	
0,11	Sell during mutation	
0,05	Sale per complex	
0,17	Continue to exploit	
0,42	Major renovation/restructuring	

10	0,4063250000	--> highest achievable priority score
0	0,0741630000	--> lowest achievable score

Point scale	Score 1-10	1 scoring point per 0,0327701
0,332162	10	0,0332162
0,2989458	9	0,0332162
0,2657296	8	0,0332162
0,2325134	7	0,0332162
0,1992972	6	0,0332162
0,166081	5	0,0332162
0,1328648	4	0,0332162
0,0996486	3	0,0332162
0,0664324	2	0,0332162
0,0332162	1	0,0332162
0	0	0

1. Formula | 2. Housing data | 3. Scoring | 4. Prioritization overview

Tab 2) Housing data

Amount of rentable dwellings	Complex number	Street nam	City	TVH Municipali	Planned execution T	Date in line with criteria years	Average energy label compl	Construction year	Renovation year	Exploitation strategy housing associatio	Exploitation strategy in line with naming of criteria	Investment per dwelling (All-Electric) (nom)	Investment per complex (All-Electric) (nom)	Investment per dwelling (Heating grid) (nom)	Investment per complex (Heating grid) (nom)	Budget (in euros) per dwelling fitting TVH of municipali	Planned to comprise with The Standard by 2050 (according to HA)
22	101	Zevenhovenstraat	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	A	1950	2020	Doorexploiteren	Doorexploiteren	36734	808148	27734	610148	36734	Yes
35	102	Plantsoen	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	E	1962	1971	Doorexploiteren	Doorexploiteren	57724	2020340	48724	1705340	57724	Yes
58	103	Blasseklijnstraat	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	C	1969	2015	Doorexploiteren	Doorexploiteren	52330	3035140	43330	2513140	52330	Yes
40	104	Klaverpad	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	C	1977		Doorexploiteren	Doorexploiteren	44752	1790080	35752	1430080	44752	Yes
10	105	Doctor Ingelseplein	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	C	1986		Doorexploiteren	Doorexploiteren	50124	501240	41124	411240	50124	Yes
32	106	Peppelstraat	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	B	1991	2015	Doorexploiteren/SAH (3-14)	Doorexploiteren	42728	1367296	33728	1079296	42728	Yes
32	107	Amandelhof	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	A	2007		Doorexploiteren/SAH (1-4)	Doorexploiteren	27916	893312	23916	765312	27916	Yes
5	109	Boterbloemstraat	Bleskensgraaf	AE	2022-2035 Startbuurt	<2030	A	2012		Doorexploiteren/SAH (2-13)	Doorexploiteren	37000	185000	28000	140000	37000	Yes
51	201	Julianastraat	Brandwijk	AE	2022-2040 Natuurlijk tempo	<2030	D	1963	2000	Doorexploiteren/SAH (2-9)	Doorexploiteren	57472	2931072	48472	2472072	57472	Yes
29	202	Bernhardstraat	Brandwijk	AE	2022-2040 Natuurlijk tempo	<2030	C	1975	2000	Doorexploiteren	Doorexploiteren	49836	1445244	40836	1184244	49836	Yes
22	203	Prins Clausstraat	Brandwijk	AE	2022-2040 Natuurlijk tempo	<2030	B	1991	2000	Doorexploiteren	Doorexploiteren	44746	984412	35746	786412	44746	Yes
12	204	Klimroos	Brandwijk	AE	2022-2040 Natuurlijk tempo	<2030	A	1998		Doorexploiteren	Doorexploiteren	41644	499728	32644	391728	41644	Yes
30	301	Raadhuisstraat	Goudfaan	AE	2035-2050 Lange termijn	>2030	C	1961		Doorexploiteren	Doorexploiteren	56542	1696260	47542	1426260	56542	Yes
31	302	Van Tetsstraat	Goudfaan	AE	2035-2050 Lange termijn	>2030	C	1978		Doorexploiteren	Doorexploiteren	52480	1626880	43480	1347880	52480	Yes
25	401	Molenhoek	Molenaarsgraaf	AE	2025-2040 Middellange termijn	<2030	E	1960		Doorexploiteren	Doorexploiteren	26000	650000	17000	425000	26000	No
15	402	Graveland	Molenaarsgraaf	AE	2025-2040 Middellange termijn	<2030	C	1967	2010	Doorexploiteren	Doorexploiteren	26000	390000	17000	255000	26000	No
8	403	Dorpsstraat	Molenaarsgraaf	AE	2025-2040 Middellange termijn	<2030	B	1970	2015	Doorexploiteren	Doorexploiteren	40316	322528	36316	290528	40316	Yes
26	404	Tielmanstraat	Molenaarsgraaf	AE	2025-2040 Middellange termijn	<2030	C	1985		Doorexploiteren	Doorexploiteren	47816	1243216	38816	1009216	47816	Yes

1. Formula | **2. Housing data** | 3. Scoring | 4. Prioritization overview

	2023	2024	2025	2026-2030	2031-2035
Amount of complexes	12	16	5	533	343
Amount of dwellings	382	888	266	18621056	8523200
Total investment (nom)	13103992	26761148	9570194	3724211,2	1704640
Investment per dwelling (nom.)	34303,64398	30136,42793	35978,17293	34936,3152	24848,97959
Extra maintenance costs (nom.)	132170	195130	281590	352338	449722

Actions to be carried out plotted in time according to The Roadmap

2023

11	12	13	14	15	16	17	18	19	20
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
B3	0	0	WN1	WN2	WN3	WN5	0	PVh	0
0	0	0	0	0	0	0	0	0	0

2024

21	22	23	24	25	26	27	28	29	30
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
B3	PVc	0	WN1	WN2	WN3	WN5	0	0	0
B3	0	0	WN1	WN2	WN3	WN5	0	PVh	0
0	0	0	0	0	0	0	0	0	0
B3	PVc	0	WN1	WN2	WN3	WN5	0	0	0
0	0	0	0	0	0	0	0	0	0
B3	PVc	0	WN1	WN2	WN3	WN5	0	0	0

2025

31	32	33	34	35	36	37	38	39	40
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
B3	0	0	WN1	WN2	WN3	WN5	0	PVh	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

2026-2030

41	42	43	44	45	46	47	48	49	50
B3	PVc	0	WN1	WN2	WN3	WN6	0	0	0
B3	PVc	0	WN1	WN2	WN3	WN5	0	0	0
B3	0	0	WN1	WN2	WN3	WN5	0	PVh	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

2031-2035

1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

1. Formula | 2. Housing data | 3. Scoring | 4. Prioritization overview

Tab 3) Scoring

Point-scoring in accordance with preference scores of categories and associated weighted criteria scorings																								
Complex and rental dwellings		**Average energetic quality of complex**				**Transition vision heating**							**Process in which dwelling will be made energy efficient**						**Strategy**	**Budget per dwelling to be made energy efficient**				**Weighted scores**	
Amount of rentable dwelling	Complex number	Energy label A+ or better	Energy label A or B	Energy label C or D	Energylabel E, F or G	All-Electric < 2030	All-Electric > 2030	Heating grid < 2030	Heating grid > 2030	Green gass < 2030	Green gass > 2030	No explicit area vision other than good insulatio	Intervention All-Electric < 2030	Intervention All-Electric > 2030	Intervention Heating grid < 2030	Intervention Heating grid > 2030	Process per individual component to be mad	Planned sustainability interventi	Strategy	Budget max €10,000	Budget €10,000-€30,000	Budget €30,000-€50,000	Budget > €50,000	Total weighted score	Score 0-10
20	602	0	0	0	0,07406	0	0,0174	0	0	0	0	0	0	0	0	0	0,0286	2036-2040	0,11975	0	0	0	0,02096	0,26077	5,617951482
133	804	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0	0,05148	0	0	2024	0,08143	0	0	0,06157	0	0,25805	5,536063728
28	806	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0	0,05148	0	0	2026-2030	0,08143	0	0	0,06157	0	0,25805	5,536063728
48	807	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0	0,05148	0	0	2023	0,08143	0	0	0,06157	0	0,25805	5,536063728
8	810	0	0	0	0,07406	0	0	0,01044	0	0	0	0	0	0	0	0	0,0286	0	0,08143	0	0	0,06157	0	0,2561	5,477357434
40	104	0	0	0,05313	0	0,00696	0	0	0	0	0	0	0	0	0,05148	0	0	2024	0,08143	0	0	0,06157	0	0,25457	5,431295573
29	202	0	0	0,05313	0	0,00696	0	0	0	0	0	0	0	0	0,05148	0	0	2022	0,08143	0	0	0,06157	0	0,25457	5,431295573
10	811	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2036-2040	0,08143	0	0	0,06157	0	0,24804	5,234704753
159	814	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2036-2040	0,08143	0	0	0,06157	0	0,24804	5,234704753
106	815	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0	0	0,04147	0	2036-2040	0,08143	0	0	0,06157	0	0,24804	5,234704753
47	817	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0	0	0,04147	0	2031-2035	0,08143	0	0	0,06157	0	0,24804	5,234704753
70	818	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0	0	0,04147	0	2031-2035	0,08143	0	0	0,06157	0	0,24804	5,234704753
44	820	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2041-2045	0,08143	0	0	0,06157	0	0,24804	5,234704753
59	825	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2041-2045	0,08143	0	0	0,06157	0	0,24804	5,234704753
102	905	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2046-2050	0,08143	0	0	0,06157	0	0,24804	5,234704753
60	906	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2036-2040	0,08143	0	0	0,06157	0	0,24804	5,234704753
114	918	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2036-2040	0,08143	0	0	0,06157	0	0,24804	5,234704753
48	919	0	0	0,05313	0	0	0	0,01044	0	0	0	0	0	0,04147	0	0	0	2036-2040	0,08143	0	0	0,06157	0	0,24804	5,234704753

1. Formula | 2. Housing data | **3. Scoring** | 4. Prioritization overview

Tab 4) Prioritization overview

Prioritization and data of complexes								
Priority ranking	Complex number	Average energy label complex	TVH Municipality	Construction year	Planned sustainability intervention	Exploitation strategy in line with naming of criter	Budget (in euros) per dwelling fitting TVH of municipality	Planned to comprise with The Standard by 2050 (according to H
1	602	F	AE	1968	2036-2040	Doorexploiteren	65654	Yes
2	804	D	WN	1956	2024	Doorexploiteren	42770	Yes
3	806	C	WN	1964	2026-2030	Doorexploiteren	41194	Yes
4	807	D	WN	1965	2023	Doorexploiteren	47840	Yes
5	810	E	WN	1968	0	Doorexploiteren	38023	Yes
6	104	C	AE	1977	2024	Doorexploiteren	44752	Yes
7	202	C	AE	1975	2022	Doorexploiteren	49836	Yes
8	811	C	WN	1969	2036-2040	Doorexploiteren	42042	Yes
9	814	C	WN	1976	2036-2040	Doorexploiteren	40412	Yes
10	815	D	WN	1978	2036-2040	Doorexploiteren	32526	Yes
11	817	C	WN	1987	2031-2035	Doorexploiteren	36212	Yes
12	818	C	WN	1989	2031-2035	Doorexploiteren	34986	Yes
13	820	C	WN	1992	2041-2045	Doorexploiteren	34502	Yes
14	825	C	WN	1988	2041-2045	Doorexploiteren	33788	Yes
15	905	C	WN	1958	2046-2050	Doorexploiteren	45690	Yes
16	906	C	WN	1963	2036-2040	Doorexploiteren	41484	Yes
17	918	C	WN	1959	2036-2040	Doorexploiteren	45218	Yes
18	919	C	WN	1965	2036-2040	Doorexploiteren	34430	Yes
19	922	D	WN	1968	2046-2050	Doorexploiteren	39681	Yes
20	927	C	WN	1978	2031-2035	Doorexploiteren	40976	Yes
21	929	D	WN	1980	0	Doorexploiteren	46460	Yes
22	401	E	AE	1960	2022	Doorexploiteren	26000	No
23	404	C	AE	1985	2046-2050	Doorexploiteren	47816	Yes
24	605	B	AE	1995	2026-2030	Sloop	34900	Yes
25	604	C	AE	1987	2023	Doorexploiteren	26000	No

1. Formula | 2. Housing data | 3. Scoring | **4. Prioritization overview**

Appendix E – Full list of prioritization of complexes

Prioritization and data of complexes								
Priority ranking	Complex number	Average energy label complex	TVH Municipality	Construction year	Planned sustainability intervention	Exploitation strategy in line with naming of criteria	Budget (in euros) per dwelling fitting TVH of municipality	Planned to comprise with The Standard by 2050 (according to HA)
1	602	F	AE	1968	2036-2040	Doorexploiteren	65654	Yes
2	804	D	WN	1956	2024	Doorexploiteren	42770	Yes
3	806	C	WN	1964	2026-2030	Doorexploiteren	41194	Yes
4	807	D	WN	1965	2023	Doorexploiteren	47840	Yes
5	810	E	WN	1968	0	Doorexploiteren	38023	Yes
6	104	C	AE	1977	2024	Doorexploiteren	44752	Yes
7	202	C	AE	1975	2022	Doorexploiteren	49836	Yes
8	811	C	WN	1969	2036-2040	Doorexploiteren	42042	Yes
9	814	C	WN	1976	2036-2040	Doorexploiteren	40412	Yes
10	815	D	WN	1978	2036-2040	Doorexploiteren	32526	Yes
11	817	C	WN	1987	2031-2035	Doorexploiteren	36212	Yes
12	818	C	WN	1989	2031-2035	Doorexploiteren	34986	Yes
13	820	C	WN	1992	2041-2045	Doorexploiteren	34502	Yes
14	825	C	WN	1988	2041-2045	Doorexploiteren	33788	Yes
15	905	C	WN	1958	2046-2050	Doorexploiteren	45690	Yes
16	906	C	WN	1963	2036-2040	Doorexploiteren	41484	Yes
17	918	C	WN	1959	2036-2040	Doorexploiteren	45218	Yes
18	919	C	WN	1965	2036-2040	Doorexploiteren	34430	Yes
19	922	D	WN	1968	2046-2050	Doorexploiteren	39681	Yes
20	927	C	WN	1978	2031-2035	Doorexploiteren	40976	Yes
21	929	D	WN	1980	0	Doorexploiteren	46460	Yes
22	401	E	AE	1960	2022	Doorexploiteren	26000	No
23	404	C	AE	1985	2046-2050	Doorexploiteren	47816	Yes
24	605	B	AE	1995	2026-2030	Sloop	34900	Yes
25	604	C	AE	1987	2023	Doorexploiteren	26000	No
26	802	A	WN	2008	2023	Doorexploiteren	31772	Yes
27	809	A	WN	1966	2026-2030	Doorexploiteren	30358	Yes
28	910	B	WN	1966	2023	Doorexploiteren	40144	Yes
29	914	B	WN	1995	2024	Doorexploiteren	34522	Yes
30	907	D	WN	1964	0	Doorexploiteren	48506	Yes
31	981	D	WN	1981	0	Doorexploiteren	41920	No
32	102	E	AE	1962	2026-2030	Doorexploiteren	57724	Yes
33	101	A	AE	1950	2026-2030	Doorexploiteren	36734	Yes
34	106	B	AE	1991	2025	Doorexploiteren	42728	Yes
35	109	A	AE	2012	2023	Doorexploiteren	37000	Yes
36	203	B	AE	1991	2024	Doorexploiteren	44746	Yes
37	204	A	AE	1998	2026-2030	Doorexploiteren	41644	Yes
38	403	B	AE	1970	2026-2030	Doorexploiteren	40316	Yes
39	703	B	AE	1990	2025	Doorexploiteren	42936	Yes
40	805	D	WN	1960	2023	Doorexploiteren	17000	No
41	903	E	WN	1949	2046-2050	Doorexploiteren	56750	Yes
42	402	C	AE	1967	2026-2030	Doorexploiteren	26000	No
43	816	B	WN	1986	2031-2035	Doorexploiteren	33622	Yes
44	819	B	WN	1991	2031-2035	Doorexploiteren	33516	Yes
45	822	A	WN	2000	2036-2040	Doorexploiteren	32684	Yes
46	880	B	WN	1965	2041-2045	Doorexploiteren	30254	Yes
47	881	A	WN	1960	2036-2040	Doorexploiteren	34034	Yes
48	925	A	WN	2008	2031-2035	Doorexploiteren	30044	Yes

49	926	B	WN	1974	2031-2035	Doorexploiteren	37556	Yes
50	928	B	WN	1981	2031-2035	Doorexploiteren	37900	Yes
51	301	C	AE	1961	2022	Doorexploiteren	56542	Yes
52	302	C	AE	1978	2024	Doorexploiteren	52480	Yes
53	603	D	AE	1975	2024	Doorexploiteren	56552	Yes
54	812	E	WN	1971	2022	Doorexploiteren	0	No
55	606	A	AE	2011	2024	Doorexploiteren	30000	Yes
56	501	D	AE	1966	2036-2040	Doorexploiteren	56638	Yes
57	502	D	AE	1976	2036-2040	Doorexploiteren	53358	Yes
58	503	C	AE	1979	2036-2040	Doorexploiteren	50488	Yes
59	601	C	AE	1962	2036-2040	Doorexploiteren	52808	Yes
60	103	C	AE	1969	2026-2030	Doorexploiteren	52330	Yes
61	105	C	AE	1986	2024	Doorexploiteren	50124	Yes
62	201	D	AE	1963	2024	Doorexploiteren	57472	Yes
63	701	D	AE	1957	2023	Doorexploiteren	57584	Yes
64	702	D	AE	1970	2024	Doorexploiteren	55954	Yes
65	930	B	WN	1984	0	Doorexploiteren	33154	Yes
66	932	B	WN	1993	0	Doorexploiteren	32906	Yes
67	933	B	WN	1993	0	Doorexploiteren	33776	Yes
68	935	B	WN	1996	0	Doorexploiteren	33914	Yes
69	936	B	WN	1996	0	Doorexploiteren	32808	Yes
70	937	B	WN	1996	0	Doorexploiteren	32988	Yes
71	941	B	WN	1997	0	Doorexploiteren	32742	Yes
72	984	B	WN	1981	0	Doorexploiteren	32438	No
73	801	A	WN	2007	2023	Doorexploiteren	29504	Yes
74	916	A	WN	1955	2023	Doorexploiteren	29486	No
75	923	C	WN	1969	2046-2050	Doorexploiteren	50718	Yes
76	813	E	WN	1971	2031-2035	Doorexploiteren	0	No
77	107	A	AE	2007	2024	Doorexploiteren	27916	Yes
78	821	B	WN	1996	2041-2045	Doorexploiteren	28842	Yes
79	823	B	WN	2001	2041-2045	Doorexploiteren	25060	Yes
80	824	A	WN	2012	2041-2045	Doorexploiteren	23500	Yes
81	826	A	WN	2014	2041-2045	Doorexploiteren	23500	Yes
82	902	A	WN	2016	2041-2045	Doorexploiteren	20500	Yes
83	924	A	WN	1971	2031-2035	Doorexploiteren	24831	Yes
84	939	A	WN	2009	2031-2035	Doorexploiteren	29800	Yes
85	940	A	WN	2008	2031-2035	Doorexploiteren	27890	No
86	908	D	WN	1965	2026-2030	Doorexploiteren	0	No
87	909	D	WN	1967	2023	Doorexploiteren	0	No
88	920	D	WN	1965	2036-2040	Doorexploiteren	0	No
89	921	D	WN	1967	2046-2050	Doorexploiteren	0	No
90	934	B	WN	1939	0	Doorexploiteren	18968	Yes
91	938	A	WN	2008	0	Doorexploiteren	27192	Yes
92	942	A	WN	2009	0	Doorexploiteren	29428	Yes
93	943	A	WN	2011	0	Doorexploiteren	29644	Yes
94	944	A	WN	2012	0	Doorexploiteren	28068	Yes
95	953	A	WN	2013	0	Doorexploiteren	28310	No
96	956	A	WN	2014	0	Doorexploiteren	23788	No
97	982	B	WN	1981	0	Doorexploiteren	27240	No
98	831	A+	WN	2018	2023	Doorexploiteren	18500	Yes
99	912	B	WN	1931	2026-2030	Doorexploiteren	0	Yes

100	917	B	WN	1956	2023	Doorexploiteren	0	No
101	830	A+	WN	2018	2036-2040	Doorexploiteren	18500	Yes
102	832	A+	WN	2020	2036-2040	Doorexploiteren	18500	No
103	833	A+	WN	2020	2046-2050	Doorexploiteren	20500	No
104	405	A+	AE	2018	2036-2040	Doorexploiteren	22500	Yes
105	954	A+	WN	2015	0	Doorexploiteren	20500	Yes
106	955	A+	WN	2015	0	Doorexploiteren	18500	Yes
107	Onbekend	A	WN	2020	0	Doorexploiteren	0	Yes
108	950	A+	WN	2012	0	Doorexploiteren	9080	Yes
109	951	A+	WN	2012	0	Doorexploiteren	9000	Yes